Scientific Programming for Industry 5.0: Theory, Applications, and Technological Development

Lead Guest Editor: Ahmed Farouk
Guest Editors: Heena Rathore and Kapal Dev

Scientific Programming for Industry 5.0: Theory, Applications, and Technological Development

Scientific Programming for Industry 5.0: Theory, Applications, and Technological Development

Lead Guest Editor: Ahmed Farouk
Guest Editors: Heena Rathore and Kapal Dev

Contents

Contents

Contents

Contents

Hindawi
Scientific Programming
Volume 2023, Article ID 9874567, 1 page
https://doi.org/10.1155/2023/9874567

Retraction

Retracted: Design and Research of Computer-Aided Translation Teaching Course under the Background of Embedded Microprocessor Wireless Communication

Scientific Programming

Received 29 August 2023; Accepted 29 August 2023; Published 30 August 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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

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

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

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

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

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

References

[1] X. Yuan and R. Zhu, "Design and Research of Computer-Aided Translation Teaching Course under the Background of Embedded Microprocessor Wireless Communication," *Scientific Programming*, vol. 2022, Article ID 8594212, 14 pages, 2022.

Hindawi
Scientific Programming
Volume 2023, Article ID 9825960, 1 page
https://doi.org/10.1155/2023/9825960

Retraction

Retracted: Investigation and Interpersonal Relationship of College Students with Intelligent Big Data

Scientific Programming

Received 29 August 2023; Accepted 29 August 2023; Published 30 August 2023

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

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

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

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

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

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

References

[1] Y. Zheng, S. Zheng, and L. Bao, "Investigation and Interpersonal Relationship of College Students with Intelligent Big Data," *Scientific Programming*, vol. 2022, Article ID 2780841, 12 pages, 2022.

Hindawi
Scientific Programming
Volume 2023, Article ID 9856029, 1 page
https://doi.org/10.1155/2023/9856029

Retraction

Retracted: The Role of Confucian-Transformational Leadership in Shaping and Influencing Chinese MNEs

Scientific Programming

Received 1 August 2023; Accepted 1 August 2023; Published 2 August 2023

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

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

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

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

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

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

References

[1] Y. Hui, "The Role of Confucian-Transformational Leadership in Shaping and Influencing Chinese MNEs," *Scientific Programming*, vol. 2022, Article ID 5839223, 11 pages, 2022.

Hindawi
Scientific Programming
Volume 2023, Article ID 9825960, 1 page
https://doi.org/10.1155/2023/9825960

Retraction

Retracted: Investigation and Interpersonal Relationship of College Students with Intelligent Big Data

Scientific Programming

Received 29 August 2023; Accepted 29 August 2023; Published 30 August 2023

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

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

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

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

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

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

References

[1] Y. Zheng, S. Zheng, and L. Bao, "Investigation and Interpersonal Relationship of College Students with Intelligent Big Data," *Scientific Programming*, vol. 2022, Article ID 2780841, 12 pages, 2022.

Hindawi
Scientific Programming
Volume 2022, Article ID 2780841, 12 pages
https://doi.org/10.1155/2022/2780841

Research Article

Investigation and Interpersonal Relationship of College Students with Intelligent Big Data

Yuxin Zheng,[1] **Siyi Zheng**,[2] **and Lanlan Bao**[3]

[1]*Mental Health Education Center of Chengdu University of Technology, Chengdu 610059, Sichuan, China*
[2]*College of Mathematics and Information Science, Neijiang Normal University, Neijiang 641100, Sichuan, China*
[3]*School of Foreign Languages, Chengdu University of Technology, Chengdu 610059, Sichuan, China*

Correspondence should be addressed to Yuxin Zheng; yuxinzheng1103@163.com

Received 22 April 2022; Revised 14 June 2022; Accepted 28 June 2022; Published 21 July 2022

Academic Editor: Ahmed Farouk

An interpersonal relationship is a relationship that arises and develops in the process of people's extensive material and spiritual exchanges. College students, as a special group, not only have the general characteristics of modern young people's interpersonal communication but also have remarkable characteristics of their own communication. The purpose of this paper is to study how to use intelligent big data to conduct a brief survey and research on the interpersonal relationships of college students so that college students can discover their own problems and establish sound and good interpersonal relationships. This paper proposes data mining based on intelligent big data. Data mining plays an important role in information processing. Data mining includes many algorithms. This paper selects cluster analysis for the need to classify the influencing factors in interpersonal relationships. The cluster analysis algorithm can classify similar information well. The experimental results of this paper show that the most important skills given by the five companies that are considered to be necessary for talents are the interpersonal relationship, self-ability, and academic qualifications. Among them, five companies gave the highest score of 8.9 points to the interpersonal relationship and the lowest score of 8.0 points, with an average of about 8 points, while the scores of their own ability and education were below 8 points. It can be seen that entrepreneurs think that the necessary skills for talents are not academic qualifications and their own abilities but good interpersonal relationships. Therefore, it is very important to establish good interpersonal relationships.

1. Introduction

Today's college students are positive thinking and energetic. They have a wide range of interests. The interpersonal relationship of college students is an important part of social interpersonal relationships, and college students have both universality and particularity. Therefore, it is very important in theory and practice to study and discuss relevant measures to promote the harmony of interpersonal relationships among college students. Modern college students are the hope of the motherland and the future of the country. Their interpersonal skills play an important role in the progress and development of human society.

After the 1990s, the interpersonal relationship of college students has become a topic of scholarly research. With the development of the times and the rise of intelligent big data, the research on the interpersonal relationship of college students with the background of intelligent big data will deepen with the development of times. Intelligent big data not only guide the trend of social development but also have a great impact on the interpersonal relationships of college students. College students are an important part of social interpersonal relationships. The interpersonal relationship of college students is closely related to the personality health of college students, the formation of self-consciousness, the development of health psychology, and the social adaptability of college students.

The innovations of this paper are as follows: (1) this paper introduces the relevant theoretical knowledge of intelligent big data and college students' interpersonal relationships. And it proposes a cluster analysis algorithm based on intelligent big data and analyzes how the cluster analysis algorithm plays a role in the investigation of college students' interpersonal relationships. (2) This paper compares and analyzes the cluster analysis algorithm before and after improvement. Through the experiment, we can know that the improved cluster analysis algorithm is beneficial for accurately classifying various data of college students' interpersonal relationships. This paper explores the factors that affect the interpersonal relationship of college students.

2. Related Work

Good interpersonal relationships are not only very important in society but also play an important role in developing a healthy personality. Clem et al. studied the interpersonal relationship between teachers and students. They believe that if the relationship between teachers and students is good, students' academic performance will also be improved, and students will become more interested in learning. They surveyed 52 students and found that most high-achieving students had good relationships with teachers. Although the scholar has drawn specific conclusions, their experimental data are not clear [1]. In order to reduce the amount of data collected by the internet of things and improve the processing speed of big data, Xue et al. proposed the method of compressed sensing sampling. Aiming at the high computational complexity of the compressed sensing algorithm, they uses the multiobjective optimization particle swarm optimization algorithm to improve it. It can effectively improve the reconstruction accuracy of the algorithm. The results show that the reconstruction power is higher than the traditional algorithm, so it has better reconstruction performance. The scholars believe that the improved algorithm they proposed can have a better reconstruction function, but they did not prove why the algorithm has a reconstruction function [2]. Kuang et al. found that diversity and accuracy are two distinct characteristics of large-scale heterogeneous data. It has always been a great challenge to represent and process big data efficiently with a unified scheme. They proposed a unified tensor model to represent a variety of different data. They used the tensor expansion operator to combine into a unified tensor. One of their case studies shows that approximate data for the algorithm typically guarantee 93 percent accuracy. But the scholars did not describe the case he proposed [3]. Stergiou and Psannis found that the internet of things (IoT) is a new technology that is developing rapidly in the field of telecommunications, especially in modern wireless telecommunications. In addition, based on wireless network technology, mobile cloud computing (MCC) and IoT technologies are developing rapidly. They combine the above two technologies (i.e., MCC and IoT) with big data technologies to examine their common characteristics. They found that the advantages of MCC and IoT could increase the usage of big data applications. The scholar mentioned combining the advantages of the two technologies, but they did not introduce the advantages of the two technologies [4]. Zhang et al. found that the explosion of data volume and the growing demand for data value extraction have brought people into the era of big data. Cloud computing is one of the representative technologies that utilize virtualized resources, parallel processing, and data service integration. However, the limitation of cloud computing in supporting lightweight terminal devices greatly hinders the vigorous development of cloud computing. The scholar realized that the limitations of cloud computing will affect its development but did not explain how to solve the limitations of cloud computing [5]. Xu et al. found that the increasing popularity and development of data mining technology has brought serious threats to personal information security. In recent years, privacy protection in data mining has been extensively studied. They looked at privacy issues related to data mining from a broader perspective and examined various ways to help protect sensitive information. They identified four different types of users involved in data mining applications. The scholars found that data mining will bring privacy and security problems but did not explain how to solve it, nor did they describe the four different types of users [6].

3. Cluster Algorithm Based on Intelligent Big Data

3.1. Characteristics and Significance of Harmonious Interpersonal Relationships among College Students. The formation of harmonious interpersonal relationships is beneficial to national prosperity, social stability, personal growth, and career success. The psychological development and social maturity of college students are inseparable from interpersonal relationships [7]. Interpersonal relationships are interdependent and interconnected social relationships formed by interactions among social groups [8]. Humans are social animals, and each individual has their own unique thoughts, backgrounds, attitudes, personalities, behavior patterns, and values. The paper summed up the importance of harmonious interpersonal relationships for the healthy growth of college students, as shown in Figure 1.

As shown in Figure 1, the significance of harmonious interpersonal relationships for college students is as follows.

3.1.1. Help Promote the Socialization of College Students. Interpersonal communication is closely related to everyone's life, but it does not mean that everyone can build good relationships. Looking at the whole society, all people are engaged in interpersonal activities, and some people do it well, but some people are frowning all day because of interpersonal relationships. The so-called effective interpersonal relationship refers to the realization of heart-to-heart communication between people and the connection between emotions and emotions [9]. Healthy relationships ensure a person's mental health and emotional balance because a person will face all kinds of setbacks and difficulties in order to survive in society. In many cases, this is unbearable for the individual, and they need the help of relatives and friends around them to overcome the difficulties [10].

3.1.2. Contribute to Cultivating the Sound Personality of College Students. It maintains normal interpersonal relationships, it can get along well with others, and it humbly

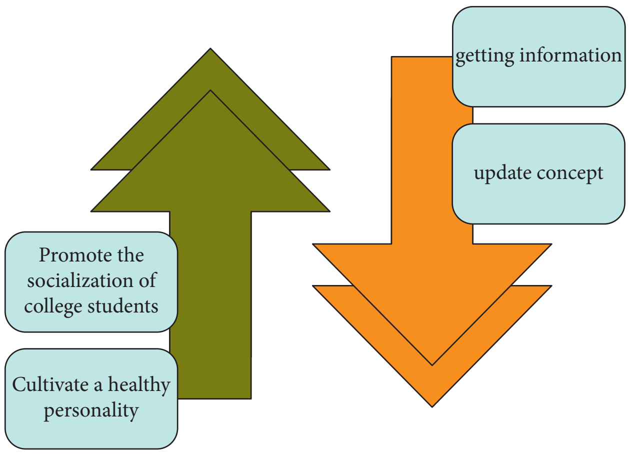


Figure 1: The significance of harmonious interpersonal relationships for college students.

accepts others' corrections. It accepts the strengths and weaknesses of others and has strong emotional control. It affects people's physical and psychological conditions. If people lack positive interpersonal communication, they cannot treat themselves and others properly [11]. People who are narrow-minded and short-sighted can easily form huge mental and psychological pressures. It is difficult to resolve psychological contradictions and may lead to morbid psychology in severe cases. The harm caused by bad interpersonal relationships is shown in Figure 2.

As shown in Figure 2, the consequences of bad interpersonal relationships are withdrawn personality, mental illness, and so on, so good interpersonal relationships may maintain psychological balance and make emotional responses consistent with external stimuli. These aspects are inseparable from interpersonal communication [12]. More than 80% of successful people have high IQ and emotional intelligence interpersonal skills. In contrast, the intelligence factor, which is generally considered to be very important, only accounts for less than 20%. Today's society emphasizes win-win cooperation and the establishment of good interpersonal relationships. On the one hand, it is closely related to the formation of good character and quality of college students.

3.1.3. Help College Students to Obtain Information and Update Their Concepts. The self-development of college students is inseparable from interpersonal relationships, and interpersonal relationships play an important role in college students. On the one hand, good interpersonal relationships can help college students vent their negative emotions, relieve academic and life pressure, and help college students form positive and optimistic character traits and physical and mental health. The formation of interpersonal relationships can help college students have a broader vision and knowledge [13]. Through interpersonal relationships, college students can understand themselves from different aspects, so as to better carry out self-improvement and self-development.

3.2. Advantages of Cluster in Investigation of Interpersonal Relationships of College Students. Cluster analysis is a more general analysis method, and it is engaged in research in various fields because there are great differences in different data types according to the industry [14, 15]. So it is necessary to understand the data structure of the initial data, which is helpful for the data processing in the data mining process. The results of cluster analysis vary according to the measure of similarity of data objects [16]; it can cluster dense data sets of arbitrary shape. It can find outliers while clustering, and it is not sensitive to outliers in the data set, as shown in Figure 3.

As shown in Figure 3, the advantages of the cluster analysis algorithm mainly include the following aspects.

3.2.1. The Algorithm Is Scalable. Currently, large amounts of data are stored in databases in all fields. In the interpersonal relationship survey of college students, because of the need to process a lot of data, the scale of the data will continue to expand. As far as the current research is concerned, many cluster analysis algorithms have higher computational speed and better clustering results for the data set [17].

3.2.2. The Algorithm Has the Function of Processing High-Order Raw Data. The more data attribute values, the higher the maintenance of the database. The meaning of data is getting richer and richer, and if the attributes required to represent the data increase, there will be many data entries in each tuple in the database [18]. Clustering algorithms have excellent processing capabilities for records with relatively few data items and can generally mine meaningful results.

3.2.3. Algorithms Can Deal with and Process Abnormal Data. In many cases, the data set has two identical records. In practical applications, in order to make data mining more meaningful, additional constraints are required. The clustering algorithm must have sufficient volume for the constraints [19]. Even if the constraints are met, it has excellent cluster analysis capabilities.

3.3. Similarity Measurement Method for Cluster. As can be seen from the definition of clustering, its intuitive description is to cluster similar data objects in a data set into one class, so that different data objects belong to different classes. Cluster analysis refers to the analytical process of grouping a collection of physical or abstract objects into classes of similar objects. This conceptual definition is very simple, but in a particular cluster analysis, the purpose of clustering is very different, and the results obtained are also different. Therefore, it is difficult to clearly judge that clustering structure is correct and reasonable [20]. Two distinct clustering structures that can be observed under different similarity measure scales are shown in Figure 4.

As shown in Figure 4, cluster analysis is the grouping of data objects based on the information found in the data that describes the objects and their relationships. The goal is to find out the similarity between objects within a group. This

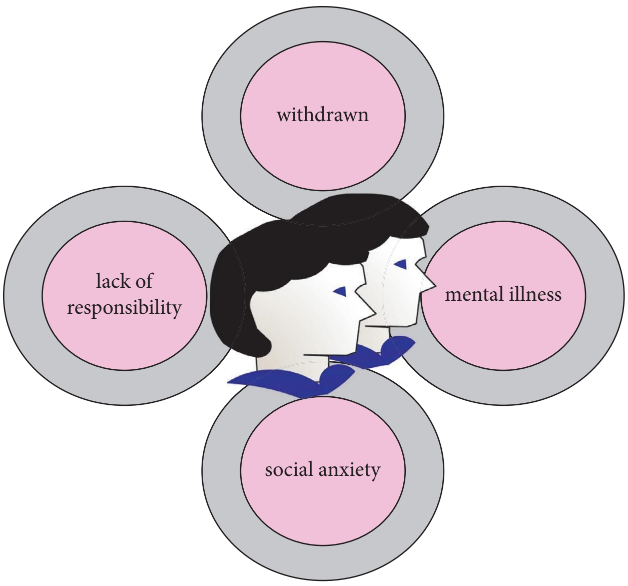


Figure 2: Consequences of bad relationships.

paper divides the similarity of cluster analysis into three aspects. These measurement methods are mainly manifested in two important stages of cluster analysis, namely the algorithm design stage and the result evaluation stage, and the three similarity degrees all represent the relationship between data units. But the granularity level of the data unit is different [21], as shown in Figure 5.

As shown in Figure 5, after the data is saved, it will exist in various forms. Next, when performing cluster analysis, certain methods are required in order to represent the structure of the data. This facilitates the processing of relevant data [22]. The following two expressions are usually used.

3.3.1. Data Matrix. If there are a total of s records in the data set, each record has n attributes. Then, it is represented using matrix $n \times s$, as in the following formula:

$$\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1s} \\ a_{21} & a_{22} & \dots & a_{2s} \\ a_{31} & a_{32} & \dots & a_{3s} \\ a_{n1} & a_{n2} & \dots & a_{ns} \end{bmatrix}. \tag{1}$$

In order to make the clustering effect better, people need to standardize the data, as follows:

$$s_q = \frac{1}{n}\left(\left|a_{1q} - m_q\right| + \left|a_{2q} - m_q\right| + \cdots + \left|a_{nq} - m_q\right|\right), \tag{2}$$

where $(a_{1q}, a_{2q}, \dots, a_{nq})$ is the n measure of q.
The normalized measure is calculated as follows:

$$z_{kq} = \frac{a_{kq} - m_q}{s_q}. \tag{3}$$

The choice of distance function or similarity function is usually determined by experience and relevant background knowledge in practical clustering applications. The commonly used measurement method is the Euclidean distance. Euclidean distance generally refers to the Euclidean metric. In mathematics, the Euclidean distance or Euclidean metric is the “ordinary” (i.e., straight line) distance between two points in Euclidean space, as follows:

$$d(i, j) = \sqrt{\left|a_{i1} - a_{j1}\right|^2 + \left|a_{i2} - a_{j2}\right|^2 + \cdots + \left|a_{in} - a_{jn}\right|^2}, \tag{4}$$

where both a_i and a_j data sets have n attributes. In addition, according to different clustering objectives, the Manhattan distance can also be used. Manhattan distance is a geometric term used in geometric metric spaces to indicate the sum of the absolute wheel distances of two points in a standard coordinate system, as in the following formula:

$$d_{\text{man}}(i, j) = \left|a_{i1} - a_{j1}\right| + \left|a_{i2} - a_{j2}\right| + \cdots \left|a_{in} - a_{jn}\right|. \tag{5}$$

The Mahalanobis distance is calculated as follows:

$$d(i, j) = \sqrt{\left(a_i - a_j\right)^T \Sigma^{-1}\left(a_i - a_j\right)}. \tag{6}$$

Minkowski distance is a further generalization of Euclidean distance. The Minkowski distance is calculated as follows:

$$d(i, j) = \sqrt[p]{\left|a_{i1} - a_{j1}\right|^P + \left|a_{i2} - a_{j2}\right|^P + \cdots + \left|a_{in} - a_{jn}\right|^P}, \tag{7}$$

where if $P = 1$, one can find that this expression is the same as that of Manhattan distance. When $P = 2$, one can find that this expression is the same as that of Euclidean distance [23]. The cosine of the included angle is used to express their similarity coefficient as in the following formula:

$$\text{sim}(i, j) = \frac{\sum_{k=1}^{k}\left(a_{ik}, a_{jk}\right)}{\sqrt{\sum_{k=1}^{k} a_{ik}^2}}. \tag{8}$$

A metric related to the Jaccard coefficient is the Jaccard distance, which is used to describe the dissimilarity. Jaccard coefficients are often used to express the similarity between sets. The following formula is to use the Jaccard coefficient to express the similarity of two sets T_i and T_j, as follows:

$$\text{sim}\left(T_i, T_j\right) = \frac{\left|T_i \cap T_j\right|}{\left|T_i \cup T_j\right|}. \tag{9}$$

In the case of different needs and different problems, people may have different representations for the types of attributes, and they will be stored in different forms. It is relatively simple and easy to measure the similarity coefficient based on distance, and it is often chosen by everyone [24]. When the value of the similarity coefficient is consistent with the degree of similarity, it is called the blindness coefficient. When it is inconsistent with the degree of similarity, it is called the dissimilarity coefficient. The commonly used similarity coefficients include distance coefficient, correlation coefficient, and joint coefficient.

3.4. Hierarchical Cluster Algorithm. The similarity measure in hierarchical clustering mainly involves the similarity

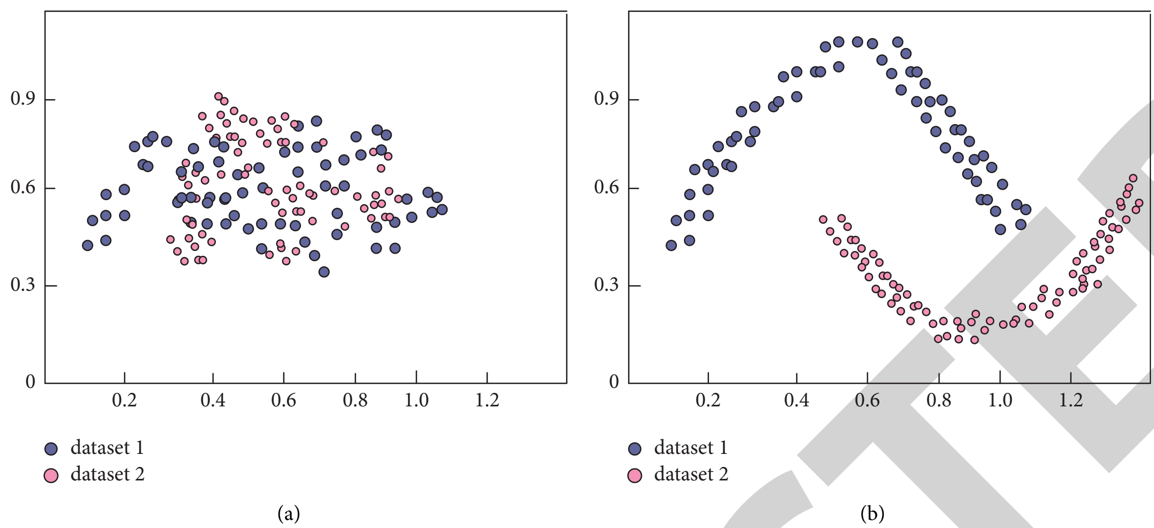


Figure 3: Effect of cluster analysis: (a) data set before clustering and (b) clustered data set.

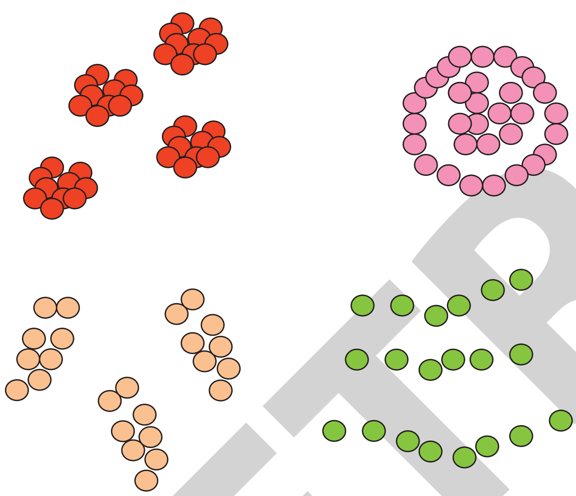


Figure 4: Two distinct clustering structures observable at different similarity measure scales.

relationship between class objects. $D_{nn}(C, C\prime)$ is the two subclasses in the clustering structure, and $d(i, j)$ represents the distance between any two data elements. There are four commonly used distance definitions:

A single join, also known as the nearest neighbor distance, can be expressed as follows:

$$D_{nn}(C, C') = \min d(i, j). \tag{10}$$

In the evaluation stage of the clustering results, in order to test the performance of the clustering algorithm, it is often necessary to compare the results generated by the algorithm with the "real" clustering results (generally obtained by human annotation), as follows:

$$a(C_1, C_2) = \sum_{u_i \in C_1} \max \left| u_i \cap v_j \right|. \tag{11}$$

It measures the degree of matching between C_1 and C_2 and takes the maximum value if and only when $C_1 = C_2$.

Cross-entropy is an important concept in Shannon's information theory, which is mainly used to measure the difference in information between two probability distributions. The performance of language models is usually measured in terms of cross-entropy and complexity. "Cross" entropy can measure the relationship between two data sets through nonparametric estimation, which is more sufficient to describe the data distribution than general second-order statistics. If C_1 and C_2, respectively, represent two subclasses in the cluster structure, the Renyi entropy distance between C_1 and C_2 is defined as follows:

$$D_R = -\log\left(\frac{1}{\mathrm{MN}} \sum_{i=1}^{N} \sum_{j=1}^{M} G\left(a_i - b_j\right), \sigma^2\right), \tag{12}$$

where G represents the Gaussian kernel function and σ^2 is the variance of the Gaussian function.

In general hierarchical clustering, each individual data element is initially treated as a subclass. It then merges the two subclasses with the smallest distance step by step and finally forms a tree-like hierarchy. Each layer represents a granularity-level clustering structure [25]. Hierarchical clustering is a kind of clustering algorithm that creates a hierarchical nested clustering tree by calculating the similarity between data points of different categories.

3.5. Ant Colony Clustering Algorithm and Improvement. In the process of ants foraging, the behavior of a single ant is relatively simple, but the whole ant colony can reflect some intelligent behaviors. This is because the ants in the ant colony can transmit information through a certain information mechanism. Ant colony algorithm is a bionic optimization algorithm, which has many advantages. However, the ant colony algorithm also has some shortcomings, which will affect the solution to these problems. The study found

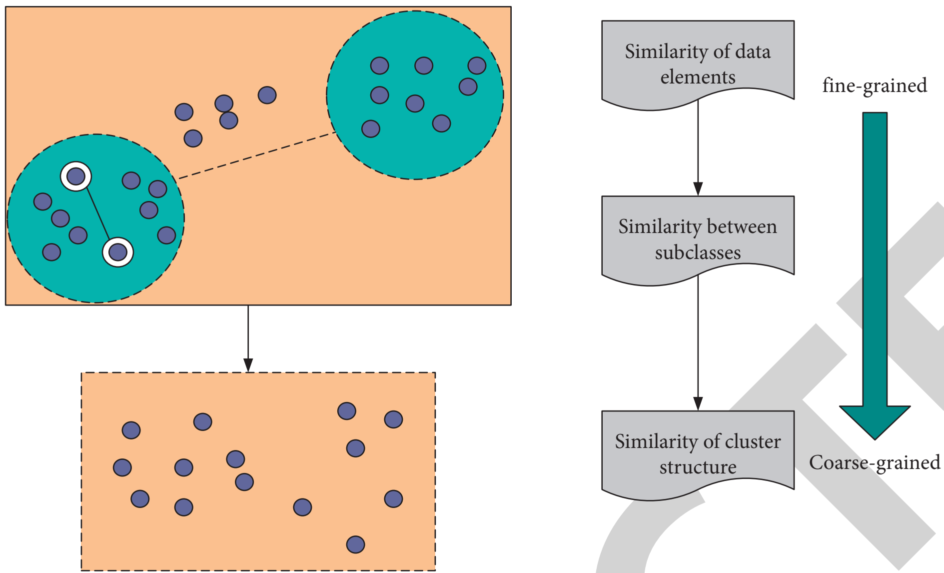


Figure 5: Data units of different granularity levels corresponding to three similarity measures.

that the combination of the ant colony algorithm and cluster analysis could better solve the above problems. This has become a research trend in recent years. The ant colony clustering algorithm is shown in Figure 6.

As shown in Figure 6, although the ant colony algorithm solves the problem of clustering, the number of clusters no longer needs to be manually given, but the maximum number of iterations still needs to be given in advance before clustering. If the grasp of the scale of the problem is not accurate enough, the prediction of the number of iterations will be biased. If the diversity is excessive and the system is too active, it will lead to excessive random motion and fall into a chaotic state. If the diversity is not enough and the positive feedback is too strong, it will lead to rigidity. When the environment changes, the ant colony cannot adjust accordingly. Assuming that the number of iterations is too large, the algorithm has converged before reaching the maximum number of iterations. It has already obtained the clustering result, which will cause the algorithm to do unnecessary iterations and waste the execution time. Therefore, this paper improves the ant colony clustering algorithm.

In the realization process of the clustering algorithm based on the principle of ant foraging, people first need to determine the number of target clusters. It then selects a cluster center for each cluster, and the choice of the initial cluster center is likely to affect the final clustering effect. $\tau_{ij}(0) = 0$; the dissimilarity between objects is represented by Euclidean distance; and the distance and dissimilarity are positively correlated. Then the calculation expression of the pheromone concentration $\tau_{ij}(t)$ on the path at time t is as follows:

$$\tau_{\mathrm{ij}}(t) = \begin{cases} 1, d_{\mathrm{ij}} \leq r \\ 0, d_{\mathrm{ij}} \succ r \end{cases}, \tag{13}$$

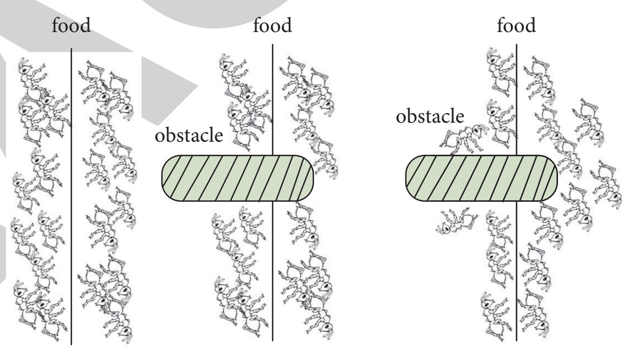


Figure 6: Ant colony clustering algorithm.

where d_{ij} represents the weighted Euclidean distance from object i to object j. The probability of object a_i moving towards object a_j is as follows:

$$p_{ij}(t) = \frac{\tau_{ij}(t)\eta_{ij}^{\beta}(t)}{\sum_{s\in S}\tau_{sj}^{\alpha}(t)\eta_{sj}^{\beta}(t)}, \tag{14}$$

where α and β are control parameters.

Iteration is the activity of repeating a feedback process, usually with the aim of approaching a desired goal or result. Each repetition of the process is called an “iteration,” and the result of each iteration is used as the initial value for the next iteration. After an iteration, the data objects in each cluster are different from those before the iteration. At this time, people need to update the cluster center of each class, as shown in the following formula:

$$\bar{C}_j = \frac{1}{w}\sum_{i=1}^{w} a_i. \tag{15}$$

The dissimilarity of data objects in the same class is calculated as follows:

$$d_{ij} = d\left(a_i, a_j\right) = \sqrt{\sum_{i=1}^{m} P_i\left(a_{i1} - a_{j1}\right)^2}. \tag{16}$$

Finally, the result of clustering is judged. If the sum of the dissimilarities of all classes is less than the parameter e of the end of the clustering, the clustering ends. Otherwise, it is necessary to recluster until the cluster termination condition is met.

In a two-dimensional grid, the ants move continuously and perform pick-up and drop-down behaviors. When an ant encounters a data object O_i at position r at a certain moment, one needs to calculate its local density by the following expression:

$$f\left(o_i\right) = \begin{cases} \dfrac{1}{s^2}\sum\limits_{o_i}\left[1 - \dfrac{d\left(o_i, o_j\right)}{2}\right], \text{else} \\ 0, f > 0 \end{cases}, \tag{17}$$

where $f\left(o_i\right)$ represents the similarity density between the object and other surrounding objects.

When an ant moves in a two-dimensional grid, the probabilities of picking up and putting down are as follows:

$$P_p = \left(\frac{k_1}{k_1 + f\left(O_i\right)}\right)^2, \tag{18}$$

$$P_p = \left(\frac{k_1}{k_1 + f\left(O_i\right)}\right)^2. \tag{19}$$

If the similarity between the data in a certain neighborhood of the ant's moving path and the data carried by the ant is higher than the specified threshold, the data will be placed in this position. Then the ants continue to move randomly, repeatedly picking up and putting down, until the number of repetitions is greater than the maximum number of iterations, the algorithm ends, and the clustering result is obtained.

3.6. Application of Cluster Investigation of Interpersonal Relationships among College Students. The original data obtained may be stored in different ways, resulting in inconsistent data forms. Data merging refers to combining data from different databases or different formats to resolve ambiguity in meaning. If the data source is different, there will be many mismatches in the data structure, data unit, data naming rules, and so on. Data merging refers to merging data, which transforms, refines, and summarizes data from the original data. To obtain raw data, data mining is necessary.

In the investigation of college students' interpersonal relationships, interpersonal relationships can reflect the personality of college students. Not only that, but student achievement is also an important measure of student learning. Scientific analysis of students' interpersonal relationships can help students know how to adjust their interpersonal relationships by grasping their own strengths and weaknesses and mastering methods that are more suitable for them. If the relationship is poor, it needs to be improved. Scientific analysis and evaluation of students' interpersonal relationships can help teachers understand the interpersonal relationships of all students.

Applying cluster analysis to the investigation of college students' interpersonal relationships, we hope to dig out useful information. The result of clustering is to divide the influencing factors of college students' interpersonal relationships into several groups (i.e., clusters). Then, in the same cluster of cluster, whether the influencing factors of students' college students' interpersonal relationships will be similar needs to be confirmed through experiments combined with relevant investigations. Then, based on the experimental results, it makes the best of its strengths and avoids its weaknesses.

4. Experiment and Interpersonal Relationships among College Students Based on Cluster

4.1. Experiment and Cluster Algorithm before and after Improvement. The experimental data used in this experiment is the IRIS data set in the UCI machine learning database. This paper uses MATLAB for simulation experiments. After having the experimental condition data, simulation experiments were carried out on the k-means algorithm, the standard ant colony clustering algorithm, and the improved ant colony clustering algorithm. The results are shown in Tables 1 and 2.

As shown in Tables 1 and 2, from the error rate, it can be seen that the error rate of the k-means algorithm is relatively high. The improved ant colony clustering algorithm has a lower error rate. For the improvement of the ant colony clustering algorithm, people only carry out the verification of small data sets; if conditions permit, people need to verify the effect of cluster analysis on huge data sets.

This paper analyzes the execution time and work efficiency of the two algorithms, as shown in Figure 7.

As shown in Figure 7, comparing the execution efficiency of the two algorithms, it is found that the improved ant colony clustering algorithm takes less time and has higher execution efficiency. From these two aspects, the improved ant colony clustering algorithm has shown advantages and can continue to be studied. The goal of clustering is to dig out the internal structure of the data in the interpersonal relationships of college students. It provides meaningful information for further data analysis.

4.2. Student Interpersonal Relationship Survey Based on Cluster. The interpersonal communication of college students has the characteristics of self-interest and autonomy. With the reform and development of society, people's values are changing quietly, and the current interpersonal utilitarianism of college students is

Table 1: Clustering results of standard ant colony clustering algorithm.

Cluster category	Records	Incorrect record count	Error rate (%)
Category 1	40	8	16.7
Category 2	50	11	18.0
Category 3	54	10	15.6
Category 4	59	12	16.9
Category 5	60	9	13.0

Table 2: Clustering results of improved ant colony clustering algorithm.

Cluster category	Records	Incorrect record count	Error rate (%)
Category 1	45	3	6.2
Category 2	55	4	6.7
Category 3	60	3	4.7
Category 4	65	2	2.9
Category 5	70	5	6.6

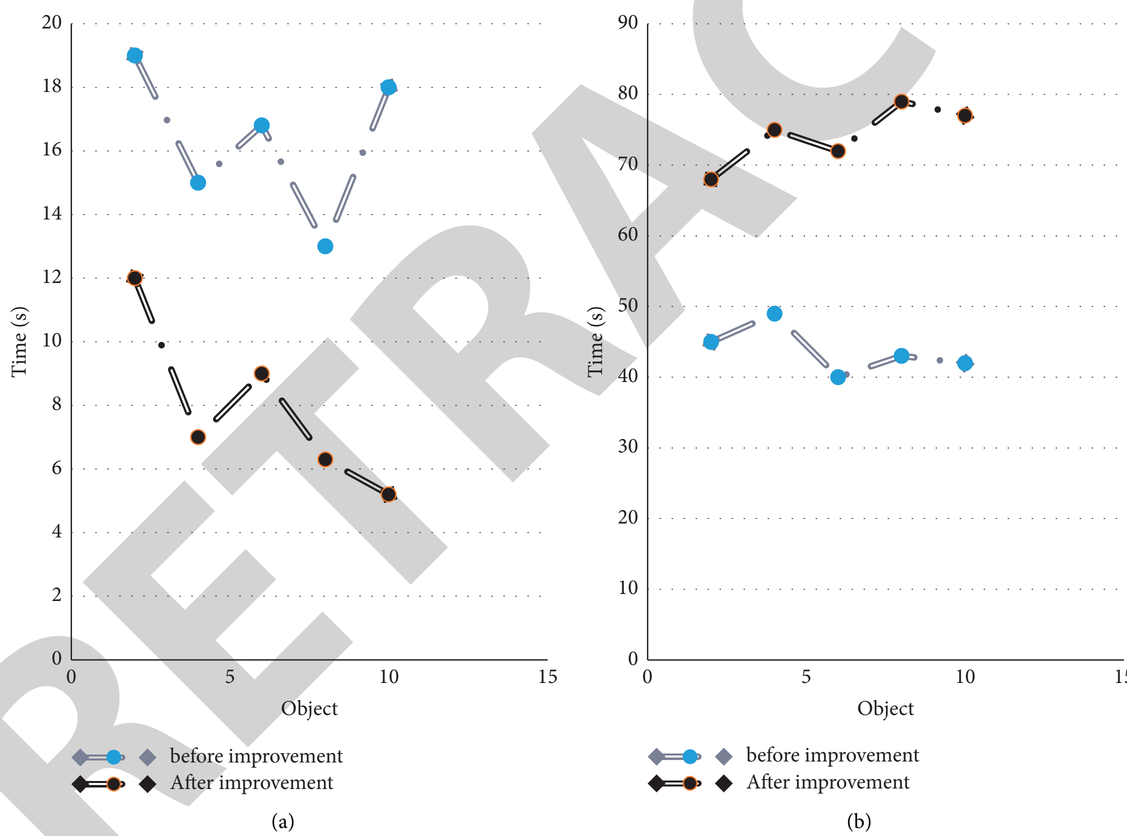


Figure 7: Comparison of execution time and work efficiency of the two algorithms: (a)the execution time of the two algorithms and (b) the work efficiency of the two algorithms.

gradually surpassing emotional communication. This article investigates whether college students at a university consider interpersonal relationships important. It uses cluster analysis to mine useful information and classify it, as shown in Figure 8.

As shown in Figure 8, the highest percentage of them considered "important" was 23%. Surprisingly, a small number of students think it is not important at all to build good relationships in college. This status quo should arouse the great attention of ideological and political educators in colleges and universities. It is necessary to carry out correct education and guidance for college students.

This paper analyzes the importance of interpersonal relationships in five companies, as shown in Table 3.

As shown in Table 3, 5 companies believe that interpersonal relationships are the most important skills required

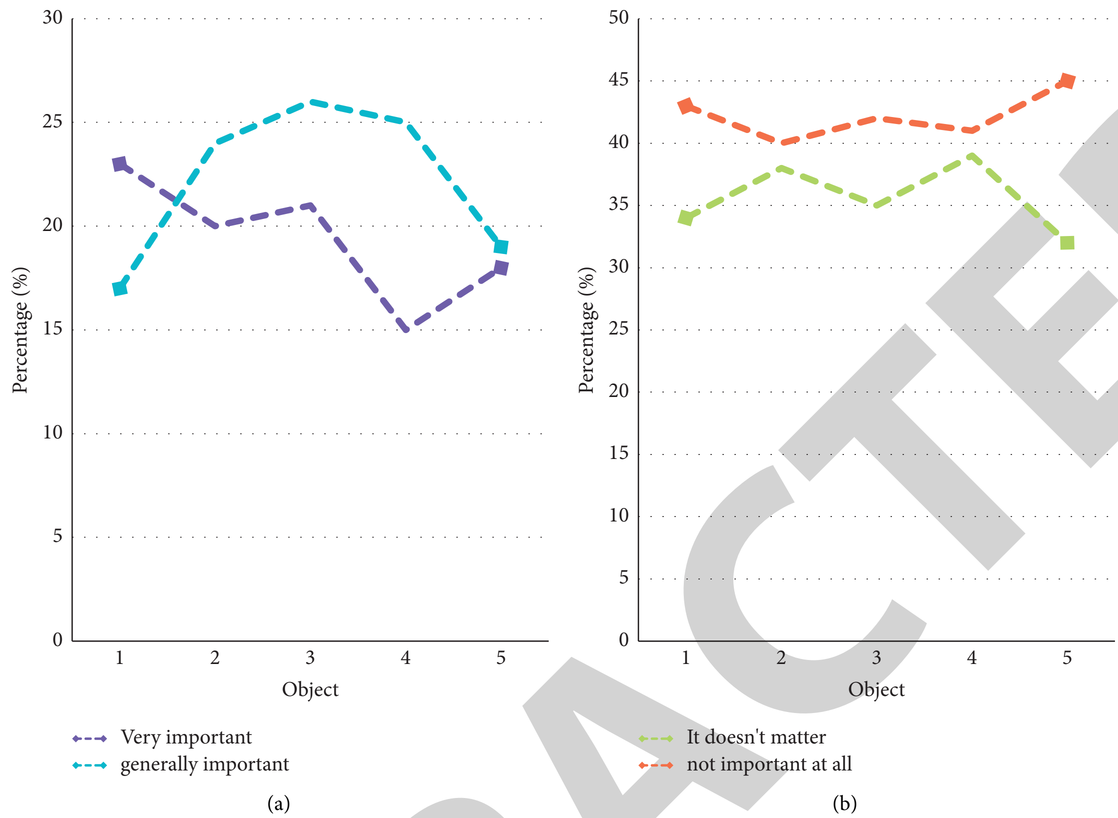


Figure 8: How important college students consider relationships to be.

Table 3: Teaching quality evaluation data before the implementation of the new system of teaching.

Research object	Interpersonal relationship	Self-capability	Education
1	8.5	7.6	7.3
2	8.4	7.3	7.0
3	8.9	7.5	7.2
4	8.2	7.8	7.1
5	8.0	7.7	6.9

Table 4: Questionnaire on interpersonal relationships of 80 students.

Grade	Number of people	Percentage (%)	Effective percentage (%)
A	13	16.25	16.25
B	21	26.25	26.25
C	30	37.5	37.5
D	16	20	20

for talents, and now schools of all levels and types have their own survey methods for interpersonal relationships among students. It achieves an objective analysis of students' interpersonal relationships through certain investigation methods.

It divides the quality of interpersonal relationships into grades *A*, *B*, *C*, and *D*, which correspond in turn from good to bad. It also divides each grade into a certain interval and then divides the interpersonal relationship of students into grades according to the interval. This blurs the numerical distinctions between students' interpersonal relationships. This paper investigates the quality of interpersonal relationships among 80 students, as shown in Table 4.

As shown in Table 4, it can be seen from the clustering results that there are 13 people with good interpersonal relationships, accounting for 16.25%. There are 21 people with normal interpersonal relationships, accounting for 26.25%, and 30 people with poor interpersonal relationships, accounting for 37.5%, ranking first. There are 16 people with poor interpersonal relationships, accounting for 20%. It can be seen from this that most of the students' interpersonal relationships are not very good, so they should strengthen their own interpersonal relationships and better adapt to society.

As an open learning exchange platform, the source of students also has a variety of different backgrounds, growth locations, and different concepts. Because the interpersonal relationships of college students are special in many aspects, the most obvious feature of interpersonal relationships among college students is that distance determines proximity. This paper investigates the influencing factors of college students' interpersonal relationships, as shown in Figure 9.

As shown in Figure 9, the influencing factors of college students' interpersonal relationships are as follows: subjective individual factors, social value orientation factors, employment competition pressure factors, and new media technology development factors. At present, teenagers are the largest group of people who use new media for interpersonal

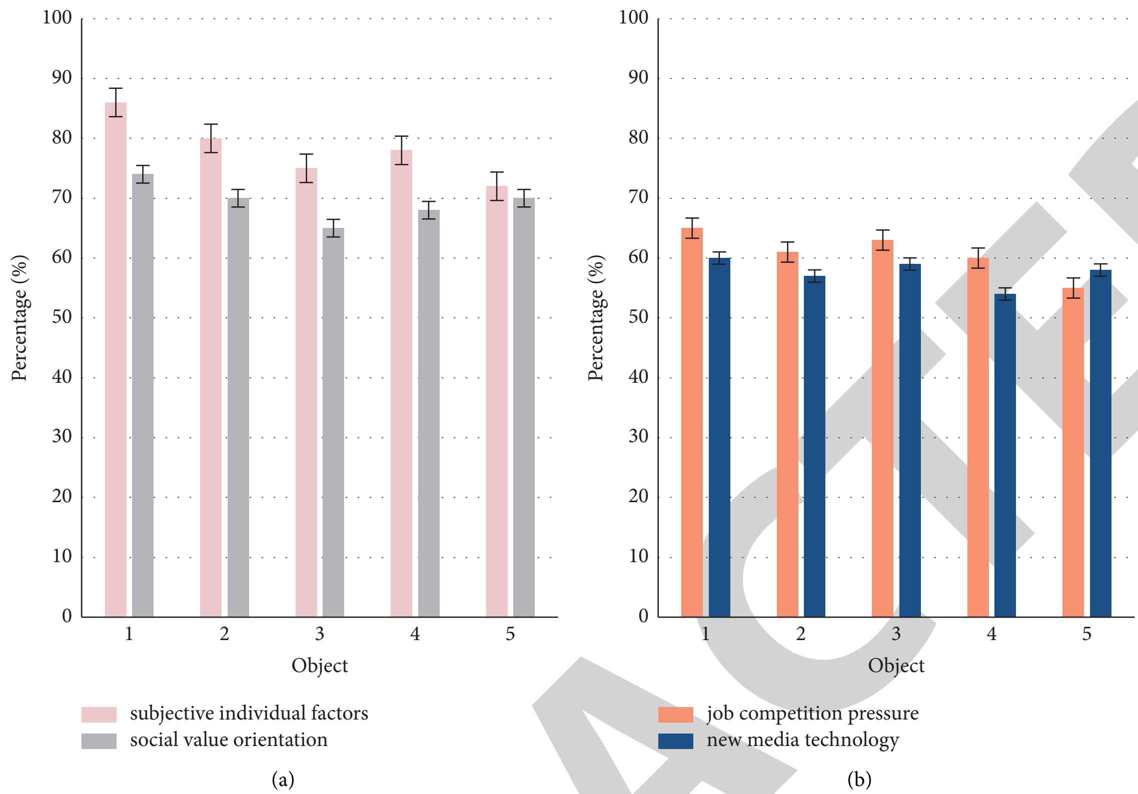


Figure 9: Factors influencing college students' interpersonal relationships.

communication, and college students are the main force of this group. College is an important period for everyone's life development, and colleagues are also the most vulnerable and confusing period in everyone's life. College students have spent more than 10 years of youth in school; their psychology is not yet mature; their social experience is almost zero; and their adaptability is very poor after entering society.

4.3. Countermeasures to Promote Harmonious Interpersonal Relationships among College Students Today

4.3.1. The Education of Harmonious Interpersonal Relationship Runs through the Daily Management of Students. As the direct implementer of student management, counselors should always run through the education of harmonious interpersonal relationships in the daily life and study of college students, so as to combine daily management with ideological education. It regulates and manages the daily behavior of college students and takes effective measures to praise the harmonious behavior of college students. It punishes the disharmonious behavior of college students, actively promotes the formation of harmonious quality of college students, and makes college students feel the beautiful atmosphere of a harmonious campus and harmonious dormitory.

4.3.2. Strengthen the Construction of Campus Spiritual Culture. Campus spiritual culture is the core and soul of campus culture, which pervades every corner of the school atmosphere. It is reflected in the whole interpersonal communication and cultural atmosphere, which highlights the style and characteristics of the school. To strengthen the construction of campus spiritual culture, the focus is to strengthen the construction of school spirit. A good school spirit can stimulate the internal motivation of the school and can resist bad psychological tendencies and behaviors. Teachers should develop a rigorous academic attitude, possess unique personality charm, and be an example of harmonious interpersonal relationships. Only in this way can it help adjust the teacher-student relationship and the various contradictions encountered in teaching. It contributes to the construction of a harmonious campus.

4.3.3. Attach Importance to the Ideological Education of College Students and Strengthen the Training of Communication Skills. The first thing to do is to understand oneself better. In particular, it is necessary to carefully understand their own character and put forward practical specific goals. On this basis, one should control their own actions and communication processes. It is very important to establish a harmonious interpersonal relationship by objectively and correctly understanding one's own physiological state, psychological characteristics, relationship with others, and the purpose of communication.

5. Conclusion

The self-education of college students' interpersonal communication is a self-enlightening activity for college students to achieve their own growth goals. In order to cultivate students' self-education ability, it is necessary to take effective methods. To improve the relationship with classmates, it is necessary to consider the problem from the perspective of others and be good at making appropriate self-sacrifice. However, the traditional survey of college students' interpersonal relationships is too complicated and cannot accurately mine useful information and make use of it. Therefore, based on intelligent big data, this paper proposes clustering analysis in the data mining algorithm. It investigates the interpersonal relationship of college students. This article is very clear about the concept of big data and college students' interpersonal relationships. In the method part, this paper expounds on the cluster analysis algorithm. Cluster analysis algorithms not only can find similar data in interpersonal relationships but also can remove redundant data. It enables college students to have a more detailed understanding of their own interpersonal relationships, so as to establish better interpersonal relationships and better enter society. The experimental part not only conducts experiments on cluster analysis before and after improvement but also investigates whether many college students think that interpersonal relationships are important. The results show that most students think that interpersonal relationships are not very important, which is also the main reason for modern college students to be withdrawn and indifferent. In response to this problem, this paper puts forward some measures to establish a good interpersonal relationship at the end. This article hopes to help college students with poor interpersonal relationships improve their interpersonal relationships and have a better campus life.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This article was partially supported by the project on talent training quality and teaching reform in higher education of Chengdu University of Technology from 2021 to 2023 (Grant no. JG2130124).

References

[1] A. L. Clem, K. M. Rudasill, R. Hirvonen, K. Aunola, and N. Kiuru, "The roles of teacher–student relationship quality and self-concept of ability in adolescents' achievement emotions: temperament as a moderator," *European Journal of Psychology of Education*, vol. 36, no. 2, pp. 263–286, 2021.

[2] J. W. Xue, X. K. Xu, and F. Zhang, "Big data dynamic compressive sensing system architecture and optimization algorithm for internet of things," *Discrete & Continuous Dynamical Systems - S*, vol. 8, no. 6, pp. 1401–1414, 2015.

[3] L. Kuang, F. Hao, L. T. Yang, M. Lin, C. Luo, and G. Min, "A tensor-based approach for big data representation and dimensionality reduction," *IEEE Transactions on Emerging Topics in Computing*, vol. 2, no. 3, pp. 280–291, 2014.

[4] C. Stergiou and K. E. Psannis, "Recent advances delivered by mobile cloud computing and internet of things for big data applications: a survey," *International Journal of Network Management*, vol. 27, no. 3, p. e1930, 2017.

[5] Y. Zhang, J. Ren, J. Liu, C. Xu, H. Guo, and Y. Liu, "A survey on emerging computing paradigms for big data," *Chinese Journal of Electronics*, vol. 26, no. 1, pp. 1–12, 2017.

[6] L. Xu, C. Jiang, J. Wang, Yuan Jian, and Ren Yong, "Information security in big data: privacy and data mining," *IEEE Access*, vol. 2, no. 2, pp. 1149–1176, 2014.

[7] H. Cai, B. Xu, L. Jiang, and A. V. Vasilakos, "IoT-based big data storage systems in cloud computing: perspectives and challenges," *IEEE Internet of Things Journal*, vol. 4, no. 1, pp. 75–87, 2017.

[8] K. Vijay, "Collaborating the textual reviews of the merchandise and foretelling the rating supported social sentiment," *Journal of Cognitive Human-Computer Interaction*, vol. 1, no. 2, pp. 63–72, 2021, https://doi.org/10.54216/JCHCI.010203.

[9] F. Kache and S. Seuring, "Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management," *International Journal of Operations & Production Management*, vol. 37, no. 1, pp. 10–36, 2017.

[10] M. M. U. Rathore, A. Paul, A. Ahmad, B. W. Chen, B. Huang, and W. Ji, "Real-time big data analytical architecture for remote sensing application," *Ieee Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 8, no. 10, pp. 4610–4621, 2015.

[11] F. Li, C. Wang, and X. Yue, "Impact of doctoral student training process fit on doctoral students' mental health," *International Journal of Mental Health Promotion*, vol. 24, no. 2, pp. 169–187, 2022.

[12] H. Xing, A. Qian, R. C. Qiu, W. Huang, L. Piao, and H. Liu, "A big data architecture design for smart grids based on random matrix theory," *IEEE Transactions on Smart Grid*, vol. 8, no. 2, pp. 674–686, 2017.

[13] Y. Wang, L. A. Kung, and T. A. Byrd, "Big data analytics: understanding its capabilities and potential benefits for healthcare organizations," *Technological Forecasting and Social Change*, vol. 126, no. JAN, pp. 3–13, 2018.

[14] G. Li, F. Liu, A. Sharma et al., "Research on the natural language recognition method based on cluster Analysis using neural network," *Mathematical Problems in Engineering*, vol. 1, Article ID 9982305, 13 pages, 2021.

[15] A. Zaid and A. Li, "Network user interest mining method based on Neutrosophic cluster analysis," *International Journal of Neutrosophic Science*, vol. 18, no. 2, pp. 186–198, 2022.

[16] Y. Zhang, M. Qiu, C. W. Tsai, M. M. Hassan, and A. Alamri, "Health-CPS: healthcare cyber-physical system Assisted by cloud and big data," *IEEE Systems Journal*, vol. 11, no. 1, pp. 88–95, 2017.

[17] S. Athey, "Beyond prediction: using big data for policy problems," *Science*, vol. 355, no. 6324, pp. 483–485, 2017.

[18] S. H. Lee and E. Y. Hwang, "The effects of group music activity on the improvement interpersonal relationship ability and quality of life of chronic schizophrenia," *Journal of Arts Psychotherapy*, vol. 16, no. 3, pp. 39–65, 2020.

[19] J. Kim and Y. Kim, "A study on the interpersonal relationship tendency in accordance with cluster Analysis of university

Hindawi
Scientific Programming
Volume 2022, Article ID 3456302, 7 pages
https://doi.org/10.1155/2022/3456302

Research Article

A Theoretical Scientific Programming Framework for Application of Linear Matrix Transformation in Plane Computer Graphics

Mingcan Chen

College of Management, Henan Institute of Economics and Trade, Zhengzhou 450008, Henan, China

Correspondence should be addressed to Mingcan Chen; chenmingcan@henetc.edu.cn

Received 10 April 2022; Revised 16 May 2022; Accepted 8 June 2022; Published 21 July 2022

Academic Editor: Ahmed Farouk

Plane computer graphics are basic information carriers in many industrial scenarios, such as engineering simulation, automatic control, and software design. Plane computer graphics are generally a kind of digital signals guided by mathematical symbols, and each vertex of a plane computer graph forms a graph matrix. Therefore, linear matrix transformation serves as the most common algorithmic unit to realize various information processing operations. To improve ease of graph matrix computing in practical engineering scenarios, this paper proposes a theoretical scientific programming framework for application of linear matrix transformation in plane computer graphics. Firstly, theoretical basis of linear matrix transformation in homogeneous plane coordinates is displayed and analyzed. Then, the universal theorem about linear transformation of graph matrices is deduced, and corresponding proofs are also given. Finally, a case study is set up to demonstrate the main workflow of the proposed theoretical scientific programming framework. The simulative results reveal feasibility of the proposal.

1. Introduction

Geometric graphics transformation refers to some specific graphics process operations [1, 2], including movement of the defined graphics from one position to another [3], change of size and shape for graphics, or generation of complex graphics from existing graphics [4, 5]. And it is also named as graphics transformation for short [6, 7]. Graphics transformation can help deduce required graphics with the aid of two-dimensional or three-dimensional transformation operations [8, 9]. Figure 1 gives a typical example of 2D linear matrix transformation in plane space [10, 11]. Graphic transformation is usually realized via matrix transformation, and matrices used for transformation varies with different scenes [12, 13]. With the development of computer science and simulation modeling, graphics transformation is usually implemented by computer algorithms [14], forming the discipline of computer graphics [15]. In order to enhance engineering ease of digital signal processing in plane graphics [16], this work concentrates the theoretical scientific programming framework for application of linear matrix transformation in plane computer graphics [17, 18].

Points are the basic elements of a graph [19]. In analytic geometry, points are represented by vectors [20, 21]. For example, points in two-dimensional space (plane) and in three-dimensional space are separately represented by

$$\begin{aligned} P_{2d} &\in (x, y)', \\ P_{3d} &\in (x, y, z)'. \end{aligned} \tag{1}$$

A planar (two-dimensional) figure or a spatial (three-dimensional) shape can be represented by a set of points (referred to as a set of points) [22, 23]. A planar graph can be represented by a matrix as follows:

$$\mathrm{Mat}_{2d} = \begin{bmatrix} x_1 & x_2 & \cdots & x_n \\ y_1 & y_2 & \cdots & y_n \end{bmatrix}, \tag{2}$$

where the set of vertices $(x_1, y_1)', (x_2, y_2)', \ldots, (x_n, y_n)'$ are included and a three-dimensional graph can be represented by a matrix as follows:

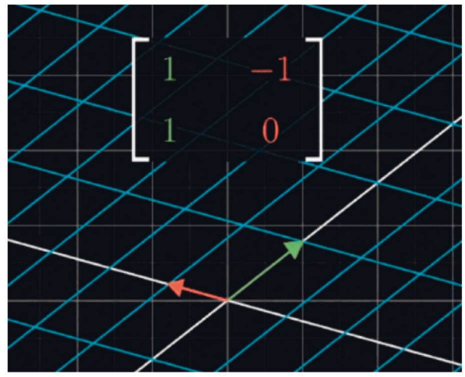


Figure 1: A typical example of linear matrix transformation in plane space.

$$\mathrm{Mat}_{3\,d} = \begin{bmatrix} x_1 & x_2 & \cdots & x_n \\ y_1 & y_2 & \cdots & y_n \\ z_1 & z_2 & \cdots & z_n \end{bmatrix}. \tag{3}$$

When the point set is represented by a matrix, the transformation of the point can be realized by the following linear transformation:

$$\mathbf{A}\mathbf{x} = \mathbf{y}, \tag{4}$$

where $\mathbf{x}$ denotes the old point coordinates, $\mathbf{A}$ denotes the transformation matrix, and $\mathbf{y}$ denotes the new point coordinates. There is a one-to-one correspondence between linear transformation and matrix.

2. Plane Graph Transformation in Homogeneous Coordinates

First of all, it is supposed to illustrate four basic transformation types which are shown in Figure 2: translation, scale, rotation, and skew [24, 25]. The commonly used transformation matrix of plane graphics contains four types: proportional transformation, symmetrical transformation, rotation transformation, and the translation transformation [26, 27].

Definition 1. The proportional transformation is represented as the following format:

$$T = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix}, \tag{5}$$

where s_x and s_y are the proportional coefficient along the x-axis and y-axis, respectively, and they satisfy the condition: $s_x > 0, s_y > 0$. The different value setting of s_x and s_y leads to different scenes.

(i) When $s_x = s_y = 1$, it is a constant proportional transformation, that is, the figure is unchanged.

(ii) When $s_x = s_y > 1$, the figure magnifies proportionally along the two axes.

(iii) When $s_x = s_y < 1$, the figure shrinks proportionally along the two axes.

(iv) When $s_x \neq s_y$, the figure changes nonuniformly along the two axes, and the result is graphic distortion.

Definition 2. The symmetrical transformation is represented as the following format:

$$T = \begin{bmatrix} a & b \\ c & d \end{bmatrix}, \tag{6}$$

where a, b, c, and d are the symmetrical coefficients. The different value setting of a, b, c, and d leads to different scenes.

(i) When $a = 1, d = -1, b = c = 0$, it is a symmetrical transformation about the X-axis.

(ii) When $a = -1, d = 1, b = c = 0$, it is the symmetric transformation about the Y-axis.

(iii) When $a = -1, d = -1, b = c = 0$, it is the symmetric transformation about the origin.

(iv) When $a = d = 0, b = c = 1$, it is the symmetric transformation about the straight line $x - y = 0$.

(v) When $a = d = 0, b = c = -1$, it is the symmetric transformation about the straight line $x + y = 0$.

Definition 3. The rotation transformation is represented as the following format:

$$T = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}, \tag{7}$$

where θ is the angle rotated around the origin of the coordinate. The different value setting of θ leads to different scenes.

(i) The value of this angle is positive $(\theta > 0)$ when it rotates counterclockwise.

(ii) The value of this angle is negative $(\theta < 0)$ when it rotates clockwise.

Definition 4. The translation transformation is represented as the following format:

$$T = \begin{cases} x' = x + m, \\ y' = y + n, \end{cases} \tag{8}$$

or the following format:

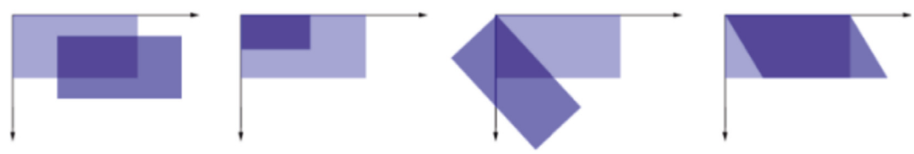


Figure 2: Four basic transformation types: translation, scale, rotation, and skew.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} m \\ n \end{bmatrix}. \tag{9}$$

As the translation transformation cannot be written in form of $\mathbf{Ax} = \mathbf{y}$, it is not with the linear type. In order to change translation transformation into linear transformation, we can uniformly use linear matrix operations to study plane graphic transformation [28]. The homogeneous coordinates are generated, in which n-dimensional vectors are represented by $(n+1)$-dimensional ones. When the homogeneous coordinate of the vector $(x_1, x_2, \ldots, x_n)'$ equals to $(hx_1, hx_2, \ldots, hx_n, h)'$, where h is a real number, the homogeneous coordinate representation of a vector is not unique, and different values of the homogeneous coordinate h represents the same point. A homogeneous coordinate $(8,4,2)'$, $(4,2,1)'$ represents the point $(4,2)'$ on the plane. Hence, the following definition can be deduced.

Definition 5. When $h = 1$, the homogeneous coordinate $(x_1, x_2, \ldots, x_n, h)'$ is called as the normalized homogeneous coordinate.

After the introduction of homogeneous coordinates, translation transformation defined in Definition 4 can be written as follows:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & m \\ 0 & 1 & n \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} x+m \\ y+n \\ 1 \end{bmatrix}. \tag{10}$$

It is a linear transformation, and the different value setting of a, b, c, and d leads to different scenes.

(i) When $m > 0$, the graph translates positively along the X-axis.

(ii) When $m < 0$, the graph translates negatively along the X-axis.

(iii) When $n > 0$, the graph translates positively along the Y-axis.

(iv) When $n < 0$, the graph translates negatively along the Y-axis.

3. Theorem and Proof for Plane Graphics Transformation

Theorem 1. *When the transformation matrix of the plane graph is denoted as follows:*

$$T = \begin{bmatrix} a & b & m \\ c & d & n \\ 0 & 0 & s \end{bmatrix}, \tag{11}$$

the $\begin{bmatrix} a & b \\ c & d \end{bmatrix}$ *causes proportional, symmetric, and rotational transformation of the planar graph, and* $\begin{bmatrix} m \\ n \end{bmatrix}$ *causes the plane graph to produce translation transformation.*

Proof. Supposing that $y = Tx$, the following formula can be deduced:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & m \\ c & d & n \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}, \tag{12}$$

where y, x, and T are separately represented as follows:

$$\begin{aligned} y &= \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} Y \\ 1 \end{bmatrix}, \\ x &= \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} X \\ 1 \end{bmatrix}, \\ T &= \begin{bmatrix} a & b & m \\ c & d & n \\ 0 & 0 & s \end{bmatrix} = \begin{bmatrix} T_1 & T_2 \\ T_3 & T_4 \end{bmatrix}. \end{aligned} \tag{13}$$

According to the matrix block method, the following six formulas can be further deduced as follows:

$$\begin{aligned} Y &= \begin{bmatrix} x' \\ y' \end{bmatrix}, \\ X &= \begin{bmatrix} x \\ y \end{bmatrix}, \\ T_1 &= \begin{bmatrix} a & b \\ c & d \end{bmatrix}, \\ T_2 &= \begin{bmatrix} m \\ n \end{bmatrix}, \\ T_3 &= (0,0), \\ T_4 &= s. \end{aligned} \tag{14}$$

Then, the $y = Tx$ can be rewritten as follows:

$$\begin{aligned}\begin{bmatrix} Y \\ 1 \end{bmatrix} &= T\begin{bmatrix} X \\ 1 \end{bmatrix} \\ &= \begin{bmatrix} T_1 & T_2 \\ T_3 & T_4 \end{bmatrix}\begin{bmatrix} X \\ 1 \end{bmatrix} \\ &= \begin{bmatrix} T_1X + T_2 \\ T_3X + T_4 \end{bmatrix} \\ &= \begin{bmatrix} T_1X + T_2 \\ T_4 \end{bmatrix}.\end{aligned} \quad (15)$$

Obviously, T_1X is the basic transformation of two-dimensional graphics, thus translation transformation $T_1X + T_2$ can be deduced as follows:

$$T_1X + T_2 = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} m \\ n \end{bmatrix}. \quad (16)$$

To sum up, the transformation of plane graphics can be represented by a unified matrix.

$$T = \begin{bmatrix} a & b & m \\ c & d & n \\ 0 & 0 & s \end{bmatrix}. \quad (17)$$

The proof for Theorem 1 is to be finished so far.

Points are often used in computer graphics, and if the position of point changes, so does the figure [29]. Therefore, if transform the graph, it is needed to change the point [30]. The effect of the product of a matrix and a vector in linear transformation provides a method of graphic transformation, which can be used to produce the effect of the graphic change in the computer [31, 32].

For a closed figure in a plane coordinate system, it is represented by a matrix x, and each column of x represents the coordinates of a vertex of the graph. To close the graph, the last column of x is the same as the first column [33]. In order to realize the translation of graphics by using linear transformation, a row with elements of 1 is added to matrix x so that the shape of matrix $[3 \times n]$.

The following two transformation matrices are given as

$$\begin{aligned} M &= \begin{bmatrix} 1 & 0 & m \\ 0 & 1 & n \\ 0 & 0 & 1 \end{bmatrix}, \\ R &= \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix},\end{aligned} \quad (18)$$

for two transformation processes $Y_1 = MX$ and $Y_2 = RX$, they can be separately explained as follows:

(i) Y_1 is the transformation result of X, in which m is translated along the positive direction of the X-axis, n is translated along the positive direction of the Y-axis.

(ii) Y_2 is the result of the inverse (clockwise) rotation of the θ angle of the graph X with the coordinate origin as the center.

The letter A is moved 15 up, 30 to the left, the $\pi/3$ counterclockwise, and then 30 up, 20 to the right, then turn counterclockwise by $3/4\pi$, and the MATLAB software is used to draw transformed graphics [34, 35]. The graphic matrix of the letter A can be constructed from Table 1. For this example, X is deduced as follows:

$$X = \begin{bmatrix} 0 & 4 & 6 & 10 & 8 & 5 & 3.5 & 6.1 & 6.5 & 3.2 & 2 & 0 \\ 0 & 14 & 14 & 0 & 0 & 11 & 6 & 6 & 4.5 & 4.5 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}. \quad (19)$$

From the meaning of the question, it can be seen that the transformation matrix of figure a moving up 15 and moving left 30, which can be represented as the following matrix:

$$M_1 = \begin{bmatrix} 1 & 0 & -30 \\ 0 & 1 & 15 \\ 0 & 0 & 1 \end{bmatrix}. \quad (20)$$

And the transformation matrix can be represented as

$$R_1 = \begin{bmatrix} \cos\dfrac{\pi}{3} & -\sin\dfrac{\pi}{3} & 0 \\ \sin\dfrac{\pi}{3} & \cos\dfrac{\pi}{3} & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad (21)$$

where rotating counterclockwise of graph A is $\pi/3$. The transformation matrices of moving figure A up 30, 20 to the right, and $3/4\pi$ counterclockwise, respectively, are as follows:

$$\begin{aligned} M_2 &= \begin{bmatrix} 1 & 0 & 20 \\ 0 & 1 & 30 \\ 0 & 0 & 1 \end{bmatrix}, \\ R_2 &= \begin{bmatrix} \cos\dfrac{3\pi}{4} & -\sin\dfrac{3\pi}{4} & 0 \\ \sin\dfrac{3\pi}{4} & \cos\dfrac{3\pi}{4} & 0 \\ 0 & 0 & 1 \end{bmatrix}.\end{aligned} \quad (22)$$

So, these three transformation matrices are respectively R_1, M_1, and R_2M_2, and one of them R_2M_2 is a combinatorial transformation. □

Table 1: Data sheet with letter A.

x	0	4	6	10	8	5	3.5	6.1	6.5	3.2	2	0
y	0	14	14	0	0	11	6	6	4.5	4.5	0	0

INPUT: X, M_1, M_2, R_1, R_2
OUTPUT: Y_1, Y_2
(1) **while** Each graph **do**
(2) **for** Dimension: $1 \longrightarrow 3$ **do**
(3) Plot plane graph of letter A
(4) Define transformation matrix M_1 for letter A
(5) Calculate transformation result Y_1 for letter A
(6) Define transformation matrix R_1 for letter A
(7) Calculate transformation result Y_2 for letter A
(8) Define transformation matrices R_2 and M_2 for letter A
(9) Calculate transformation result Y_3 for letter A
(10) Output graphics for letter A
(11) **end for**
(12) **end while**

Algorithm 1: Workflow of the proposed theoretical programming framework.

4. Scientific Programming Demo for the Case Study

Having analyzed basic linear matrix transformation theory and proved its efficiency, this section manages to give a practical scientific programming demo for the above case study. Its pseudo codes reveal major workflow of the proposed theoretical scientific programming framework, which is illustrated in Algorithm 1. Through such suggested theoretical scientific programming framework, it is expected to facilitate engineering practice in relevant areas. The proposed scientific programming demo for the above case study in MATLAB is given as follows:

```
>>close all;
>>X = [0,4,6,10,8,5,3.5,6.1,6.5,3.2,2,0;
0,14,14,0,0,11,6,6,4.5,4.5,0,0;
ones(1,12)];
>>plot(X(1,:),X(2,:));
% Draw the letter A figure hold on;
>>M1 = [1,0,–30; 0,1,15; 0,0,1];
>>Y1 = M1 * X;
hold on;
>>fill(Y1(1,:),Y1(2,:), “red”);
%Draw the figure after the translation of the letter A.
>>R1 = [cos(pi/3), −sin(pi/3),0];
sin(pi/3),cos(pi/3),0;
[0,0,1];
>>Y2 = R1 * X;
hold on;
>>fill(Y2(1,:),Y2(2,:), “blue”);
%Draw the figure after the letter A is rotated.
>>M2 = [1,0,20; 0,1,30; 0,0,1];
>>R2 = [cos(3 * pi/4), −sin(3 * pi/4),0];
sin(3 * pi/4),cos(3 * pi/4),0;
[0,0,1];
>>Y3 = M2 * R2 * X;
hold on;
>>fill(Y3(1,:),Y3(2,:), “black”);
%Draw the figure after the letter A is translated and rotated.
```

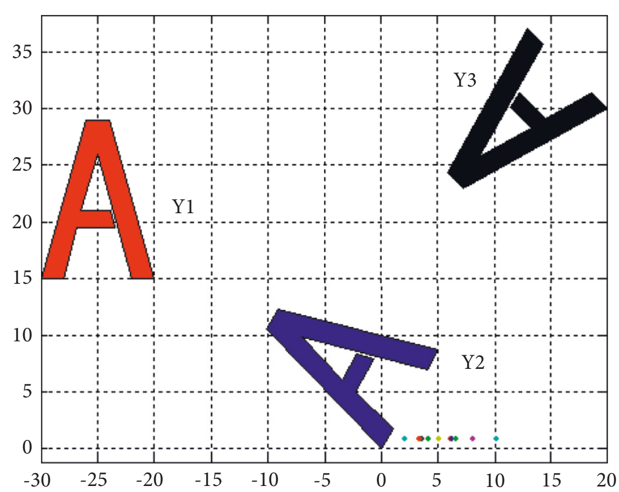


Figure 3: Transformation diagram of letter A.

Running result of the above programming code leads to the graph in Figure 3.

5. Conclusion

Plane graph transformation mainly includes proportion, symmetry, rotation, translation, and so on [36]. These transformations are unified into linear transformations under homogeneous coordinates and studied by the matrix [37]. This provides a unified transformation matrix method for coordinate transformation of two-dimensional, three-dimensional, and even high-dimensional space of geometric graphics, and these transformations can be easily combined [38]. The complexity of the transformation matrix is related to transformation steps, that is, the more steps, the more transformation matrix, which can produce the transformation of the complex graph [39, 40].

Data Availability

The data are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] S. Lee and C. Tseng, "Design of graph filter based on transformation matrix and spectral response," in *Proceedings of the International Symposium on Intelligent Signal Processing and Communication Systems*, pp. 16–19, IEEE, Hualien City, Taiwan, November 2021.

[2] A. Aristidou, J. Lasenby, Y. Chrysanthou, and A. Shamir, "Inverse kinematics techniques in computer graphics: a survey," *Computer Graphics Forum*, vol. 37, no. 6, pp. 35–58, 2018.

[3] G. Teh, W. C. Teh, Elementary matrix equivalence and core transformation graphs for parikh matrices," *Discrete Applied Mathematics*, vol. 251, pp. 276–289, 2018.

[4] L. Zhen, Y. Zhang, K. Yu, N. Kumar, A. Barnawi, and Y. Xie, "Early collision detection for massive random access in satellite-based internet of things," *IEEE Transactions on Vehicular Technology*, vol. 70, no. 5, pp. 5184–5189, 2021.

[5] Z. Guo, L. Tang, T. Guo, K. Yu, M. Alazab, and A. Shalaginov, "Deep graph neural network-based spammer detection under the perspective of heterogeneous cyberspace," *Future Generation Computer Systems*, vol. 117, pp. 205–218, 2021.

[6] K. Yu, L. Tan, L. Lin, X. Cheng, Z. Yi, and T. Sato, "Deep-learning-empowered breast cancer auxiliary diagnosis for 5gb remote e-health," *IEEE Wireless Communications*, vol. 28, no. 3, pp. 54–61, 2021.

[7] H. Y. Tian, B. Tian, Y. Sun, and C. R. Zhang, "Three-component coupled nonlinear Schrödinger system in a multimode optical fiber: darboux transformation induced via a rank-two projection matrix," *Communications in Nonlinear Science and Numerical Simulation*, vol. 107, Article ID 106097, 2022.

[8] Z. Guo, K. Yu, A. Jolfaei, A. K. Bashir, A. O. Almagrabi, and N. Kumar, "A Fuzzy Detection System for Rumors through Explainable Adaptive Learning," *IEEE Trans. Fuzzy Syst*, vol. 29, 2021.

[9] P. Liang, H. T. Likassa, C. Zhang, and J. Guo, "New robust PCA for outliers and heavy sparse noises' detection via affine transformation, the L { ∗ }, w and L 2, 1 norms, and spatial weight matrix in high-dimensional images: from the perspective of signal processing," *International Journal of Mathematics and Mathematical Sciences*, vol. 2021, Article ID 3047712, 9 pages, 2021.

[10] Z. Guo, K. Yu, Y. Li, G. Srivastava, and J. C. W. Lin, "Deep learning embedded social internet of things for ambiguity-aware social recommendations," *IEEE Trans. Netw. Sci. Eng.*vol. 9, no. 3, pp. 1067–1081, 2021.

[11] S. Vologiannidis, E. N. Antoniou, N. P. Karampetakis, and A. I. G. Vardulakis, "Polynomial matrix equivalences: system transformations and structural invariants," *IMA Journal of Mathematical Control and Information*, vol. 38, no. 1, pp. 54–73, 2021.

[12] K. Yu, Z. Guo, Y. Shen, W. Wang, J. C. wei Lin, and T. Sato, "Secure Artificial Intelligence of Things for Implicit Group Recommendations," *IEEE Internet Things J*, vol. 9, no. 4, 2021.

[13] R. Geng and X. Geng, "A matrix yajima-oikawa long-wave-short-wave resonance equation, darboux transformations and rogue wave solutions," *Communications in Nonlinear Science and Numerical Simulation*, vol. 90, Article ID 105408, 2020.

[14] S. C. Chu, Y. Chen, F. Meng, C. Yang, J. S. Pan, and Z. Meng, "Internal search of the evolution matrix in quasi-affine transformation evolution (QUATRE) algorithm," *Journal of Intelligent and Fuzzy Systems*, vol. 38, no. 5, pp. 5673–5684, 2020.

[15] L. M. Anguas, M. I. Bueno, and F. M. Dopico, "Conditioning and backward errors of eigenvalues of homogeneous matrix polynomials under Möbius transformations," *Mathematics of Computation*, vol. 89, no. 322, pp. 767–805, 2019.

[16] G. Horváth, I. Horváth, S. A. D. Almousa, and M. Telek, "Numerical inverse laplace transformation using concentrated matrix exponential distributions," *Performance Evaluation*, vol. 137, Article ID 102067, 2020.

[17] K. Usevich, J. Li, and P. Comon, "Approximate matrix and tensor diagonalization by unitary transformations: convergence of Jacobi-type algorithms," *SIAM Journal on Optimization*, vol. 30, no. 4, pp. 2998–3028, 2020.

[18] B. Zhang, N. Uysal, D. Fan, and R. Ewetz, "Handling stuck-at-fault defects using matrix transformation for robust inference of dnns," *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, vol. 39, no. 10, pp. 2448–2460, 2020.

[19] R. Wang and Y. Wang, "Forward looking infrared target matching algorithm based on depth learning and matrix double transformation," *Cluster Computing*, vol. 22, no. S3, pp. 7055–7062, 2019.

[20] A. Kahla and H. B. Kahla, "An upper J-Hessenberg reduction of a matrix through symplectic householder transformations," *Computers & Mathematics with Applications*, vol. 78, no. 1, pp. 178–190, 2019.

[21] V. A. Sanzharov and V. V. Sanzharov, "Modern problems of software integration in computer graphics applications and ways to solve them," *Programming and Computer Software*, vol. 44, no. 4, pp. 233–239, 2018.

[22] S. Le Borne, "Factorization, symmetrization, and truncated transformation of radial basis function-ga stabilized Gaussian radial basis functions," *SIAM Journal on Matrix Analysis and Applications*, vol. 40, no. 2, pp. 517–541, 2019.

[23] P. C. Lopes, R. L. Rangel and L. F. Martha, An interactive user interface for a structural analysis software using computer graphics techniques in MATLAB," *Computer Applications in Engineering Education*, vol. 29, no. 6, pp. 1505–1525, 2021.

[24] W. E. Carlson, R. Hackathorn, and R. E. Parent, "Computer graphics and animation at the Ohio state university," *IEEE*

Computer Graphics and Applications, vol. 41, no. 3, pp. 8–17, 2021.

[25] B. S. Santos, G. Domik, and E. F. Anderson, "Foreword to the special section on computer graphics education in the time of covid," *Graphics and Visual Computing*, vol. 4, Article ID 200028, 2021.

[26] E. Y. Denisov, A. G. Voloboy, E. D. Biryukov, M. S. Kopylov, and I. A. Kalugina, "Automated software testing technologies for realistic computer graphics," *Programming and Computer Software*, vol. 47, no. 1, pp. 76–87, 2021.

[27] T. Feng, F. Fan, and T. Bednarz, "A review of computer graphics approaches to urban modeling from a machine learning perspective," *Frontiers of Information Technology & Electronic Engineering*, vol. 22, no. 7, pp. 915–925, 2021.

[28] C. Andujar, C. R. Vijulie, À. Vinacua, B. S. Santos, and G. Alford, "Syntactic and semantic analysis for extended feedback on computer graphics assignments," *IEEE Computer Graphics and Applications*, vol. 40, no. 3, pp. 105–111, 2020.

[29] M. Li and Y. Li, "The application of computer graphics processing in visual communication design," *Journal of Intelligent and Fuzzy Systems*, vol. 39, no. 4, pp. 5183–5191, 2020.

[30] N. Christoff, "A survey of human modelling in computer graphics," *Journal Multim. Process. Technology*, vol. 11, no. 4, pp. 130–136, 2020.

[31] N. Bonneel, D. Coeurjolly, J. Digne, and N. Mellado, "Code replicability in computer graphics," *ACM Transactions on Graphics*, vol. 39, no. 4, p. 93, 2020.

[32] M. Long, F. Peng, and Y. Zhu, "Identifying natural images and computer generated graphics based on binary similarity measures of PRNU," *Multimedia Tools and Applications*, vol. 78, no. 1, pp. 489–506, 2019.

[33] V. Cantoni, P. Dondi, L. Lombardi, and A. Setti, "Teaching computer graphics through a digital humanities project," *IEEE Computer Graphics and Applications*, vol. 39, no. 2, pp. 89–94, 2019.

[34] M. Hoppe and H. Hoppe, "An adaptive multi-grid solver for applications in computer graphics," *Computer Graphics Forum*, vol. 38, no. 1, pp. 138–150, 2019.

[35] L. L. Khoroshko, P. A. Ukhov, and P. P. Keyno, "Development of massive open online courses based on 3d computer graphics and multimedia," *International Journal of Engineering Pedagogy (iJEP)*, vol. 9, no. 4, p. 4, 2019.

[36] M. Huang, M. Xu, T. Qiao, T. Wu, and N. Zheng, "Designing statistical model-based discriminator for identifying computer-generated graphics from natural images," *Journal of Universal Computer Science*, vol. 25, no. 9, pp. 1151–1160, 2019.

[37] R. F. Sproull, "Publishing a computer graphics book with prototype desktop publishing tools," *IEEE Annals of the History of Computing*, vol. 40, no. 4, pp. 69–76, 2018.

[38] A. Agrawal, "Application of machine learning to computer graphics," *IEEE Computer Graphics and Applications*, vol. 38, no. 4, pp. 93–96, 2018.

[39] D. Meng, Y. Xiao, Z. Guo et al., "A data-driven intelligent planning model for uavs routing networks in mobile internet of things," *Computer Communications*, vol. 179, pp. 231–241, 2021.

[40] Q. Zhang, K. Yu, Z. Guo et al., "Graph neural networks-driven traffic forecasting for connected internet of vehicles," *IEEE Transactions on Network Science and Engineering*, 2021.

Hindawi
Scientific Programming
Volume 2022, Article ID 3816306, 14 pages
https://doi.org/10.1155/2022/3816306

Research Article

An Evaluation Model of Plant Variety Rights Capitalization Operation Value Based on Big Data Analysis

Xiang He,[1,2] Liping Wu,[1] Kai Hu,[1] and Lin Wan[2]

[1]*School of Economics and Management, Jiangxi Agricultural University, Nanchang 330045, Jangxi, China*
[2]*School of Wealth Management, Nanchang Institute of Science and Technology, Nanchang 330108, Jangxi, China*

Correspondence should be addressed to Kai Hu; hx985@stu.jxau.edu.cn

Received 2 March 2022; Revised 9 May 2022; Accepted 8 June 2022; Published 19 July 2022

Academic Editor: Ahmed Farouk

Plant variety rights are essential for agricultural development and food security. This paper mainly starts with the cost-benefit issue of plant variety rights that enterprises are concerned about, and introduces the cost-benefit analysis method into the research and development, application, and protection of plant variety rights. This research takes the new plant variety rights as the research object, clarifies the development status of the world plant variety rights from the perspective of time series development characteristics and spatial distribution pattern, explores the location of the variety rights in the world, and uses methods such as knowledge measurement and data mining, to carry out in-depth research on the application and authorization of plant variety rights, the scope of protection catalogues, the structure of variety rights, and the applicant unit. Finally, the regression model is tested from five aspects: regression model significance test, model goodness-of-fit test, Hosmer goodness-of-fit test, goodness-of-fit test, and overall accuracy test of model prediction. The regression coefficient of plant variety rights cooperation in the research process was 1.908, and the statistical test value was significant at the 5% level ($P = 0.022 < 0.05$). Using system dynamics to evaluate its risks, it provides new ideas for the risk analysis and prevention of seed industry enterprises' variety rights capitalization operation.

1. Introduction

In the licensing of variety rights, the licensee of variety rights is highly dependent on the related varieties, and once monopoly occurs, the harm will be huge. In the process of variety rights licensing, the exclusiveness and monopoly of the variety rights make it possible for the variety rights holders to take advantage of this exclusive and monopolistic position to implement behaviors that restrict competition. At the international level, with the opening of China's seed market, foreign large-scale agricultural technology companies with abundant capital and advanced technology have expanded aggressively, threatening the living space of the domestic breeding industry, and challenging the development of China's seed industry and food security.

As a major agricultural country, agricultural, scientific, and technological achievements are produced in batches every year, and the task of promoting the smooth transformation of these achievements is very important. Doing a good job in the evaluation of the value of agricultural, scientific, and technological achievements has an important role and significance in improving the efficiency of achievement transformation and accelerating the application of achievement transformation.

This paper mainly starts with the cost-benefit issue of plant variety rights that enterprises are concerned about, and introduces the cost-benefit analysis method into the research and development, application, and protection of plant variety rights. Based on the above research, it is found that the domestic research on the value evaluation of agricultural, scientific, and technological achievements, especially the value evaluation method of new plant variety rights, is still very much lacking. Most of them are limited to traditional value evaluation methods, which makes the reference significance and accuracy of the evaluation results very low, and it is impossible to evaluate the value of new plant variety rights scientifically, reasonably, and pertinently. For the current scientific and technological achievements transformation trading market, the reference transaction value is of great significance for promoting the successful transaction of achievements. Therefore, it is indispensable to study the method of evaluating the value of new plant variety rights.

2. Related Work

The implementation of the new plant variety protection system has created a suitable legal environment for the healthy development of seed enterprises and scientific research units, promoted the breeding and innovation of new plant varieties, and found a breakthrough for the seed industry to face the world and improve its core competitiveness. The concept of an Essential Derivative Variety (EDV) under the 1991 UPOV Convention presents a number of challenges for both UPOV and users of the system. Bostyn believes that the concept of EDV is not only expressed in a rather difficult language in regulations but has proven equally difficult to apply. Furthermore, due to the lack of clarity in the provisions of the UPOV 1991 Convention, reaching a consensus on the exact interpretation of the concept, to be implemented later by courts and guidelines, is equally challenging. He has made novel and original contributions to research in the field of EDV. The approach presented here is inspired by other areas of (intellectual property) law. His careful study of the proposed solutions shows that at least some of them can effectively end at least some of the deadlock and legal uncertainty surrounding the concept of EDV [1]. Wijesundara et al. consider Plant Patents (PP) and Plant Breeders' Rights (PBR) as two forms of Intellectual Property Rights (IPR) granted to improved varieties of crops. Authoritative national governments issue PPs and PBRs after confirming the uniqueness of the breed identity. Uniqueness depends on the uniqueness, consistency, and stability of the new variety. In the presence of a large number of closely related breeds as a reference set, morphological, physiological, and biochemical descriptors are less able to obtain IPR in breed identification, but advanced molecular tools, such as DNA fingerprinting and sequencing, have a high potential to detect uniqueness. DNA fingerprinting and sequencing have identified varietal traits in many crops, such as rice, apple, wheat, and soybean, revealing the potential for the successful use of molecular descriptors in patenting or PBR. Novelty verification is the first step in the process of allowing a patent or PBR. The Patent or Plant Variety Protection Office requires breeders to submit an application that includes all the details of the plant variety [2]. Li et al. applied the 15 N labeling methods to the leaves of Arabidopsis rosettes to characterize their protein degradation rates and understand their determinants. Stepwise labeling of new peptides with 15 N and measuring the decrease in abundance over time of more than 60,000 existing peptides allowed him to determine the degradation rates of 1228 proteins in vivo [3]. High-yielding Spanish bunch peanut culture ICGV 00351 (cross-derivative of ICGV 87290 × ICGV 87846) developed by Vindhiyavarman et al. at ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Patancheru, Andhra Pradesh, with six other promising drought varieties were evaluated together. The overall average dry pod yield of cultivated ICGV 00351 under rainfed conditions was 2189 kg/ha. This cultivar with a duration of 105 to 110 days increased pod yield by 17% and 26%, respectively, over the region's popular varieties VRI (Gn) 6 and TMV (Gn) 13 [4]. As an important agricultural intellectual property rights, plant variety rights operate and develop worldwide, which can enhance the international competitiveness of plant variety rights and the ability to participate in international affairs. The securitization of plant variety rights is inseparable from the development of finance, economy, and society, and is an important way to protect plant variety rights and operate assets. Their research on plant variety rights lacks practical practice, and this study will further explore this issue.

3. Method of Evaluation Model of Capitalization Operation Value of Plant Variety Rights Based on Big Data

3.1. Supply-Side Value Range Evaluation Model. The construction of the value range evaluation model for the supply side of new plant variety rights should start from the perspective of producers, and consider two aspects of R&D and income: First, the supplier of new plant variety rights should not only maintain the simple reproduction of the enterprise's products but also provide funds for the enterprise to further expand its production scale. Therefore, the value of the new plant variety rights should not only compensate the consumption of the cost of the supply side but also distribute the benefits brought by the new plant variety rights, so as to provide effective financial support for the enterprise to further proceed anyway. Secondly, various risks and intangible losses of new plant variety rights should be considered in the value of new plant variety rights. This research is based on agricultural intellectual property rights, a hot issue of general concern, and takes plant variety rights, a unique intellectual property rights in the agricultural field, as the research object. Therefore, the main research line of the cost-benefit analysis of plant variety rights is shown in Figure 1.

3.1.1. The Lower Limit of the Supply-Side Value Assessment Range. The formula for the lower limit of the transfer value of the supplier of new plant variety rights in the study is:

$$P_{s-\min} = R + T + F * i + O. \tag{1}$$

In the formula, R is the research and development cost of new plant variety rights.

3.1.2. The Upper Limit of the Supply-Side Value Assessment Range. The upper limit of the price determined by the supplier for the transfer of new plant variety rights is:

$$P_{s-\max} = R + T + F * i + O + S + E. \tag{2}$$

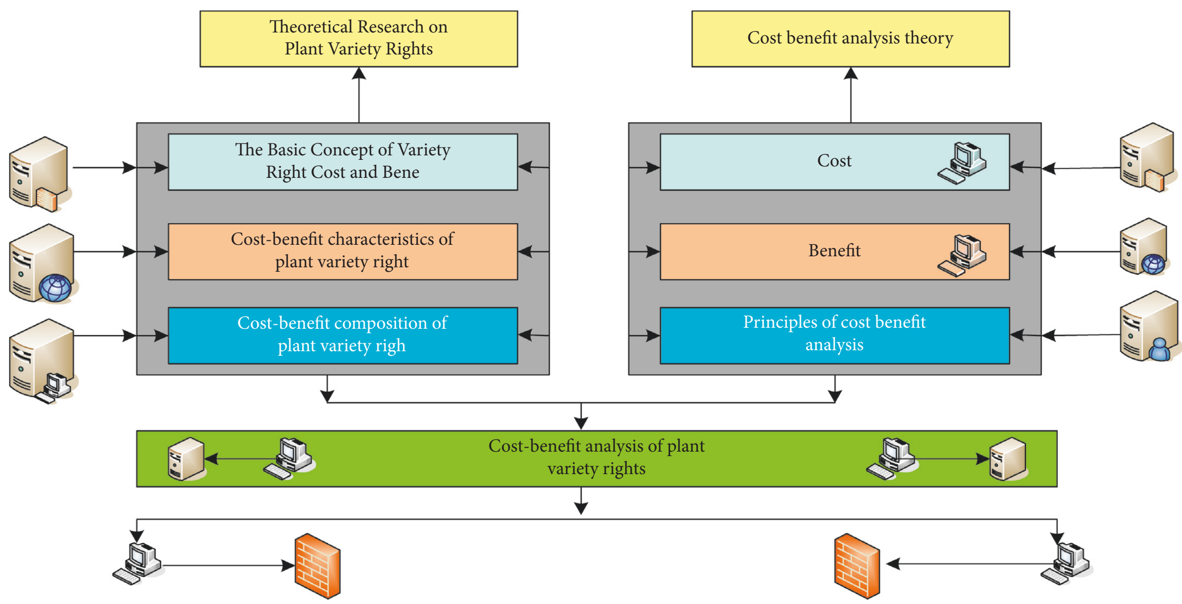


Figure 1: Research thread of plant variety rights cost-benefit analysis.

The sunk cost of research and development of new plant variety rights is S; the expected benefit of the supplier is E.

$$E = \alpha \sum_{i=1}^{k} \alpha \sum_{j=1}^{n} \Delta M_{ij}, \tag{3}$$

ΔM_{ij} is the income increment generated by the kth enterprise purchasing the new plant variety right in the jth year [5].

$$P_{s-\max} = R + T + F * i + O + S + \alpha \sum_{i=2}^{k} \sum_{j=1}^{n} \Delta M_{ij}. \tag{4}$$

3.2. Demand-Side Value Interval Assessment Model. For the demand side, purchasing a new plant variety right is a productive investment of the enterprise. The expected return from the investment to the demander after deducting possible risks is greater than the average social capital return, or if the new plant variety can be developed by itself, the purchase price must be lower than the cost of self-development. The evaluation scheme is shown in Figure 2.

The evaluation formula for the value interval of the demand side of new plant variety rights is [6]:

$$P = \sum_{t=1}^{n} \frac{(1-\alpha)\Delta M_t + \Delta Q}{(1+R)}, \tag{5}$$

P is the transfer price of new plant variety rights.

Consider the selection and operation strategy of dual-channel retailers' channel sales mode when consumers have free-riding behavior in pre-sales services in the market and the degree of free-riding is constantly changing. Then, the formula for the upper and lower limits of the transfer price of the new plant variety right on the demand side is [7]:

$$P_{D-MAX} = \left(\sum_{T=1}^{N} \frac{(1-\alpha)\Delta M_{\max}}{(1+R)^T} - \sum_{T=1}^{N} \frac{P}{(1+R)^T} - N \right)^{-1}, \tag{6}$$

$$P_{D-\min} = \left(\sum_{T=1}^{N} \frac{(1-\alpha)\Delta M_{\min}}{(1+R)^T} - \sum_{T=1}^{N} \frac{P}{(1+R)^T} - N \right)^{-1}. \tag{7}$$

3.3. Model Selection and Variable Description. In logistic regression, assuming that the probability of $M = 1$ is P, for M, its distribution function is [8]:

$$F(M) = P^M (1-P)^M. \tag{8}$$

The binary logit model is now used, the value range of the dependent variable is [0, 1], and the maximum likelihood method is used to evaluate its regression parameters.

$$P_i = F(M_i) = \frac{1}{1+e^{-M_i}} = \frac{1}{1+e^{-M_i}}. \tag{9}$$

Among them

$$M = B_0 + B_1 X_{1i} + \cdots B_P X_{Pi}, \tag{10}$$

P is the number of independent variables, and B_0 is the regression intercept.

3.4. Determination of Value Assessment Interval. In this paper, the supply side and demand-side value evaluation interval models of a single new plant variety right are constructed, respectively [9]. The source of data is real data, and the expression of the proposed uncertainty measure is helpful to solve the current practical problems. The research on the uncertainty measure of knowledge is a hot

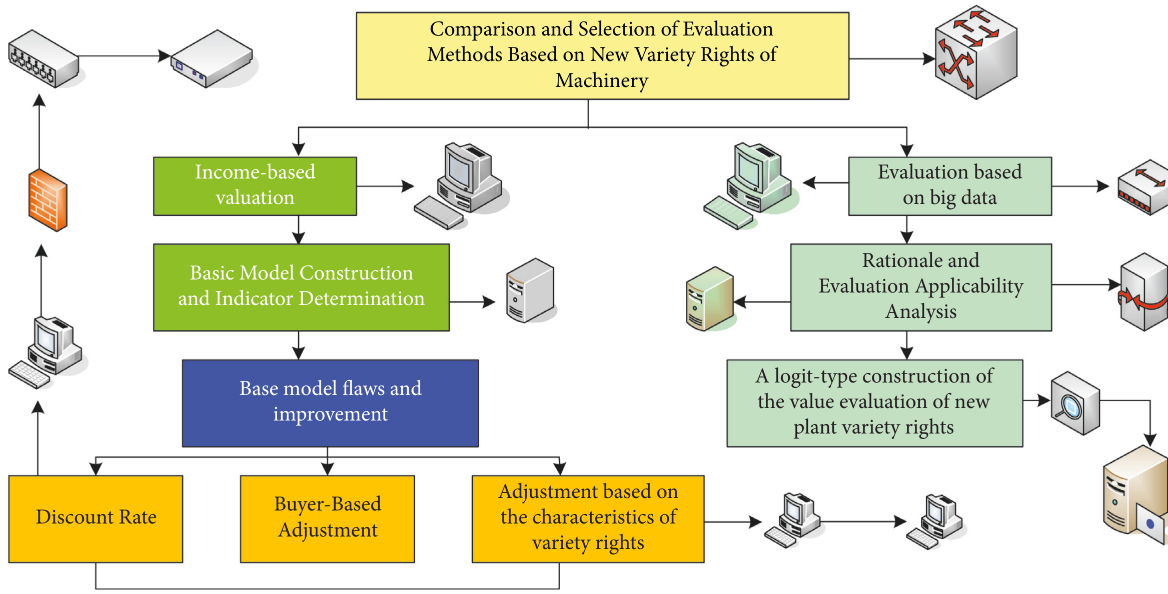


Figure 2: Evaluation scenario.

issue in the field of artificial intelligence. On the basis of reviewing several classical knowledge uncertainty measurement methods, the relationship and difference between these measurement methods are systematically studied. The results show that measures such as information granularity are equivalent to knowledge granularity, and collaborative entropy can be regarded as the derivation of information entropy, which can verify the correctness of the conclusion.

In the first case, if

$$P_{s-\min} > P_{d-\max}. \tag{11}$$

In this case, the equilibrium transfer price of new plant variety rights cannot be formed [10].

In the second case, if

$$P_{s-\max} > P_{d-\max} > P_{s-\min} > P_{d-\min}. \tag{12}$$

The intersection interval is $[P_{s-\max}, P_{d-\min}]$, which is the lowest price interval for both the supply and demand sides.

The third case, if [11]

$$P_{d-\max} > P_{s-\max} > P_{d-\min} > P_{s-\min}. \tag{13}$$

At this time, the intersection interval is $[P_{d-\min}, P_{s-\max}]$, and the equilibrium price of new plant variety rights may be formed.

The fourth case, if [12]

$$P_{d-\min} > P_{s-\max}. \tag{14}$$

At this time, when the new plant variety rights are transferred, it is very easy for both parties to trade and negotiate.

The fifth case, if

$$P_{d-\max} > P_{s-\max} > P_{s-\min} > P_{d-\min}. \tag{15}$$

At this time, the trading price range is $[P_{d-\max}, P_{d-\min}]$, which may form an equilibrium price acceptable to both parties.

The sixth case, if [13]

$$P_{s-\max} > P_{d-\max} > P_{d-\min} > P_{s-\min}. \tag{16}$$

The intersection interval is $[P_{d-\min}, P_{d-max}]$. When the new plant variety right is transferred, an equilibrium price may be formed after negotiation between the two parties.

After using big data to analyze basic information such as business conditions, capital flow, investor preferences, etc., the credit data, plant variety rights information, and plant variety rights future cash flow rating information of seed industry enterprises can be visualized and analyzed, which provides convenient conditions for enterprises to carry out the operation of plant variety rights securitization.

3.5. *Variable Setting.*

The three variables of transaction mode factor, transaction operation factor, performance factor, and four variables of media factor are assigned as follows: 1 = selected this factor, 0 = not selected this factor. The statistics of some variables are shown in Table 1.

3.6. *Regression Result Processing.*

Using SPSS16.0 statistical analysis software, logit regression analysis was carried out on the influencing factors of plant variety rights market-oriented operation satisfaction. Backward was adopted in the processing process, and the dependent variables in the research process were eliminated.

For [14],

$$\text{IVITFN}\alpha = \left([a, b, c, d]; [\phi_1, \phi_2], [\beta_1, \beta_2]\right). \tag{17}$$

Table 1: Statistics of some variables.

Variable type	Variable name	Mean	Standard deviation
Market-oriented operation of plant variety rights main factor	Education level	2.52	0.912
	Unit nature	2.78	1.191
	Scientific research strength	3.21	0.797
Market-oriented operation of plant variety rights way factor	Transfer of plant variety rights	0.69	0.466
	Plant variety rights licensing	0.61	0.489
	Plant variety rights cooperation	0.13	0.334

Its score function and exact function are, respectively, [15]

$$W(\alpha) = \frac{1}{8}(a+b+c+d)(\phi_1+\phi_2+\beta_1+\beta_2), \tag{18}$$

$$F(\alpha) = \frac{1}{8}(a+b+c+d)(\phi_1+\phi_2-\beta_1-\beta_2), \tag{19}$$

As an important strategic resource for society and enterprises, intellectual property rights are only the subject of legal rights for their owners if they cannot be used effectively, and they do not have the ability to obtain benefits by virtue of their rights. Letting α_1, α_2 be two IVITFNs whose collation is [16]

$$W(\alpha_1) > W(\alpha_2). \tag{20}$$

Then

$$\alpha_1 > \alpha_2. \tag{21}$$

If [17]

$$W(\alpha_1) = W(\alpha_2). \tag{22}$$

Then

$$F(\alpha_1) = F(\alpha_2). \tag{23}$$

The smooth operation of rights securitization creates favorable policy conditions. Participating in plant variety rights securitization through high-tech means such as big data, artificial intelligence, AI technology, and cloud computing can not only effectively control the infrastructure of plant variety rights securitization operations but also realize profit output with the latest technology [18]. Through the application of big data, cloud computing, and other technologies, plant variety rights securitization operations are under the supervision of laws, regulations, and policies, and through the smart contract mechanism, network identification and transmission technology is used to implement effective supervision in the form of encrypted codes [19]. Therefore, the formulation of relevant laws and regulations to standardize the application of regulatory technology for plant variety rights securitization is also an issue that needs to be focused on.

The income method does not take into account the many uncertainties in the process of achievement development, investment, and commercialization; the cost method ignores factors such as the value of the achievement after commercialization. In order to solve this series of difficult problems and promote the smooth transformation of agricultural scientific and technological achievements, it is particularly important to find a value evaluation method suitable for new plant variety rights in agricultural scientific and technological achievements.

If for any $\forall A, B \in P(X), A \cap B = \Phi$, then [20]

$$\psi(A\cup B) = \psi(A) + \psi(B) + \rho\psi(A)\psi(B). \tag{24}$$

The limited set is

$$X = (x_1, x_2, x_3, \ldots, x_n). \tag{25}$$

Then there is [21]

$$\Psi(X) = \frac{1}{\rho}\left(\prod_{i=1}^{m}[1+\rho\Psi(x_i)-\chi]\right). \tag{26}$$

Among them, $\rho \neq 0$.

3.7. Regression Model Test. Financial technology (Table 2) and Internet technology based on big data can solve the problem of information asymmetry in breeding research and development, application and authorization of new plant varieties, and plant variety rights securitization (Table 3) transactions and operations [22]. In this paper, regression model testing is carried out from four perspectives: regression model significance test, model goodness-of-fit test, Hosmer & Lemeshow goodness-of-fit test, and overall accuracy test of model (Table 4) prediction [23].

(1) Significance test of regression model: Chi-square is the likelihood ratio of the model, the larger the value of the chi-square statistic, the better; The P value corresponding to Sig is as small as possible. The comprehensive test results of the model coefficients are shown in Figure 2.

(2) Model goodness of fit test: The larger the value of Cox & Snell R Square and Nagelkerke R Square, the better the overall fit of the model. SPSS16.0 statistical analysis software was used to conduct a comprehensive evaluation of prefectural and municipal agricultural academies, and principal component analysis was used to extract input-output factors, scientific and technological service contribution factors, and social and economic benefit factors, and then perform hierarchical clustering analysis on the samples. The classification and ranking of the innovation ability and comprehensive strength of the

Table 2: Comprehensive tests of model coefficients.

Comprehensive inspection	Chi-square	*Df*	Sig
Step	61.535	15	0.000
Block	61.535	15	0.000
Model	61.535	15	0.000

Table 3: Model goodness-of-fit evaluation.

Step	1
−2 log likelihood	183.279
Cox & Snell R square	1.191
Nagelkerke R square	0.373

prefecture-level agricultural research institutes were analyzed, and the quantitative basis was provided for the objective evaluation of the main body of plant variety rights licensing. The goodness-of-fit evaluation of the model is shown in Figure 3.

(3) Hosmer & Lemeshow's goodness-of-fit test: Hosmer–Lemeshow is a fitting statistic, and its null hypothesis is that the equation fits the data well [24].

(4) Overall, accuracy test of model prediction: As can be seen, the overall discriminant accuracy of the model for estimated samples is 78.7%. The final observations are classified, as shown in Table 4.

4. Results of the Evaluation Model for the Capitalization of Plant Variety Rights

(1) From the perspective of the main factors of plant variety right marketization, the degree of education and the nature of the unit have different degrees of influence on the satisfaction of plant variety right marketization. The regression coefficient of education level is 0.489, and the statistical test value is significant at the level of 5% ($P = 0.040 < 0.05$), indicating that education level has an obvious impact on the satisfaction of plant variety right marketization. The more years of education the plant variety rights holders have, the more they can calmly analyze, predict, and make decisions on the plant variety rights market. More importantly, they can accurately evaluate the effect of plant variety rights marketization, and try to make the actual effect of plant variety rights marketization consistent with their prediction, so as to ensure that the plant variety rights marketization can achieve high satisfaction. The regression coefficient of unit property is −0.383, and the statistical test value is significant at the level of 5% ($P = 0.032 < 0.05$), indicating that unit property is another significant factor affecting the satisfaction of plant variety right marketization. The nature of the different units determines the different priorities of the marketization of plant variety rights. Seed companies mainly focus on the commercialization and marketization of plant variety rights, while agricultural academies and universities often focus on the research and development and promotion of new plant varieties.

(2) From the perspective of the factors of market-oriented transaction of plant variety rights, plant variety rights licensing and plant variety rights cooperation have a significant impact on the satisfaction of plant variety rights. The regression coefficient of plant variety right license is 1.055, and the statistical test value ($P = 0.010$) is significant at the level of 1%, indicating that plant variety right license significantly affects the satisfaction of plant variety right marketization, which benefits from the advantages of plant variety right license itself. Because the license of plant variety right only transfers the use right, the biggest advantage of this transaction mode is that the owner of plant variety right can transfer the use right of plant variety right to multiple people for many times, which is conducive to the owner of plant variety right to recover the funds quickly and expand the market-oriented scope of plant variety right, so as to improve the market-oriented satisfaction of plant variety right. With the improvement of China's property rights trading market, plant variety rights licensing will be more and more applied to the market-oriented practice of plant variety rights. The regression coefficient of plant variety right cooperation is 1.908, and the statistical test value is significant at the level of 5% ($P = 0.022 < 0.05$), indicating that plant variety right cooperation has a significant impact on the satisfaction of plant variety right marketization. The reason is closely related to the structure of plant variety rights holders in China. Most of China's variety rights holders are subordinate to agricultural research institutes and colleges and universities. Plant variety rights accounted for 62.8% of the total authorization, and seed industry enterprises only accounted for 33.1% of the total authorization. In addition, most of the seed industry enterprises in my country are small in scale and do not have the necessary conditions for self-implementation. They need to rely on the support of external resources such as capital, technology, and information.

According to the development report of China's seed industry [25], in 2021, the top 10 seed industry companies in terms of sales invested a total of 483.43 million yuan in breeding research and development, an increase of 48% over

Table 4: Final observation classification.

Observed		Predicted: Satisfaction with market-oriented operation of plant variety rights (Satisfied = 1; Dissatisfied = 0)		Percentage Correct
Satisfaction with market-oriented operation of plant variety rights	0	0	1	52.5
(Satisfied = 1; Dissatisfied = 0)	1	32	29	52.5
		13	123	90.4
Overall percentage		78.7		

2020 (251.37 million yuan). The applicant and variety rights types are shown in Figure 3.

Figure 4 shows the total number of applications for variety rights, the total number of grants, and the total number of effective variety rights at the end of the period in UPOV member countries.

Only 5.53% of the 4,808 variety rights authorized in 2018 were transferred, and only 3% of the varieties authorized by teaching, scientific, and educational units were implemented. The authorized variety plant types are shown in Figure 5.

However, only 19.40% of the 3,278 variety rights authorized for these five field crops have been promoted, and only 26.95% of the authorized varieties of commercial crop cotton have been promoted. The authorized promotion of field crops is shown in Figure 6.

Among the surveyed units, there are 23 individual units, 16 private enterprises, 14 collective units, 21 joint-stock units, 12 private enterprises, 12 state-owned enterprises, 2 cooperative enterprises, 1 institution of higher learning, and 7 other units, a total of 108. The top three in terms of quantity are: individual enterprises, joint-stock enterprises, and private enterprises, accounting for 22%, 19%, and 15% of all units, respectively. The specific distribution is shown in Figure 7.

The mean scores from high to low are: the R&D capability of the enterprise, the mean value is 4.18; the degree of technological innovation, the mean value is 4.07; the complexity of plant variety rights, the mean value is 3.96; the ability of enterprises to control R&D costs, the mean value is 3.94; the experimental scale of R&D, the mean value is 3.67. Based on this, it can be inferred that among all the factors affecting the R&D cost of plant variety rights, the R&D capability of the enterprise has the greatest impact on the R&D cost, while the experimental scale of R&D has the least impact on the R&D cost of plant variety rights. Figure 8 shows the statistics of factors affecting the R&D cost of plant variety rights.

The complexity score of plant variety rights is concentrated on 3, 4, and 5, which are important, very important, and extremely important, as reflected in Figure 8. The selection of these three items accounts for 97.2% of the total selection. The importance evaluation of the scale of plant variety rights R&D trials is shown in Figure 9.

It can be seen from Figure 10 that the respondents' recognition of the scale of R&D trials is mainly focused on "very important." The distribution of the scores of the remaining items is also relatively uniform, with 10 people who think that this factor has an average degree of influence, 29 people who think that the degree of influence is important, and 17 people who think it is extremely important. According to this, it can be inferred that the scale of research and development has a certain impact on the research and development costs of plant variety rights. The technical innovation evaluation of plant variety rights is shown in Figure 10.

5. Discussion

China's securitization development continues to advance, and the balance structure of the financial market is also under certain pressure. Due to the falling interest rate level, the financial market under macro-control and government policies cannot achieve equilibrium, resulting in abnormal financial institutions such as shadow banking. With the investment in research and development of new plant varieties and the continuous development of high-tech agricultural production, many breeding scientific research institutions and seed industry enterprises have begun to seek various ways to absorb social funds to obtain corporate financing, which makes the form of plant variety rights securitization developed. Breeding scientific research institutions and seed industry enterprises can cooperate with financial institutions, use computers and the Internet for securitization financing, and introduce concepts such as financial technology, Internet finance, and blockchain smart contracts for project innovation. Through the establishment of an open and transparent trust network in the untrusted cooperation, the plant variety rights securitization transactions involving multiple parties can be recognized. In this process, it is necessary to strengthen the financial supervision of the entire market and operation links [26].

From a functional point of view, intellectual property protection and anti-monopoly regulation are complementary in function. First, intellectual property protection and anti-monopoly law adjustment methods are complementary. On the one hand, intellectual property rights, as a legal

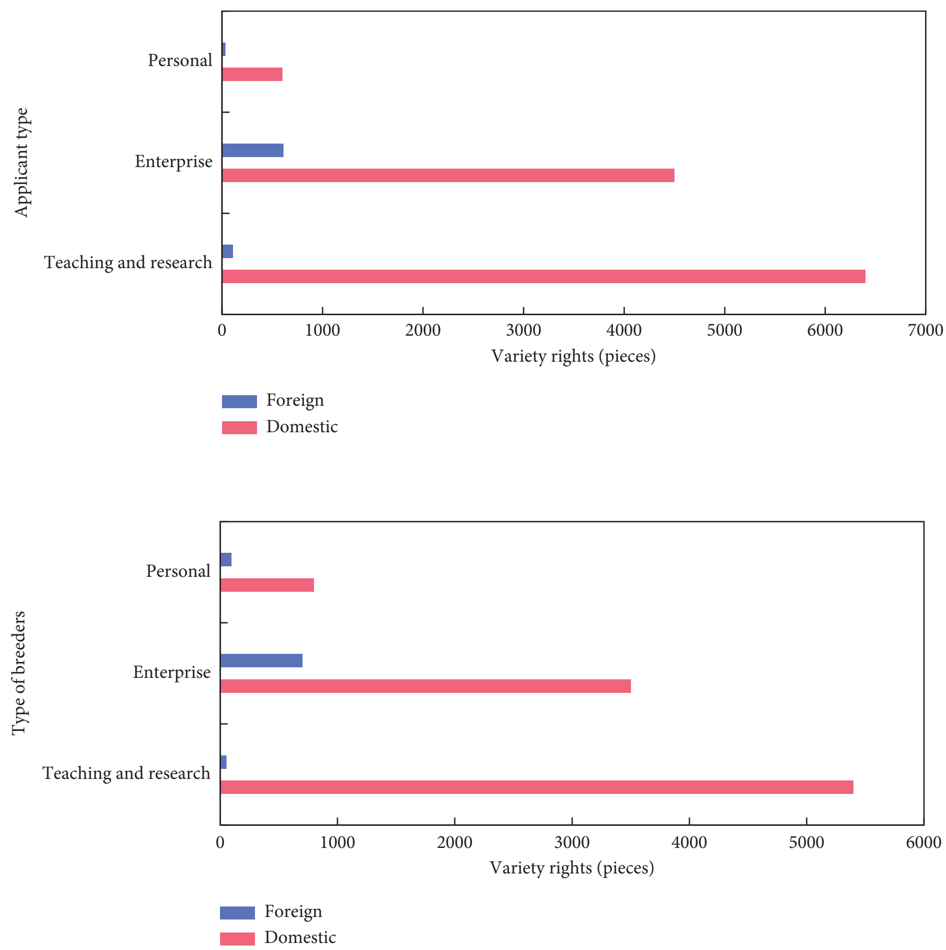


Figure 3: Applicants and types of variety rights.

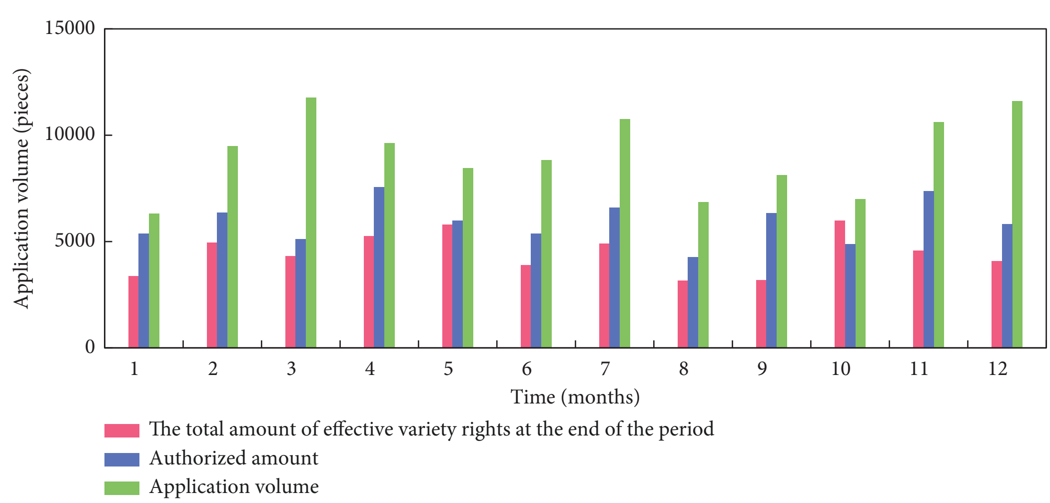


Figure 4: The total number of applications for variety rights, the total number of grants, and the total number of effective variety rights at the end of the period in UPOV member countries.

monopoly right, endow the right holder with exclusive rights and exclusive rights, guarantee profits and promote innovation; on the other hand, the anti-monopoly law prohibits behaviors that restrict competition and harm the interests of consumers. An intellectual property licensing act is undoubtedly legal in the scope of intellectual property law, but it is subject to anti-monopoly regulation because it may harm competition. Similarly, a market operation behavior that does not violate the anti-monopoly law may be prohibited by the intellectual property law because it infringes

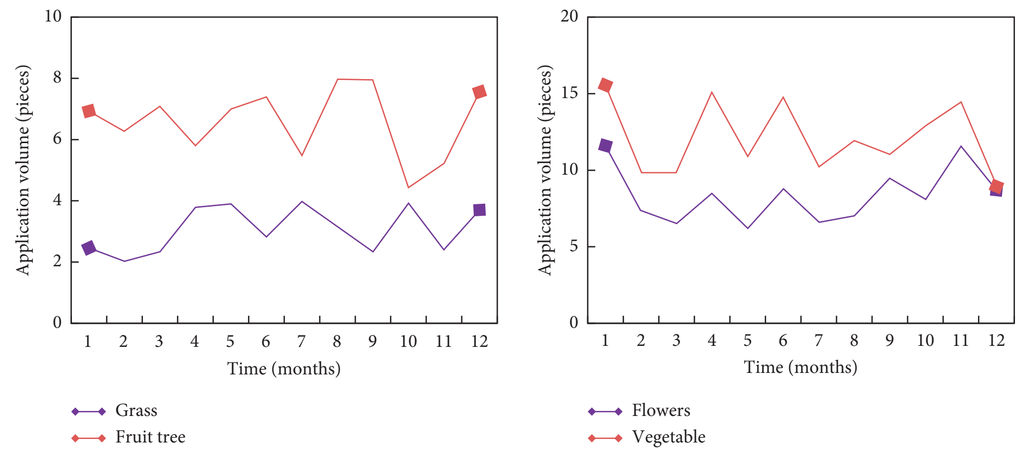


Figure 5: Authorized variety plant types.

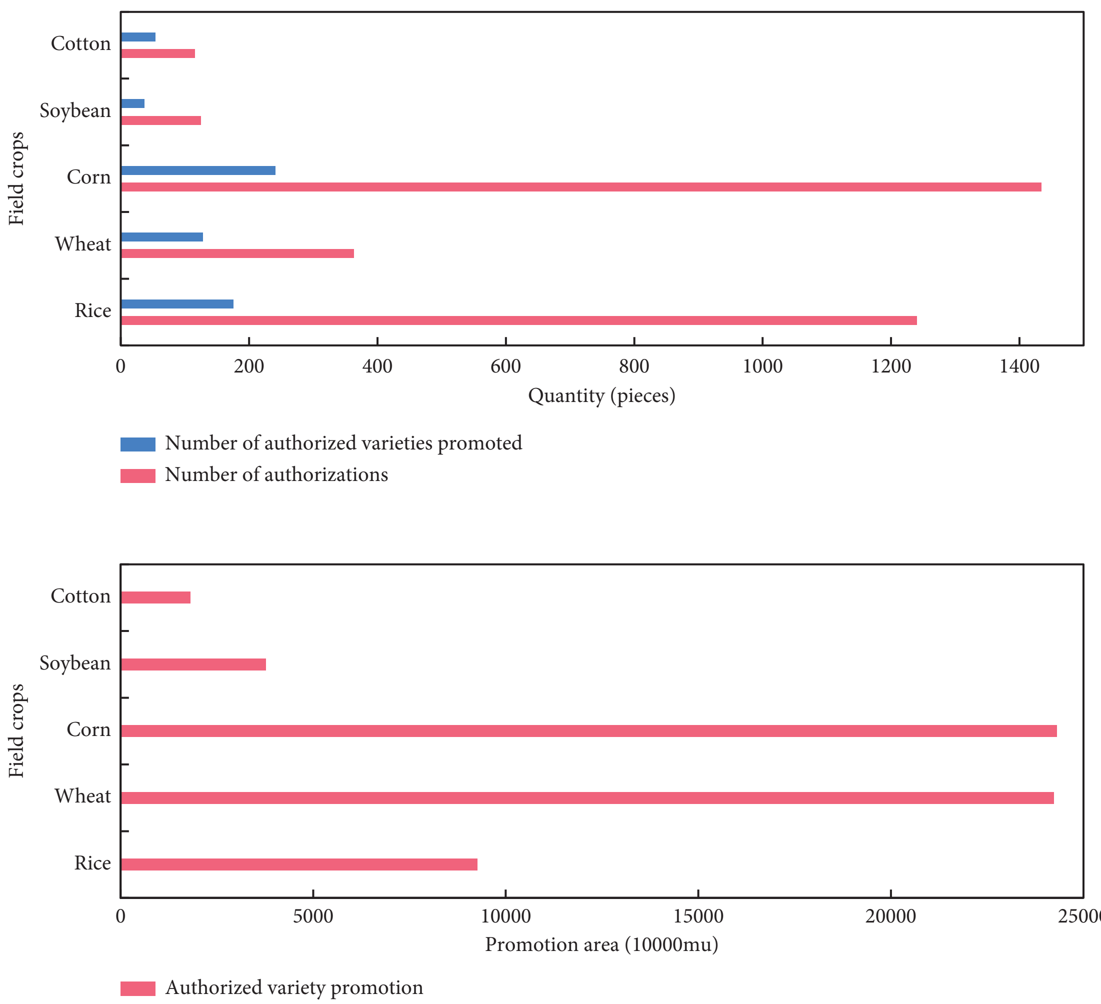


Figure 6: Authorized promotion of field crops.

the intellectual property rights of others. Second, the ways of intellectual property protection and anti-monopoly to regulate the abuse of intellectual property rights and safeguard the overall interests of society are complementary. For the anti-monopoly regulation of intellectual property restricting competition behavior, the anti-monopoly law mainly regulates from the outside, and takes measures by assessing the harm of behavior to competition. The intellectual property protection legal system evaluates the abuse of intellectual property from the perspective of rights restriction, and

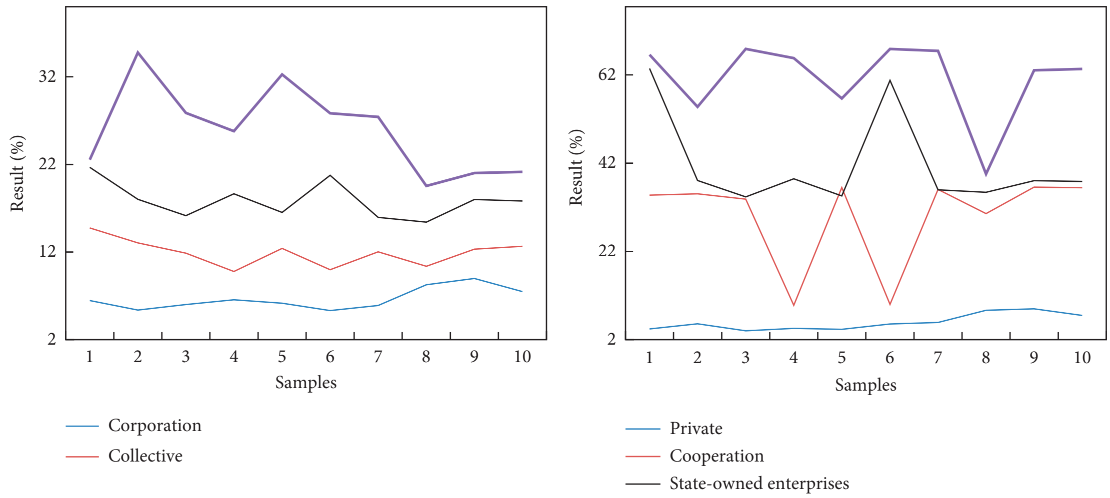


Figure 7: Distribution of specific surveys.

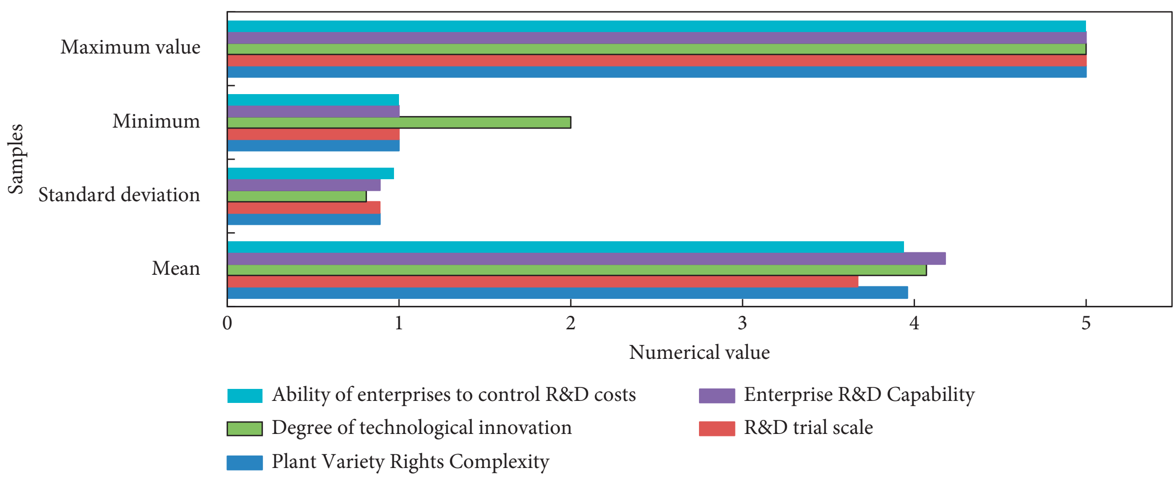


Figure 8: Statistics of factors affecting R&D costs of plant variety rights.

establishes a series of internal restriction systems of intellectual property, which self-regulate from the inside and balance the relationship between intellectual property rights and social public interests.

At the same time, a major difference between plant breeding work and industrial invention is that the former is highly dependent on existing reproductive materials and biological genetic information. If subsequent innovators cannot obtain relevant materials or genetic information, breeding work is useless. In addition, other than the exclusivity, temporality, and regionality of traditional intellectual property rights, variety rights have both self-replication, agriculture-related attributes, and seasonality and regionality of crop planting. Special consideration should be given to its protection and regulation; not only should it be given exclusive rights to maintain breeding innovation and profits but also to protect the normal competition in the seed industry market and the supply of agricultural products.

The general license for the implementation of variety rights means that the variety rights holder authorizes the licensee to implement the variety within a certain time and territory. At the same time, within this scope, the breeder can implement the breed by himself or herself or allow others to implement the breed. This model is conducive to the variety rights holders to adjust their licensing strategy in real time according to market changes, and at the same time, the variety is more widely spread, the breeding cost can be quickly recovered, and the commercial benefits can be maximized quickly. Also, the dispersion of implementation rights makes it difficult to restrict competition in the market, which is conducive to technological progress and increasing production and income. The disadvantage of this model is that the variety rights are licensed too widely, and vicious competition occurs in the relevant market, which damages the interests of both parties.

The anti-monopoly regulation of variety rights licensing is the specific application of the theory of limitation of rights in the field of variety rights. In order to maintain the research and development motivation of breeders, the breed rights protection system gives them sufficient exclusive protection, and any use without legal authorization or the consent of the

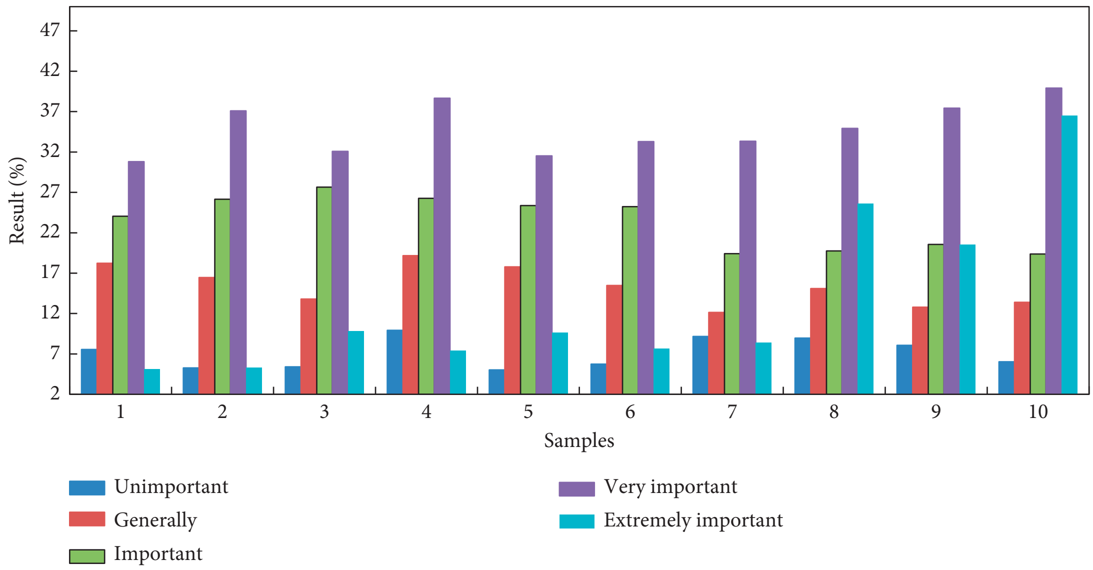


Figure 9: Evaluation of the importance of the scale of plant variety rights R&D trials.

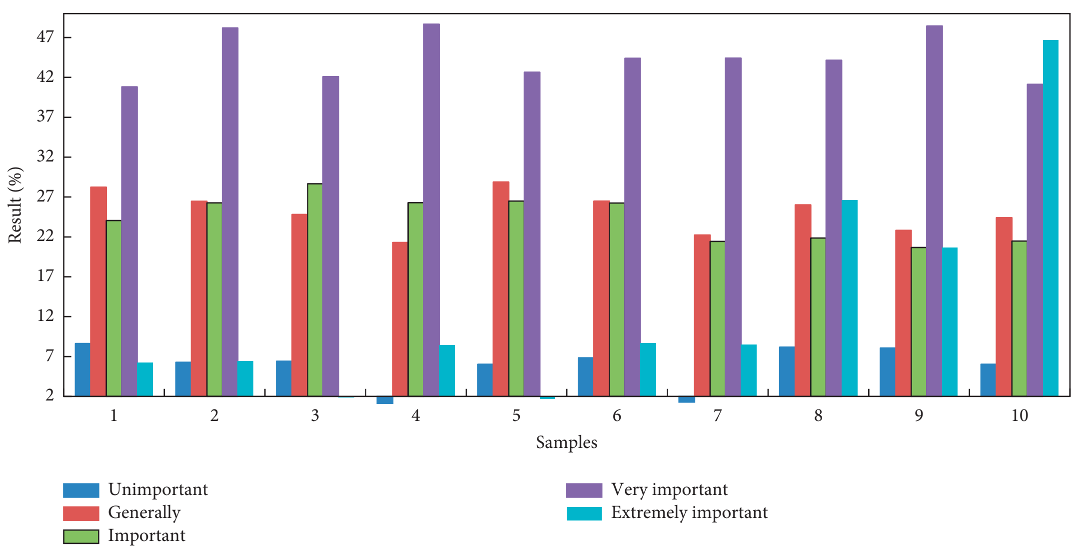


Figure 10: Evaluation of plant variety rights technology innovation.

rights holder is an infringement. At the same time, the advancement of breeding technology and the development of the agricultural industry require that the relevant plant breeding achievements can be fully disclosed, disseminated, and implemented in the field of agricultural production. Huge contradictions need to be reconciled by setting up a system through the theory of rights limitation. On the one hand, the variety rights self-restriction system, such as the variety rights licensing system (voluntary license and compulsory license), regulates the abuse of rights from within; on the other hand, while fully respecting and recognizing the variety rights, the anti-monopoly law should also restrict the variety rights through reasonable means and regulate the monopoly behavior of the variety rights. Relevant crop varieties produced, sold, and promoted by breeding companies and agricultural technology companies are often plant varieties with specific traits cultivated through scientific and technological means, such as traits suitable for specific soils, specific chemical fertilizers, or specific farming methods. After long-term production and planting, the soil composition has been basically fixed, and a certain variety has gradually adapted to the soil environment of this plot, and can obtain higher yields. Agricultural producers will gradually form a heavy dependence on the specific variety, and eventually evolve into a situation where it is difficult to carry out agricultural production if the seeds cultivated and provided by relevant breeding companies cannot be obtained. When the relevant variety rights and crop seeds are controlled by the breeding enterprise and the variety rights holder, the relevant competitors cannot copy or obtain them, and the controller has the ability and conditions to license but refuses to license the relevant rights, seed-related variety rights, and crop seeds; such variety rights and crop seeds should be identified as “critical facilities" and become a factor to consider whether to regulate related behaviors. The tying behavior in intellectual property licensing means that the right holder in a dominant market position requires the licensee to accept other unrelated intellectual property rights and products, or the act of purchasing unnecessary goods or services from the right holder or a third party designated by it. The tying sale, which is covered by the Anti-monopoly Law, requires the right holder to have a dominant market position and abuse it; such a dominant market position may be possessed by the right holder itself or it may be the dominant market position formed by the horizontal joint agreement between operators. Secondly, it is required that the tying product can be independently licensed or sold. If the right holder does not have a dominant market position, or the licensed intellectual property rights and property rights or products and services are inseparable and cannot be licensed and sold separately, this behavior is not subject to anti-monopoly laws.

It should be noted that it is necessary to avoid the balance between the compulsory license and the interests of the variety rights holder, and avoid excessive restrictions on the interests of the variety rights holder due to the abuse of compulsory license, so as to conform to the original intention of the establishment of the variety rights protection system. The anti-monopoly legal system and the variety rights protection system are the legal norms to adjust the rights and obligations between the variety owner and the licensee, agricultural producers, and even the consumers of agricultural products, and are the balancer of the interests of all parties. The anti-monopoly regulation of variety rights licensing has practical significance and an important role in the development of China's agricultural industry and the guarantee of food security; it is mainly manifested in the functions of prevention, regulation, and relief of monopoly behavior in variety rights licensing, which in turn promotes the continuous progress of breeding technology, the improvement of consumer welfare, the development of agricultural industry, and the maintenance of food security. Nowadays, China's breeding technology has made great progress, the proportion of foreign capital in China's breeding industry is also increasing year by year, and the impact of variety rights on the economy and trade is becoming more and more important. However, there are few academic studies in this field, which leads to many problems in the current anti-monopoly regulation of variety rights licensing that need to be solved urgently. Therefore, it is necessary to strengthen the research on anti-monopoly regulation of variety rights licensing, analyze and examine the interest relationship in variety rights licensing, and systematically sort out existing problems and propose solutions, in order to play its due function of preventive regulation and relief, and help the development of the seed industry [27].

This topic needs to be studied from a broader perspective. For example, economic growth is one of the purposes of improving the legal system, so it is equally important to use economic indicators to analyze the effectiveness of the legal system and to assist the implementation of the law. When conducting anti-monopoly analysis on behaviors that restrict competition by variety rights licensing, economic analysis methods can be used to evaluate the impact of relevant behaviors on competition and innovation. In the process of implementing and remedying the anti-monopoly system of variety rights licensing, the analytical method of economics can also play an important role. Enterprises may have infringement risks, commercial disclosure risks, technical risks, and product counterfeiting risks in the process of intellectual property operation. Based on this, the concept of intellectual property management is proposed to prevent these specific risks in intellectual property rights, and reduce the possibility of risk management.

The modernization of agriculture and rural areas is inseparable from science and technology. The continuous progress of breeding technology and the healthy development of agricultural industry are the powerful starting points of rural revitalization. The progress of seed industry is the basic element to promote the modernization of agriculture and rural areas. To realize technology-led rural revitalization and agricultural and rural modernization, the relationship between variety rights holders, licensees, agricultural producers, agricultural product consumers, and social public interests should be well balanced. Through the interpretation of the basic issues of anti-monopoly of variety rights licensing, this paper sorts out the system status quo of anti-monopoly regulations on variety rights licensing outside the territory. Based on the existing problems in China, a systematic research and demonstration has been carried out on the improvement of the anti-monopoly regulatory system for variety rights licensing [28].

6. Conclusion

With the widespread popularity of the Internet, mobile phones, the Internet of Things and artificial intelligence, information data have grown exponentially, generating massive data (Big Data). How to quickly and efficiently extract and display invisible data in these unstructured big data knowledge is very important. Visualization technology can solve this problem very well. The plant variety rights pricing model mainly involves technical risk, value assessment risk, operational risk, variety rights own risk, legal policy risk, and market risk. Risk warning is an important part of risk management. Collect relevant data through big data technology, collect and analyze indicators, look for potential risks, and timely warn and control risks for the plant variety rights pricing model. Western countries first put forward the concept of capitalized operation, and intellectual property capitalization is also a hot topic, but most of them are limited to the field of law. There is almost no systematic research on the capitalization of plant variety rights. Scholars have mainly discussed the three aspects of the capitalization operation of plant variety rights: pledge, capital contribution, and securitization. Few of them have studied the capitalization operation risks. Therefore, there is a lot of room for discussion in this field. From the perspective of management, this paper will make more beneficial attempts to capitalize the operational risk of plant variety rights. Based on the big data, this paper discusses and analyzes the key words of the classic literature, which provides a reference for the research on the securitization pricing of plant variety rights. The bibliometric and knowledge map analysis of securitization pricing, the use of financial big data, data collection technology and learning analysis methods, combined with cross-field and multi-disciplinary characteristics, provide a direction for the research and development of plant variety rights securitization, lay a foundation for the theoretical discussion on the securitization and pricing of plant variety rights, and also point out the way for the securitization and capitalization of plant variety rights under big data. The research on the capitalization operation risk of plant variety rights can not only help identify various risks in the capitalization operation of plant variety rights, to provide advice on risk prevention and control, and to promote the development of China's variety rights capitalization theory, but also provide guidance for seed industry enterprises to carry out the capitalization operation of plant variety rights. Therefore, this research has practical value and significance. Due to the broad development prospects of plant variety rights, seed industry enterprises and scientific research institutions urgently need to meet the financing needs of enterprises by developing the economic potential of plant variety rights. Previous studies by scholars have mainly focused on the demonstration and analysis of plant variety rights commercial bank financing, listed company financing, government behavior finance, securities investment funds, etc., but there is no comprehensive analysis of plant variety rights securitization. The risk evaluation index of plant variety rights capitalization operation of seed industry enterprises is selected, and all the risk factors in the capitalization operation system of variety rights cannot be considered, and there is a certain subjectivity. Therefore, in the future research work, the risk factors can be further studied to form more objective, systematic, and comprehensive indicators.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by: Nanchang Institute of Science and Technology Humanities and Social Sciences Research Project "Research on securitization of plant variety rights from the perspective of grain storage and technology" (NGRW-21-06). "Jiangxi Observation Report" subject and Key Project of Social Science Planning of Jiangxi Province in 2022, tracking research on building a model place for Rural Revitalization in the new era in Jiangxi, (22SQ06), 2018 decision support collaborative innovation center project for the Sustainable Development of Modern Agriculture and Its Advantageous Industries in Jiangxi, research on the measurement and improvement of China's agricultural total factor productivity, (2018B02).

References

[1] S. J. R. Bostyn, "Plant variety rights protection and essentially derived varieties: a fresh proposal to untie the gordian knot," *GRUR International*, vol. 69, no. 8, pp. 785–802, 2020.

[2] W. W. M. U. K. Wijesundara, G. K. S. Ananda, L. T. Ranaweera, U. A. K. S. Udawela, C. K. Weebadde, and S. D. S. S. Sooriyapathirana, "Intellectual property rights (IPRs) for plant breeders: a review on theoretical framework and employment of DNA-based varietal authentication for claiming IPR," *Sri Lanka Journal of Food and Agriculture*, vol. 4, no. 2, pp. 53–70, 2018.

[3] L. Li, C. J. Nelson, J. Trösch, I. Castleden, S. Huang, and A. H. Millar, "Protein degradation rate in *Arabidopsis thaliana* leaf growth and development," *The Plant Cell Online*, vol. 29, no. 2, pp. 207–228, 2017.

[4] P. Vindhiyavarman, S. Nigam, P. Janila et al., "A new high yielding Spanish bunch groundnut variety CO 7 (ICGV 00351) for the drought prone areas of Tamil Nadu," *Electronic Journal of Plant Breeding*, vol. 10, no. 1, pp. 307–311, 2019.

[5] T. Adebola, "Examining plant variety protection in Nigeria: realities, obligations and prospects," *Journal of World Intellectual Property*, vol. 22, no. 1-2, pp. 36–58, 2019.

[6] C. R. Nhemachena and B. Muchara, "Structure of the sunflower plant breeders' rights landscape in South Africa," *South African Journal of Science*, vol. 116, no. 9-10, pp. 1–6, 2020.

[7] S. H. Jamali, J. Cockram, and L. T. Hickey, "Is plant variety registration keeping pace with speed breeding techniques?" *Euphytica*, vol. 216, no. 8, p. 131, 2020.

[8] K. Fister, I. Fister, J. Murovec, and B. Bohanec, "DNA labelling of varieties covered by patent protection: a new solution for managing intellectual property rights in the seed industry," *Transgenic Research*, vol. 26, no. 1, pp. 87–95, 2017.

[9] Y. V. Juk, "Appropriability conditions and the plant variety protection law in Brazil," *Journal of Technology Management and Innovation*, vol. 15, no. 3, pp. 74–82, 2020.

[10] R. Moonka and S. Mukherjee, "Trips flexibilities and India's plant variety protection regime: the way forward," *BRICS Law Journal*, vol. 5, no. 1, pp. 117–139, 2018.

[11] O. O. Olusegun and I. A. Olubiyi, "Implications of genetically modified crops and intellectual property rights on agriculture in developing countries," *Journal of African Law*, vol. 61, no. 2, pp. 253–271, 2017.

[12] M. Blakeney, "Plants, people and practices: the nature and history of the UPOV convention," *European Intellectual Property Review*, vol. 39, no. 12, pp. 801-802, 2017.

[13] M. B. N. Alves and A. E. A. Paixão, "Intellectual property in the Brazilian agricultural sector," *International Journal for Innovation Education and Research*, vol. 7, no. 2, pp. 54–67, 2019.

[14] O. Gavrilova, "Breeders' and farmers' exceptions: how valuable are they for the world and are they a necessity for the BRICS countries?" *BRICS Law Journal*, vol. 7, no. 3, pp. 4–28, 2020.

[15] S. Natesan, G. Murugesan, N. Murugan, S. Chandran, and N. Angamuthu, "DNA fingerprinting of foxtail millet (*Setaria italica* L.) variety ATL 1 using SSR and RAPD markers along with morphological descriptors," *Tropical Plant Research*, vol. 7, no. 3, pp. 587–593, 2020.

[16] N. J. Page and R. G. Stelpflug, "Plants and seeds of corn variety CV334995," *Monsanto Technology Llc Missouri*, vol. 12, no. 7, pp. 583–586, 2017.

[17] K. Short and G. J. Holland, "Plants and seeds of hybrid corn variety CH071844," *Monsanto Technology Llc Missouri*, vol. 12, no. 7, pp. 583–586, 2017.

[18] Y. Hirakawa, K. U. Torii, and N. Uchida, "Mechanisms and strategies shaping plant peptide hormones," *Plant and Cell Physiology*, vol. 58, no. 8, pp. 1313–1318, 2017.

[19] H. Hu, Y. Wen, T. S. Chua, and X. Li, "Toward scalable systems for big data analytics: a technology tutorial," *IEEE Access*, vol. 2, no. 2, pp. 652–687, 2014.

[20] Z. Lv, R. Lou, J. Li, A. K. Singh, and H. Song, "Big data analytics for 6G-enabled massive internet of things," *IEEE Internet of Things Journal*, vol. 8, no. 7, pp. 5350–5359, 2021.

[21] N. Metawa and S. Metawa, "Internet financial risk early warning based on big data analysis," *American Journal of Business and Operations Research*, vol. 3, no. 1, pp. 48–60, 2021.

[22] S. Athey, "Beyond prediction: using big data for policy problems," *Science*, vol. 355, no. 6324, pp. 483–485, 2017.

[23] L. Kuang, F. Hao, L. T. Yang, M. Lin, C. Luo, and G. Min, "A tensor-based approach for big data representation and dimensionality reduction," *IEEE Transactions on Emerging Topics in Computing*, vol. 2, no. 3, pp. 280–291, 2014.

[24] X. Li, H. Liu, Y. Zhang, H. Lv, and Z. Lv, "Big data analysis of the internet of things in the digital twins of smart city based on deep learning," *Future Generation Computer Systems*, vol. 128, pp. 167–177, 2021.

[25] Y. Zheng, "Urban computing: enabling urban intelligence with big data," *Frontiers of Computer Science*, vol. 11, no. 1, pp. 1–3, 2017.

[26] Y. Zhang, M. Qiu, C. W. Tsai, M. M. Hassan, and A. Alamri, "Health-CPS: healthcare cyber-physical system Assisted by cloud and big data," *IEEE Systems Journal*, vol. 11, no. 1, pp. 88–95, 2017.

[27] H. Xing, A. Qian, R. C. Qiu, W. Huang, L. Piao, and H. Liu, "A big data architecture design for smart grids based on random matrix theory," *IEEE Transactions on Smart Grid*, vol. 8, no. 2, pp. 674–686, 2017.

[28] C. S. Calude and G. Longo, "The deluge of spurious correlations in big data," *Foundations of Science*, vol. 22, no. 3, pp. 595–612, 2017.

Hindawi
Scientific Programming
Volume 2022, Article ID 5495822, 9 pages
https://doi.org/10.1155/2022/5495822

Research Article

Analysis and Study on Intelligent Tourism Route Planning Scheme Based on Weighted Mining Algorithm

Yang Yu

School of Tourism Management, Xinyang Agriculture and Forestry College, Xinyang 464000, Henan, China

Correspondence should be addressed to Yang Yu; 2018300003@xyafu.edu.cn

Received 19 February 2022; Revised 20 June 2022; Accepted 28 June 2022; Published 19 July 2022

Academic Editor: Ahmed Farouk

In order to study the intelligent tourism route planning scheme based on a weighted mining algorithm, firstly, a traveling salesman problem based on an improved weighted mining algorithm is proposed. Then, based on the traveling salesman problem, the constraints of travel time and driving time are added, and the mathematical model aiming at the minimum number of travel days is established. The improved weighted mining algorithm is used to solve the model: firstly, the scenic spots are divided into regions according to provinces and solved; then, the regions of some scenic spots are modified and solved again according to the solution results, and the specific itinerary is given; finally, based on the route planning problem and considering a variety of transportation modes, a double objective mathematical model with the optimal tourism cost and the best tourism experience is established. When solving, the double objective is reasonably transformed into a single objective, the model is solved by comprehensively considering the tourism cost and tourism experience, and the specific schedule is given according to the solution results.

1. Introduction

With the development of the national economy and the continuous improvement of people's livelihoods, tourism is gradually becoming an integral part of people's lives and entertainment, and tourism is becoming a national industry. With the development of tourism, the diet of tourists has changed significantly, and the demand for quality work has increased. As a new heavy-duty, pollution-free industry, the trip is known as the "smokeless industry" and "eternal industry," and in 1990, it became the world's largest economy. With economic growth, people's incomes and lives have improved, and the economy has developed rapidly. With government support, it has become a new pillar. Tourism has become the first choice for many people to have fun and relax. In addition to promoting and enforcing tourism laws, the popularity of the Internet and the ease of access to information have gradually reduced the role of travel agencies, and more and more people are choosing to travel for free. Many travel websites, forums, and applications provide users with a wealth of information and an interactive platform that allows users to view, select, and plan [1, 2]. At the same time, people can easily share photos, thoughts, and behaviors while walking and share apps with others.

This contradicts the fundamentals that must convey the concept of smart marketing (Figure 1). Knowledge tourism refers to the use of new technologies such as weather, big data, and intelligence to provide a wide range of services to tourists via the Internet/mobile Internet and smartphones, tablets, and other devices [3]. The concept of intellectual tourism has been recognized and supported by the government. As for the topic of tourism, there is always food, accommodation, travel, trade, and entertainment. As an important part of tourism, tourism influences people to travel for their well-being. This line includes items such as travel equipment selection and travel package design. Traveler travels most of the time, and travel costs make up the bulk of the trip. Therefore, a good travel plan can save a lot of time and money on travel [4].

The services provided by these existing tourism plans also have some shortcomings. There are two big problems. First of all, the growth of the tourism sector has supported the development of self-guided tours, self-guided tours, and other self-help services, and the tourism sector has become a

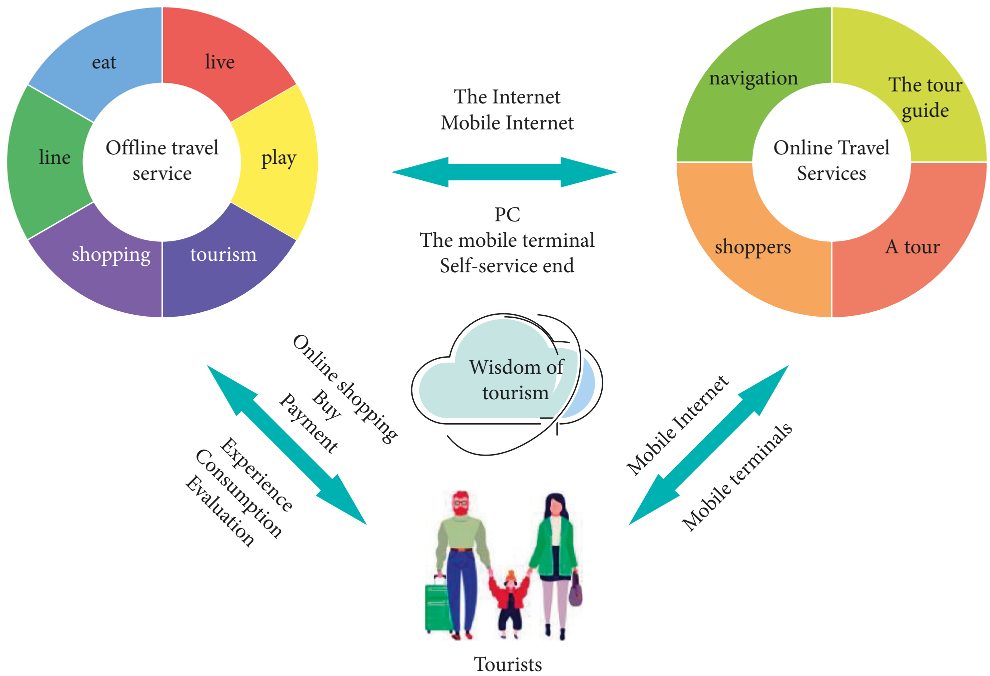


Figure 1: Intelligent tourism.

new tourist destination. However, all of the planned benefits of the existing process are provided by facilities such as commercial companies and dormitories, travel tools. The details of the tourism product are all planned and made for the return trip to the place, the scenic places to travel along the road, and the nearby hotels. It is done by a travel agency, and most consumers are not able to do it and participate in the planning and creation of this topic. Even on the Internet, netizens have begun to help with their own travel. The current situation of independent tourism planning is the gap between digitalization and the introduction of the tourism industry, and new research is needed to fill the gap [5].

The purpose of this topic is to study the smart tourism route through the method of weighted algorithm. First, it further enriches the research content of data mining and intelligent tourism route management. Through theoretical analysis, route management planning, and data mining analysis scheme design, it explores the application of data mining in route management in real tourism service platform and software, further expands the research scope of data mining, and enriches the research content of route data management in the tourism service software. Second, it further promotes the application and development of data mining technology of route management in tourism service software [6]. Specifically, using the weighted algorithm, combined with an example, it analyzes the practicability of the data weighted algorithm for smart tourism route management, verifies the importance of data mining, and provides a theoretical basis and reference measures for the application and development of route information data mining technology in other types of tourism service software, so as to promote the development of smart tourism service software route management.

2. Literature Review

Huang et al. point out that, in the current intelligent tourism, by mining the photo set with Geotag information, we can get information such as urban scenic spot area and user interest preference and use this information to provide users with personalized scenic spot recommendation services. For geophotos (photos with geographical labels), the scenic spot area is extracted by using DBSCAN (density-based spatial clustering of applications with noise) clustering algorithm, and the user's scenic spot interest matrix and scenic spot area heat vector are established. A BIPM (based on interest popularity and month) personalized scenic spot recommendation algorithm based on user preference, photo time context, and scenic spot area heat is proposed to build a personalized scenic spot recommendation model [7]. Peng et al. point out that there are information construction problems in the application of big data mining in smart tourism. From the perspective of smart tourism development, the current information construction still needs to be strengthened. There are problems with big data mining methods. At present, in the development of smart tourism in China, what is actually lacking is big data mining methods. In addition, data identification and correlation data analysis methods are difficult [8]. Liang et al. point out that intelligent systems perceive the surrounding environment, and intelligent systems are increasingly applied to the search, decision-making, and workflow of tourism information, resulting in intelligent tourism. In order to model the tourism field, intelligent system needs to have a deep understanding of its nature. Through the study of the existing tourism literature, this paper discusses the key gap of knowledge in the tourism field so as to understand the impact of intelligent system design. Specifically, it discusses the application of conceptualization technology in tourism research [9]. Liu and Zhang believe that, at the level of Internet development and tourism development, smart tourism is actually the intelligent development of tourism services, that is, using Internet technology to carry out tourism services and providing more convenient tourism services for people with the convenience of the Internet [10]. Qi C. believes that smart tourism is a new tourism management system combining the tourism industry and Internet technology. She points out that the four core contents of smart tourism are the Internet, mobile terminal, cloud computing, and artificial intelligence. On the basis of information technology, the application model of smart tourism is proposed, and its core is the data management system of the Internet [11]. Zhang believes that smart tourism cannot be equated with smart tourism in fact. He believes that smart tourism is only a product of a new era produced by the combination of tourism services and Internet information technology. Smart tourism should refer more to mobile tourism service apps, tourism products, or tourism service software. Smart tourism cannot even cover other current online tourism platforms or large tourism websites. Smart tourism is a practical tourism product relying on Internet mobile devices [12]. Zhang discusses the parameter setting of the weighting algorithm in solving the traveling salesman problem, and the results have a certain reference value [13]. Ying et al. proposes an improved ant colony algorithm by combining the ant colony algorithm and simulated annealing algorithm. The algorithm selects and repeats the paths of the ant colony algorithm through the simulated annealing algorithm to obtain the global optimal solution, which is applied to the route planning of tourist attractions.

This paper identifies and analyzes smart business planning. On the basis of the mathematical model of the self-driving travel route planning problem, it comprehensively considers factors such as the choice of transportation mode, travel time, and travel cost and establishes a mathematical model for the problem of smart tourism route planning. Combined with specific examples, it discusses how to solve the mathematical model of self-driving tour route planning problem and convert the solution results into specific itinerary.

3. Intelligent Tourism Planning Model

The goal of tourism is to spend less money and get the largest and most comfortable tourism experience, which is the main purpose of this function [14].

According to the current survey of transportation means, aircraft, high-speed rail, and self-driving tour are generally selected for interprovincial transportation means. It is assumed that f_{ij} is set as whether the transportation means from the provincial capital i to j is aircraft. f_{ij} is set as 1 if it is an aircraft; otherwise, it is set as 0. The ticket price of the aircraft is p_{ij}. Whether the adopted means of transport is a high-speed rail is set as h_{ij}. h_{ij} is 1 if it is high-speed rail and 0 if it is not high-speed rail [15], and the ticket price of high-speed rail is q_{ij}. Whether the adopted vehicle is a self-driving vehicle is set as c_{ij}. c_{ij} is set as 1 if it is a self-driving vehicle and 0 if it is not a self-driving vehicle, and the cost of a self-driving vehicle is r_{ij}. Suppose there is a tourist group with a total of m people, $m \le 5$. Considering the number of people, the vehicle used is self-driving, so the sum of the costs from the provincial capital to the provincial capital is as follows:

$$2 \times \left(f_{ij} \times p_{ij} \times m + h_{ij} \times q_{ij} m + c_{ij} \times r_{ij}\right). \tag{1}$$

The dynamic between the scenic spots i and j is expressed by S_{ijk}. If it changes between the scenic spots on the k-th day, it is 1. If it does not change, it is 0. There are two options for the road between the two scenic spots, one is an expressway, with a total length of v_{ij} [16], and the other is an ordinary highway, with a total length of $w_{ij}w_{ij}$; then, the cost from the scenic spot i to j is as follows:

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{K} s_{ijk} \times \left(v_{ij} + w_{ij} \times 0.5\right). \tag{2}$$

It is assumed that the sum of accommodation expenses on the k-th day is z_k, the sum of accommodation expenses on the trip is $\sum_{k=1}^{K} z_k$, the cost of vehicle rental is $(1 - c_{ij}) \times 300 \times k$, and the minimum value of the sum of expenses on the trip M is as shown in equation (3).

$$\begin{aligned} &2 \times \left(f_{ij} \times p_{ij} \times m + h_{ij} \times q_{ij} \times m + c_{ij} \times r_{ij}\right) \\ &\quad + \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{K} s_{ijk} \times \left(v_{ij} + w_{ij} \times 0.6\right) + \sum_{k=1}^{K} z_k. \end{aligned} \tag{3}$$

According to the investigation on the influencing factors of tourists' tourism experience, the results show that the longer the tourism time in each scenic spot, the higher the tourists' experience evaluation of this tourism [17]. The more certain the sum of travel time of each scenic spot, the less the time spent on the whole tour; that is, the less time spent on nonscenic spots, the higher the tourists' experience evaluation of this tourism. It can be concluded that the experience of tourists is related to time. Assume that F is a tourism experience function:

$$\% F = \frac{\text{Total time spent visiting the site}}{\text{Total time spent traveling + total time spent visiting scenic spots}}. \tag{4}$$

3.1. Solution Process of Weighting Algorithm. In the weighting algorithm, the path selection probability $P_{ij}^{k}(t)$ of time t weighted k transfer from city i to j is

$$P_{ij}^{k}(t)=\left[\frac{\left[\tau_{ij}(t)\right]^{\alpha}\left[\eta_{ij}(t)\right]^{\beta}}{\sum_{s\in\text{allowed}}\left[\tau_{is}(t)\right]^{\alpha}\left[\eta_{is}(t)\right]^{\beta}}\right]. \tag{5}$$

As can be seen from equation (5), there are mainly 4 parameters that determine the probability of path selection: pheromone value $\tau_{ij}(t)$ of the edge (i,j) at time t , heuristic function $\eta_{ij}(t)$, information heuristic factor α, and expectation heuristic factor β. The heuristic function is $\eta_{ij}(t)=1/d_{ij}$, where d_{ij} represents the length of the edge (i,j).

During initialization, the weighting algorithm makes the initialization pheromone $\tau_{ij}(0)=\tau_0$ of each edge (i,j), where τ_0 is a constant. This means that, in the initial stage, there will be a greater probability of selecting the next city with a larger heuristic function (shorter edge distance). In this way, after obtaining the initial solution, the global pheromone update will make the probability of the algorithm moving in the fixed direction exceed the probability of moving in other directions so as to form a local optimum.

A sign Y is set to judge whether the optimal solution is updated in this cycle. If it is not updated, it is not necessary to repeatedly calculate the optimal solution that has been locally searched, which also reduces the solution time of the algorithm to a certain extent. The termination condition of the weighted algorithm is $N_c\ge N_{\max}N_c\ge N_{\max}$; actually, the value of $N_{\max}$ is difficult to determine. When its setting is too small, the algorithm has not completed the search. If the setting is too large, an invalid cycle will be carried out after the search is completed, which increases the solution time of the algorithm. This paper sets the cycle sign C. If the current optimal solution L_{best} for 10 consecutive times remains unchanged, it is considered that the current cycle has been completed and the cycle is ended.

3.1.1. Parameter Selection. The setting of parameters has a great impact on the ant colony algorithm to solve the traveling salesman problem, so it is necessary to determine reasonable parameters for the weighting algorithm. By consulting the literature [18], heuristic factor α, expected heuristic factor, and pheromone volatilization coefficient P have a great impact, while weighted quantity m and pheromone intensity Q have a small impact.

In order to select the appropriate heuristic factor α and expected heuristic factor β, we use Oliver 30 in TSPLIB as test data. The default values of parameters are as follows: pheromone intensity $Q=100$, pheromone volatilization coefficient $P=0.3$, maximum number of iterations of the algorithm $N_{c-\max}=100$, weighted quantity $m=30$, and the combination of heuristic factor α and expected heuristic factor β is $(\alpha,\beta)\in\{(1,3),(1,4),(1,5),(2,3),(3,4),(2,5)\}$. Each group of combinations is solved 10 times, and the mean value is obtained. The solution results are shown in Table 1 [19].

As can be seen from Table 1 and Figure 2, when the pairing of heuristic factor α and expected heuristic factor β is (1, 4), the average path length is the shortest. Therefore, the pairing of selected heuristic factor α and expected heuristic factor β is (1, 4).

Table 1: Relationship between heuristic factor α, expected heuristic factor β, and average path length.

(α,β)	(1,3)	(1,4)	(1,5)	(2,3)	(2,4)	(2,5)
Average path length	423.27	424.05	424.21	424.31	414.26	423.42

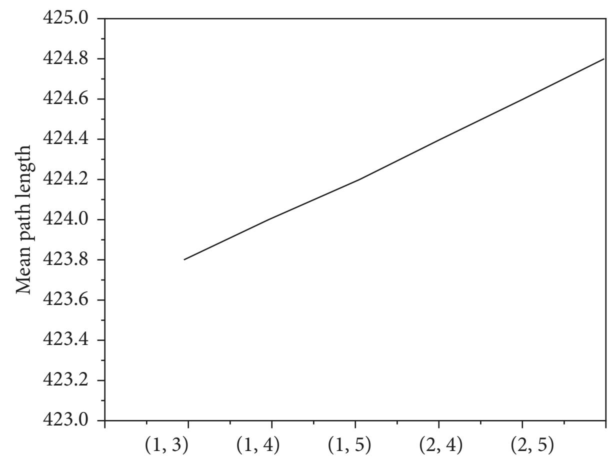


Figure 2: Relationship between heuristic factor α, expected heuristic factor β, and average path length.

Pheromone volatilization coefficient ρ and pheromone residue coefficient $1-\rho$ mainly affect the change of pheromone size. If the pheromone volatilization coefficient ρ is large, the pheromones on the path will increase or decrease rapidly and pile up when selecting the next path so that the algorithm falls into the local optimal solution. In order to select the appropriate pheromone volatilization coefficient, we use Oliver 30 in TSPLIB as the test data. The default values of the parameters are as follows: information heuristic factor $\alpha=1$, expected heuristic factor $\beta=4$, pheromone intensity $Q=100$, maximum number of iterations of algorithm $N_{c-\max}=100$, and weighted quantity $m=30m=30$. Select the pheromone strength pheromone volatilization coefficient $\rho=\{0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9\}$, solve it 10 times, and calculate the mean value. The solution results are shown in Table 2.

It can be seen from Table 2 and Figure 3 that the average path length is the shortest when the pheromone volatilization coefficient is $\rho=0.3$. In the process of pheromone updating, the pheromone volatilization coefficient ρ is very important. In most algorithms, pheromone volatilization coefficient ρ is usually set as a constant coefficient [20]. Based on the above considerations, we first link ρ with the number of cycles, and pheromone volatilization coefficient ρ is

$$\rho=\left\{\begin{array}{ll}0.2 & N_c\in\left[0,0.35N_{c-\max}\right]\\ 0.3 & N_c\in\left[0,0.35N_{c-\max},0.7N_{c-\max}\right]\\ 0.4 & N_c\in\left[0.7N_{c-\max},N_{c-\max}\right]\end{array}\right\}. \tag{6}$$

Table 2: Relationship between pheromone volatilization coefficient ρ and average path length.

Pheromone volatilization coefficient ρ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Average path length	424.20	423.18	424.44	424.32	423.46	424.86	424.11	424.54

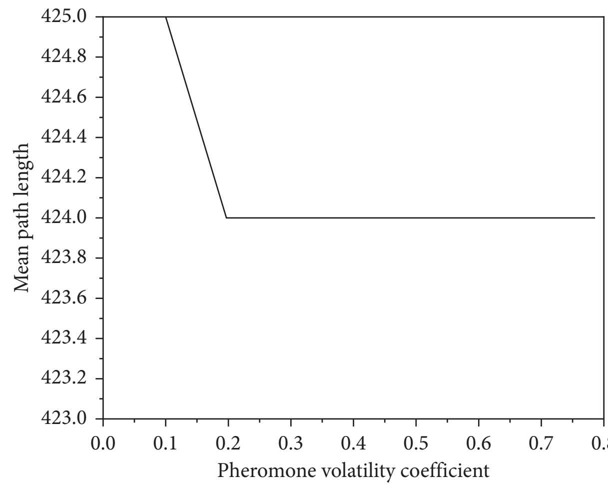


Figure 3: Relationship between pheromone volatilization coefficient ρ and average path length.

Table 3: Relationship between ant colony quantity m and average path length.

Ant colony quantity m	5	10	15	20	25	30	35	40
Average path length	425.49	425.05	424.33	424.43	424.27	424.22	424.28	424.30

In order to select the appropriate weighted quantity m, we use Oliver 30 in TSPLIB as the test data. The default values of the parameters are as follows: information heuristic factor $\alpha = 1$, expected heuristic factor $\beta = 4$, pheromone volatilization coefficient $\rho = 0.3$, maximum iteration times of the algorithm $N_{c-\max} = 100$, and pheromone intensity $Q = 100$. Select $m = \{5, 10, 15, 20, 25, 25, 30, 35, 40\}$, solve 10 times, and calculate the mean value. The solution results are shown in Table 3.

In order to select the appropriate pheromone intensity Q, we use Oliver 30 in TSPLIB as the test data. The default values of the parameters are as follows: information heuristic factor $\alpha = 1$, expected heuristic factor $\beta = 4$, pheromone volatilization coefficient $\rho = 0.3$, maximum iteration times of the algorithm $N_{c-\max} = 100$, and number of ants $m = 25$. Select the pheromone strength $Q = \{1, 10, 100, 1000\}$, solve it 10 times, and calculate the mean value. The solution results are shown in Figure 4.

It can be seen from Table 4 that there is an optimal solution when the pheromone intensity is $Q = 100$, and other cases fall into the same local optimal solution. The research results of [21, 22] show that pheromone intensity Q has little impact on the algorithm, but pheromone intensity is generally set as $Q = 100$ in small-scale traveling salesman problems.

This section proposes a solution to the traveling salesman problem based on an improved weighted algorithm. On the basis of the weighting algorithm, the path selection probability is improved by random factors; after completing one cycle, the optimal path will be searched locally; only the pheromone on the optimal path is used to update, and the threshold of the pheromone is set at the same time value; optimize the algorithm solution process; determine the reasonable parameters of the algorithm. Through performance simulation analysis, compared with the particle swarm weighted hybrid algorithm, although the algorithm in this paper is lacking in search accuracy, the solution speed is faster, and it has good practical value for solving the problem of tourist route planning.

3.2. Steps and Process of Improving Weighting Algorithm to Realize Traveling Salesman Problem. The steps of improving the weighting algorithm to realize the traveling salesman problem are as follows:

Step 1. Initialization of parameters. Set the number of cycles $N_c = 0$, set the maximum number of cycles $N_{c-\max}$, clear the taboo table $tabu_k$, make each edge (i, j), the initialization pheromone is $\tau_{ij}(0) = \tau_{\max}$, and the increment of pheromone at the initial time is $\Delta\tau_{ij}(0) = 0$.

Step 2. Number of cycles: $N_c = N_c + 1N_c = N_c + 1$.

Step 3. Place m in n cities, and then add the city of k to the taboo table $tabu_k$ of weighted kk.

Step 4. Weighted number $k = 1k = 1$.

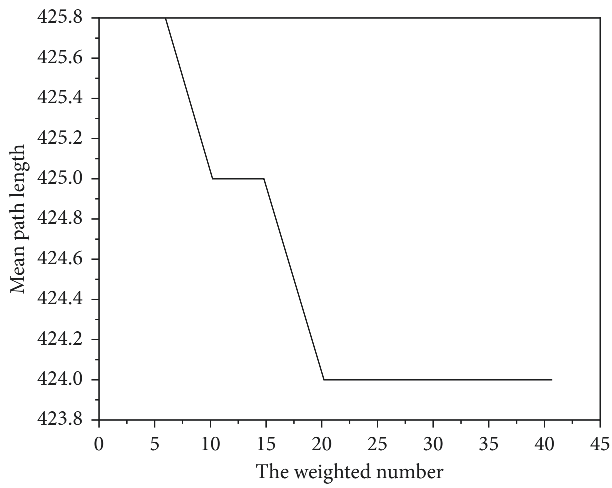


FIGURE 4: Relationship between ant colony number m and average path length.

TABLE 4: Relationship between pheromone intensity Q and average path length.

Pheromone intensity Q	1	10	100	1000
Average path length	424.16	424.13	424.32	424.44

Step 5. Calculate the path selection probability $P_{ij}^{k}(t)$ according to equation (4), judge to move to the next city J according to the random factor, and then add it to the taboo table $tabu_k$ of weighted K to calculate the current path length of k: $L_k = (k = 1, 2, \cdots, m)$. If the current path length is $L_k > L_{\text{best}}$, the search will stop.

Step 6. Weighted number $K = K + 1$.

Step 7. If $K > m$, execute Step 5. Otherwise, perform Step 8.

Step 8. Calculate the weighted path length $L_k = (k = 1, 2, \cdots, m)$, and record the current optimal solution L_{best}. If the optimal solution is updated, update the sign $Y = 1$ and cycle sign $C = C + 1$. Otherwise, update $Y = 0$ and $C = 0$.

Step 9. If the sign is updated as $Y = 1$, conduct a local search for the current optimal solution to determine whether the optimal solution L_{best} needs to be updated.

Step 10. Update the path pheromone according to equations (3) and (4), and determine the pheromone $\tau_{ij}(t)$ of each side (i, j) after updating. If it is greater than $\tau_{\max}$, then correct $\tau_{\max}$, and if it is less than $\tau_{\min}$, then correct $\tau_{\min}$.

Step 11. If $N_c \geq N_{\max}$ or $C \geq 10$ is satisfied, execute Step 12. Otherwise, clear the taboo table L_{best} and perform the step.

Step 12. Output the shortest path, and end.

The program flow of the improved weighting algorithm is shown in Figure 5.

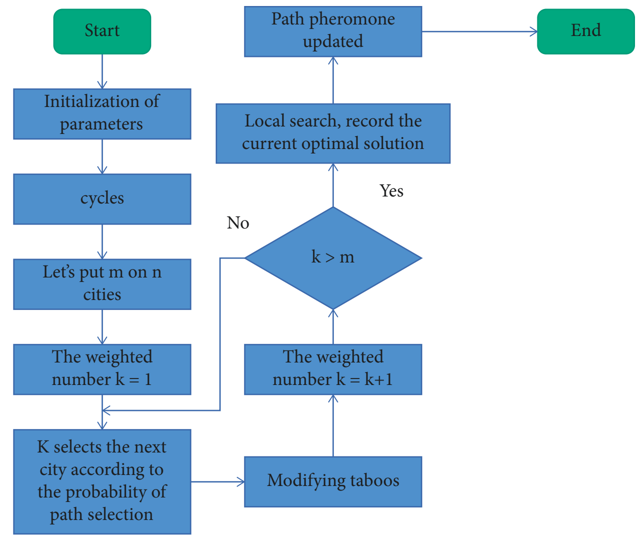


FIGURE 5: Program flow of improved weighting algorithm.

Comparing the best solutions of the algorithms in this paper and other algorithms, the algorithms in this paper can get the best solution, while the ant colony algorithm will fall into the local perspective. Costs and errors can be seen, but the best areas are less likely to fall.

4. Modeling and Solution of Intelligent Tourism Route Planning

4.1. Problem Description and Analysis. The problem of smart business planning is explained as follows. A traveler can travel by various means of transportation and travel to many beautiful places. How to create a travel guide gives travelers the best value and offers a unique travel plan [23].

The planning of smart tourism route shall include the following steps:

(1) Choose a time to visit the natural sights and all the sights according to the traveler's plan.

(1) According to the location of tourists and scenic spots, calculate the distance between tourists and scenic spots and the distance between scenic spots and scenic spots.

(3) According to the relevant location and distance, comprehensively consider the travel cost, select the appropriate means of transportation, determine the smart tourism route, and give the specific smart tourism route planning.

The specific smart tourism route planning should include the following seven aspects: (1) the starting place of each day; (2) specific transportation mode; (3) travel time; (4) driving mileage; (5) scenic spots visited; (6) time of scenic spot tour; (7) travel expenses.

The selection of scenic spots in smart tourism can be realized through big data analysis. Through big data analysis, we can recommend suitable scenic spots for tourists and analyze the appropriate travel time of each scenic spot. Similarly, according to travelers, through big data analysis in itinerary arrangement, recommendations including hotels, restaurants, and shopping can also be provided. In view of the limited space of the paper, this section focuses on the route planning of smart tourism.

According to the above analysis, we find that the core of smart route planning lies in how to select appropriate means of transportation, determine the route of smart tourism, and ensure the rationality of the smart tourism route. The process of solving the intelligent tourism route planning problem by mathematical modeling is shown in Figure 6.

In terms of considering various modes of transportation, three modes of transportation are considered: automobile, train, and aircraft. Although ship tourism may have more prominent aspects in the tourism experience, it is reasonable not to consider it. The factors of travel cost include the cost of transportation and the cost of travel and accommodation. Compared with the mathematical model of self-driving travel route planning, the model is more complex.

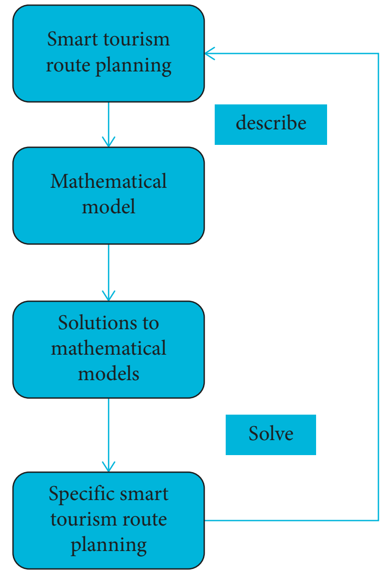


Figure 6: Solution process of intelligent tourism route planning problem.

4.2. Establishment of the Weighted Data Algorithm Model. The problem with smart business planning is that it needs to be simplified for a number of reasons.

It is important to plan a self-guided trip. The accommodation fee is simplified to 200 yuan/person/day for provincial capital cities and scenic spots, 150 yuan/person/day for prefecture-level cities, and 100 yuan/person/day for counties. The driving cost is simplified to the average fuel consumption plus the toll of an expressway is 1.00 yuan/km, and the average fuel consumption on an ordinary highway is 0.60 yuan/km.

From the above definition of travel experience, we can see that we consider linking travel experience with travel time. Through the analysis, we can see that the tourism experience F we define is in line with the actual situation.

In general, a multitask programming solution is to turn multiple goals into a single task problem with the appropriate tools. We consider setting the comprehensive objective as P and then solving the single objective; then

$$\min P = M \times (1 - F), \tag{7}$$

where M refers to all the expenses of a trip, F is the satisfaction of a trip, and $1 - F$ is the dissatisfaction of a trip. Therefore, P can be understood as the expenses spent by tourism enthusiasts on dissatisfied activities during a trip. The lower the value P, the better the comprehensive evaluation. The higher the value P, the worse the comprehensive evaluation.

In the actual solution, we found that it is difficult to get the solution result when the aircraft, high-speed rail, and self-driving are completely mixed together. The improved weighted mining algorithm is used to solve each region, and the shortest path and required days of each region are obtained.

The definition of tourism value is the definition of the tourism product as a result of the value of tourism product of the main force of education. In terms of the value of the natural tourism landscape, the objectification of the vital force of tourism education and the subjectivity of tourism products are the basis of its value. The former is an indirect source and creates intrinsic value, while the latter is a direct source and creates real value; the first determines the interest rate, and the second determines the validity of the value. The theme of its benefits for landscape tourism culture is the integration of the concept of studying the vital force of tourism education and tourism equipment. Therefore, the meaning of tourism products is the key to tourism spending, and the content is the impact of tourism products on the main force of education.

4.3. Solution Results. According to the shortest path of each region, the specific itinerary of smart tourism route planning can be sorted out. The number of travel days, total travel expenses, and scenic spots visited in each area are shown in Figure 7. Sort out the specific itinerary of smart tourism according to the regional browsing plan.

According to the rationalization assumption of the mathematical model, the total number of trips per year shall not exceed 30 days, and the total number shall be less than 4. Through a reasonable combination of the days spent on tourism in each region, we can visit all regions in fewer years. The annual tour area plan is shown in Table 5.

The specific itinerary of the intelligent tourism route planning problem given is the optimal route in theory, but whether it is reasonable should be tested according to the actual situation, such as whether the road is unobstructed. At the same time, it can also be classified according to the characteristics of the actual scenic spots so that tourists can choose the types of scenic spots they are interested in for recommendation.

Compared with the simple self-driving tour, the travel plan formulated by comprehensively considering various modes of transportation has significantly improved in time.

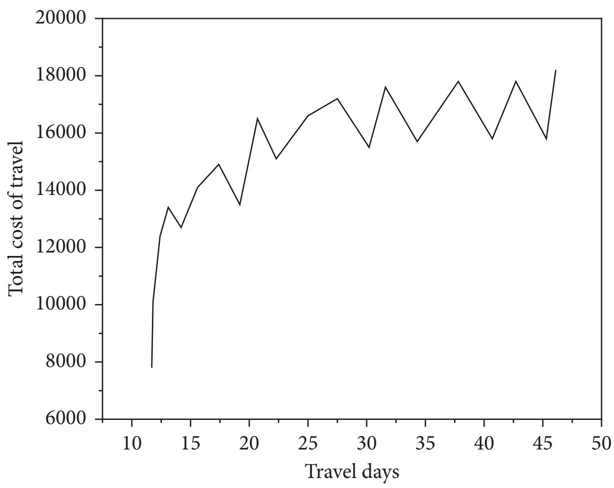


Figure 7: Travel days, total travel expenses, and the number of scenic spots visited in each region.

Table 5: Regional plan for visiting 201 5A scenic spots in China.

Year	Area number browsed	Total travel days
1	1, 2	20
2	3, 4, 5	35
3	6, 7, 8	40
4	9, 10, 11	30
5	12, 13, 14	30
9	15, 16, 17	20
10	18, 19, 20	28

The tourist routes of regions 1, 3, 20, 26, and 27 are a combination of aircraft and self-driving. Their corresponding tourist provinces are mainly far away from Xinjiang, Tibet, Hainan, and Yunnan. In addition to the above five regions, the solution results of the remaining 22 regions are only self-driving. The price data of air tickets and train tickets are from question F of the 2016 National Postgraduate Mathematical Modeling Competition. In fact, the prices of air tickets and train tickets given in the annex are relatively high, which has a certain impact on the solution results of the model to a certain extent. At the same time, the case considers the situation of a family of three. Compared with the plan of traveling alone, self-driving travel has certain cost advantages when many people travel together.

Regardless of the travel time limit, the travel plan of “poor travel” can be formulated. The travel plan of “rich tour” can be formulated without considering the restriction of travel expenses. Considering the travel time and cost, the travel plan of “economic tour” can be formulated. Different plans are suitable for people with different needs.

Based on the problem of smart travel route planning, a mathematical model with the dual goals of optimal travel cost and optimal travel experience is established by considering multiple modes of transportation. When solving, the dual objective is reasonably transformed into a single objective, and the model is solved by comprehensively considering the travel cost and travel experience. For multiple traffic modes, the optimal solution results are determined by comparing each traffic mode separately. Finally, the specific itinerary is given according to the optimal solution result.

5. Conclusion

This paper provides mathematical models for heavy data mining for intelligent brigade planning. The best solution is determined by comparing and resolving all types of vehicles for different types of traffic. The best solution was to move to smarter tourism industry in the planning area and eventually develop a smart business plan. Compared to the current state of tourism and natural attractions, the travel plan given in this form has the following advantages: Good results indicate importance and can serve as a basis for research in tourism planning. Smart marketing is always seen in ready-made, accessible, and popular information services. Encouraged by public demand, some industrial service companies continue to promote self-service and develop specialized products. Smart tourism integrates a wealth of tourism information based on the principles of consumer-friendly tourism and makes this information relevant to all travelers through intelligent management.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This work was supported by 2022 Soft Science Project of Science and Technology Department of Henan Province.

References

[1] X. Zhou, B. Sun, S. Li, and S. Liu, “Tour route planning algorithm based on precise interested tourist sight data mining,” *IEEE Access*, vol. 8, pp. 153134–153168, 2020.

[2] G. Tang and H. Zeng, “Evaluation of tourism E-Commerce user satisfaction,” *Journal of Organizational and End User Computing (JOEUC)*, vol. 33, no. 5, pp. 25–41, 2021.

[3] J. Du, “Research on intelligent tourism information system based on data mining algorithm,” *Mobile Information Systems*, vol. 2021, no. 1, pp. 1–10, 2021.

[4] G. Xiao, Q. Cheng, and C. Zhang, “Detecting travel modes using rule-based classification system and Gaussian process classifier,” *IEEE Access*, vol. 7, pp. 116741–116752, 2019.

[5] X. Zhou, M. Su, G. Feng, and X. Zhou, “Intelligent tourism recommendation algorithm based on text mining and mp nerve cell model of multivariate transportation modes,” *IEEE Access*, vol. 9, pp. 8121–8157, 2020.

[6] S. G. Devi and M. Sabrigiriraj, “Swarm intelligent based online feature selection (ofs) and weighted entropy frequent pattern

mining (wefpm) algorithm for big data analysis," *Cluster Computing*, vol. 22, no. S5, pp. 11791–11803, 2019.
[7] Y. Huang, J. J. C. Ying, P. S. Yu, and V. S. Tseng, "Dynamic graph mining for multi-weight multi-destination route planning with deadlines constraints," *ACM Transactions on Knowledge Discovery from Data*, vol. 15, no. 1, pp. 1–32, 2021.
[8] Z. Peng, S. Gao, Z. Li, B. Xiao, and Y. Qian, "Vehicle safety improvement through deep learning and mobile sensing," *IEEE NETWORK*, vol. 32, no. 4, pp. 28–33, 2018.
[9] A. H. Liang, B. C. Yun, C. Kan, and J. Gao, "Research and application of element logging intelligent identification model based on data mining," *IEEE Access*, vol. 7, pp. 94415–94423, 2019.
[10] Y. Liu and Q. Zhang, "Research on association rules mining algorithm based on large data," *Revista de la Facultad de Ingenieria*, vol. 32, no. 8, pp. 229–236, 2017.
[11] C. Qi, "Research on intelligent home energy scheduling algorithm," *Acta Technica CSAV (Ceskoslovensk Akademie Ved)*, vol. 62, no. 2, pp. 27–38, 2017.
[12] J. Zhang, "Research on adaptive recommendation algorithm for big data mining based on hadoop platform," *International Journal of Internet Protocol Technology*, vol. 12, no. 4, p. 213, 2019.
[13] Y. Zhang, L. Jiao, Z. Yu, Z. Lin, and M. Gan, "A tourism route-planning approach based on comprehensive attractiveness," *IEEE Access*, vol. 8, pp. 39536–39547, 2020.
[14] X. Li, H. Jianmin, B. Hou, and P. Zhang, "Exploring the innovation modes and evolution of the cloud-based service using the activity theory on the basis of big data," *Cluster Computing*, vol. 21, no. 1, pp. 907–922, 2018.
[15] Z. Ying and L. Xiaobo, "Research on the mining algorithm and calculation thinking expansion based on association rule hypergraph," *International Journal for Engineering Modelling*, vol. 31, no. 1, pp. 344–350, 2018.
[16] S. Wu, M. Wang, and Y. Zou, "Research on internet information mining based on agent algorithm," *Future Generation Computer Systems*, vol. 86, no. SEP, pp. 598–602, 2018.
[17] Z. Huang, Q. Chen, L. Zhang, and X. Hu, "Research on intelligent monitoring and analysis of physical fitness based on the internet of things," *IEEE Access*, vol. 7, pp. 177297–177308, 2019.
[18] S. Xingrong, "Research on time series data mining algorithm based on bayesian node incremental decision tree," *Cluster Computing*, vol. 22, no. S4, pp. 10361–10370, 2019.
[19] X. Zu, "Research on software development and reconstruction based on clustering algorithm and data mining," *Boletin Tecnico/technical Bulletin*, vol. 55, no. 18, pp. 314–322, 2017.
[20] Y. Y. Ye, X. L. Hao, and H. J. Chen, "Lane detection method based on lane structural analysis and cnns," *IET Intelligent Transport Systems*, vol. 12, no. 6, pp. 513–520, 2018.
[21] X. Jin, "Research into mining algorithm of efficient privacy protection frequent pattern based on granular computation," *Boletin Tecnico/Technical Bulletin*, vol. 69, no. 14, pp. 2188–2195, 2016.
[22] Y. Huang, W. Jin, Z. Yu, and B. Li, "A robust anomaly detection algorithm based on principal component analysis," *Intelligent Data Analysis*, vol. 25, no. 2, pp. 249–263, 2021.
[23] Y. Wang, Y. Yang, and Y. Li, "Recognition and difference analysis of human walking gaits based on intelligent processing of video images," *Traitement du Signal*, vol. 37, no. 6, pp. 1085–1091, 2020.

Hindawi
Scientific Programming
Volume 2022, Article ID 6566144, 9 pages
https://doi.org/10.1155/2022/6566144

Research Article

Innovation of Digital Multimedia VR Technology in Music Education Curriculum in Colleges and Universities

Hong Xiao

College of Art, Yulin University, Yulin 719000, Shaanxi, China

Correspondence should be addressed to Hong Xiao; xiaohong@yulinu.edu.cn

Received 28 January 2022; Revised 8 March 2022; Accepted 21 March 2022; Published 14 July 2022

Academic Editor: Ahmed Farouk

The art of music is the art of hearing, helping humans to establish good aesthetic interests. Music education is not only an important means of quality education for students, but also an important way to cultivate musical talents in colleges and universities. It inspires students' lofty ideals, cultivates their sentiments, and improves their aesthetic ability and cultural quality. The emergence of digital multimedia VR technology has made the traditional music education in colleges and universities seem a bit high and low. In the new era, the exploration of VR technology in music education is very challenging. It is especially important to explore the innovation of music education mode in colleges and universities in the era of digital multimedia VR technology. The goal of this paper is to explore the innovation of music curriculum in colleges and universities in the era of digital multimedia VR technology. According to the relevant research materials at home and abroad, drawing on and absorbing the new education and teaching ideas and new teaching achievements, adopting the methods of questionnaire, interview, and classroom observation, and taking the implementation of digital multimedia VR art course as a sample, the experimental results show that up to 72.2% of the classmates say that the implementation of digital multimedia VR art course is effective, and their music teachers occasionally use digital multimedia VR teaching facilities. Equipment is closed to teach digital multimedia VR courses in music class, and the data is on the rise. Through the survey on the current situation of the implementation of the digital multimedia VR teaching in colleges, it provides a more detailed basis for the reform of the music curriculum in colleges and makes the digital multimedia VR teaching tend to improve in the implementation of music in colleges.

1. Introduction

The progress of human thought and the convenience of life are inseparable from the changes brought about by the rapid development of science and technology. The emergence of the digital multimedia VR age indicates that people have faster access to information, better intelligent devices for life, more advanced methods for training the next generation of advanced ideas, and better artistic quality for training the next generation of advanced ideas are important components of people's all-round development. To train college classmates to better adapt to society and build society, we need to pay more attention to this link [1]. The digital multimedia VR represented by the Internet has become an important way for college classmates to study, work, and live, and has brought new opportunities and challenges to the cultivation of talents in colleges. It is an important reform measure in the field of higher education at the end of last century to carry out the cultural teaching quality in colleges and further to promote the teaching quality in an all-round way, which has a far-reaching impact on the cultivation of talents in colleges in China [2]. The development of an art starts with education, and the development of music education affects the development of the art education system of the whole society. Strengthening the art quality of college classmates and improving the aesthetic taste and art quality of college classmates are increasingly significant for promoting the all-round development of college classmates. The rapid, convenient, diverse, and massive information of digital multimedia VR bring new vitality to the art teaching quality of college classmates. The situational teaching under VR technology simulates the real situational experience, with a strong sense of immersion and substitution [3, 4]. In the Context Creation under VR technology, students can go deep into the context. With the movement of students' user location, the computer can send out the picture through calculation. The real context experience makes students have a desire for learning, and makes students want to learn and love learning from the inside out. Actively explore the art teaching quality of College classmates in the age of digital multimedia VR, actively use the effective carrier of digital multimedia VR, pursue advantages and avoid disadvantages, and make art have been innovated and developed to carry out teaching quality for college classmates, improve their IQ and EQ, make them become socialists with Chinese characteristics, and build excellent talents with both ability and moral integrity and all-round development [5]. Music is a greatly significant way to strengthen the aesthetic consciousness and level of modern people. More and more classmates begin to enter the art hall and feel the charm of music. Colleges are the cradle of music professionals. At present, there are many professional music schools in China, and most comprehensive universities have also established music schools [6]. Music education is in full swing all over the country. However, as the starting point of adult classmates, colleges are the intermediary between schools and society, and it is a key in the development and future of classmates [7]. The training plan and implementation of music talents in colleges have irreplaceable significance for the development of each student, so the construction of music education curriculum system in colleges is particularly important. Music education is not only an important means of teaching quality for classmates, but also an important means of cultivating musicians in colleges [8, 9]. It stimulates classmates' lofty ideals, cultivates classmates' sentiment, and improves classmates' aesthetic ability and cultural quality [10, 11].

Art education encompasses four major arts categories: music, dance, theater, and visual arts. Music is inextricably linked to the other three art categories and plays a leading, facilitating, and complementary role to the other three with its unique characteristics. Jagodzinski discussed the challenges facing art education. Art courses around the world have begun to change to adapt to new technological realities. Some people think that in our "controlled" society, the capitalist economic system determines the direction of education [12]. At the same time, under the guidance of self philosophy of new liberalism, art educators are facing the problem of how to deal with new media technology and incorporate it into art plans. They tried to prove that this direction should recognize the "emotional turn" within the media and grasp different directions in cooperation. But the practicality is not strong [13]. Grace Reid found through retrospective research that science media education is one of the most important teaching contents in and out of science classroom. They then set a research agenda that will help make science media education a key content area in both formal and informal science learning environments. In particular, they have identified research methods that we can better understand: (1) the limitations in the current practice of science media education; (2) what should science media education look like in the future; (3) how to overcome the obstacles in the implementation of new and improved science media education [14]. Authentic approaches to learning aim to immerse students in contexts that promote real-life application of knowledge and provide meaningful learning experiences that go beyond abstract teaching in the classroom. In a grounded theory study of music teaching practices in high-achieving schools by R White, 50 teachers from 23 schools in New South Wales (NSW), Australia, were asked to describe how they teach their high school students and the music environments they curate in their schools. Through the study of interview data, authentic learning was shown to have a unique place in the classroom teaching of music programs to high-achieving high school students in NSW. This is demonstrated by the use of comprehensive inquiry-based and student-centered learning tasks such as video journals, the use of professional resources and expertise, and collaborative learning in authentic settings inside and outside the classroom [15]. The above studies provide a detailed analysis of the application of new media technologies and art education. It is undeniable that these studies have greatly contributed to the development of the corresponding fields. We can learn a lot of lessons from the methods and data analysis. However, there are relatively few studies in the field of digital multimedia virtual reality technologies for music art, and it is necessary to fully apply these algorithms to the research in this field.

Through the Internet and library, this paper has consulted the majority of relevant materials, summarized the existing research results, and combed out the relevant theoretical framework, in order to provide a good theoretical reserve for the smooth development of this study; on the other hand, using the methods of observation, interview, sampling, and questionnaire survey, the implementation of the digital multimedia VR teaching of music in colleges is analyzed, and at the same time, the theory is put forward. On the full application of teaching practice, the data and results of research and investigation are analyzed, conclusions are drawn, and suggestions and measures are put forward to promote and further effectively implement the art digital multimedia VR teaching in Colleges. The innovation of this study lies in: the current school-based curriculum development tends to be theoretical, the limitations of teaching content, the single teaching means, the lack of research results, the lack of practice, and other issues. From the reality of classmates, parents, and teachers, develop curriculum to fill the gap in this field. The use of virtual reality technology for interactive experiences in music education classrooms promotes a multiform approach to teaching and learning.

2. Proposed Method

2.1. The Development of Traditional College Music Education. In terms of curriculum, most colleges and universities have set up relevant music courses, but most music courses are elective courses, with only one class per week and relatively short class time. Generally speaking, the elective courses are mainly large courses with a large number of students, and each student has different cultural levels, so the teaching does not play a targeted role and cannot fundamentally improve the students' interest in music. Although colleges and universities offer music courses such as instrument playing, music theory, music appreciation, choral conducting, etc., these courses are not connected to each other and stay in the initial stage.

In terms of teaching materials, the music teaching materials used in colleges are basically selected by the school music teachers themselves, and the teaching content is also determined by each teacher themselves, so the teaching content is too arbitrary. Most of the teaching materials are based on the western music history, while the introduction of Chinese music history and Chinese national music is relatively small. Especially in the content of Chinese opera and folk music, there is only one chapter to make college classmates who do not understand Chinese folk music not interested in their own traditional music.

In terms of teaching methods, most of the current music courses in colleges are too single, mainly reflected in the limitations of the music teaching content. For example, in the classroom, most teachers teach some boring theoretical knowledge, while ignoring the creativity and practicality of classmates' learning. The digital multimedia VR age puts forward higher requirements for teachers. In order to keep pace with the times in the future teaching, teachers are required to keep learning and upgrading. First of all, teachers should understand the popular content of contemporary college classmates, such as popular pop music, pop dance, and light music; secondly, bring the popular content that college classmates love into music teaching, and set up some popular content, such as pop music singing and pop dance teaching courses. The most important thing for the development of music education is the change and development of educators' ideology. Music education and teaching work should keep pace with the times, look at new things with new eyes, and solve new problems with new methods.

2.2. Combination of Digital Multimedia VR Technology and Music Education Classroom. Virtual reality is the combination of virtual and reality with each other. Theoretically, virtual reality (VR) is a computer simulation system that allows the creation and experience of a virtual world, using computers to generate a simulated environment into which the user is immersed. Virtual reality has three characteristics: perception. VR should have all the perception that human beings have. For the sense of existence, VR should have the feeling of immersing the experiencer; interactivity. VR should have the function of interactive experience between human and machine. Virtual reality technology emphasizes "immersion," which makes people seem to be in the scene. With the changing times, VR plays a very important role in the research of digital space art [16, 17]. Virtual reality has all the perceptual functions that humans have, such as hearing, vision, touch, taste, smell, and other perceptual systems; finally, it has a superb simulation system that truly realizes human-computer interaction so that people can operate at will and get the most realistic feedback from the environment during the operation process.

Using virtual reality technology for interactive experience in music education classroom is mainly an experience between the experiencer and the imaginary space. It shows a "sense of immersion." The so-called "sense of immersion" expresses the experiencer's feeling experience in the space. For experimenters, a good interactive experience can bring them sensory enjoyment and endless fun. The monotonous life, through the connection of virtual reality technology, has a new understanding of space. Although space art and experimenters are not the same expression subject, they make it connected and become a whole through the operation of virtual technology, and even realize the dialogue function of human-computer interaction. The experience of digital space art is realized through VR, which makes the experimenter fully communicate and contact with the machine.

Digital multimedia VR technology uses network technology, digital technology and other technical means, mobile phones, and other computing mobile terminals to provide users with a wide range of information content and entertainment services [4, 18]. With the progress of society and science and technology, the traditional way of information communication has not been able to meet the needs of modern people. It has many characteristics, such as wide range of communication, fast update, and can provide people with personalized needs. Nowadays, digital multimedia VR technology has become an indispensable part of modern people's life, study, and work, and can be applied in various fields [19].

2.3. Innovation of College Music Education Mode in the Digital Multimedia VR Age

2.3.1. Innovation of Teacher-Student Relationship. In one and a half hours of class, teachers teach independently and classmates learn knowledge passively, which leads to the decline of classmates' learning interest and poor learning effect. In recent years, it has become a key issue to optimize the music teaching mode in colleges. With the rise and development of digital multimedia VR, music education in colleges has brought infinite possibilities. First of all, classmates have changed from passive learning to active learning. Combining digital multimedia virtual reality technology in the classroom, the experiential interaction between the experiencer and the imaginary space helps students to learn better. VR technology has changed the traditional learning mode, and the learning mode of teaching in fun is conducive to the achievement of three-dimensional goals. Through the creation of situational simulation objects, students can participate in the situational simulation of real life to a certain extent, and through students' practice, they can be true. We are combining knowledge with action and using practice to test whether knowledge is used correctly. Secondly, it increases the relationship between teachers and classmates, and pays more attention to the conversation and communication between teachers and classmates. In the classroom, it is no longer just a boring explanation, but a space for conversation between teachers and classmates.

2.3.2. Innovation of Teaching Content. In the content of music teaching in colleges, because there are too many contents related to the history of Chinese and western music and music theory, and the development of digital multimedia VR technology, it is difficult and boring for non music majors to learn, which provides the necessary conditions for the innovation of teaching content, breaks the impression of "reading the course book" and "reading the PPT" in the traditional curriculum, along with the widespread use of singing software, microblog and we-chat, which is "song" Music teaching content such as singing bar providing new possibilities. Teachers can use this software to teach classmates to sing and practice songs. Finally, the recorded songs will be output to microblog or we-chat related public platforms for display, to improve classmates' interest in learning music.

2.3.3. Innovation of Teaching Methods and Expansion of Teaching Resources. The emergence of digital multimedia VR technology provides more resources for music teaching. First, in the current classroom, teachers no longer need to sing and play music in person. As long as teachers download excellent music works, they can let classmates enjoy music performances at the international level, which is conducive to the cultivation of classmates' music appreciation ability and music literacy. Secondly, we can use digital multimedia VR technology to combine music with other media and create a new form of study and conversation for College classmates. For example, the establishment of the elective music group provides a platform for classmates with music hobbies to communicate. Teachers recommend relevant music review articles or music sharing in groups every day so that music can go out of class and into classmates' life.

2.4. Deficiency of Music Education in Local Colleges

2.4.1. Curriculum Does Not Meet the Actual Needs. At present, the curriculum of music education in local colleges is not completely consistent with the actual needs, which cannot reflect the advantages and characteristics of music education. The major of music education in local colleges generally consists of three parts: the public course of basic knowledge of music, the basic course of theoretical content of music education, and the specialized course of professional skills of music. The curriculum setting of these three parts is similar to that of professional music colleges, but the nature of music education personnel training is different from that of professional music personnel, and the same course cannot highlight the difference between the two. In the curriculum of music education, local colleges do not connect music education with other related subjects and lack of comprehensive quality of teachers. For example, in local normal universities, classmates majoring in music education should not only master the relevant professional knowledge of music education but also master the basic teaching theories of pedagogy and educational psychology. The major of music education is not to train excellent music talents but to train excellent music teachers for primary and secondary schools. Therefore, the local colleges should reasonably allocate the existing educational resources and strive to cultivate excellent music teachers who study comprehensively.

2.4.2. Teachers Do Not Pay Attention to Classroom Teaching. The goal of music education is to provide qualified teachers for the society, but at present, the teachers of music education major in local colleges are influenced by many factors of the society. They put a lot of energy into extracurricular performance or extracurricular teaching activities, which to a certain extent affects the development of the society. In addition to the quality of classroom teaching, some music education professional teachers are not clear about the training objectives of music education talents. They often regard music education classmates as professional performance talents to improve their professional skills but pay little attention to the cultivation and improvement of their comprehensive quality, which is not conducive to the development of local music education.

The fundamental reason for the curriculum not meeting the actual needs and teachers not paying attention to classroom teaching is that society and schools do not pay enough attention to the development of music education and do not give enough attention and research efforts.

2.5. The Way of Curriculum Reform in Local Colleges in the Digital Multimedia VR Age

2.5.1. Using Digital Multimedia VR to Promote Curriculum Integration. The existing music education curriculum only pays attention to the development of a single discipline, neglects the integration with other related disciplines, and has obvious boundaries in the discipline. The same music teacher cannot carry out cooperative teaching, the same student's knowledge is completely separated, the professional and nonprofessional courses cannot be integrated, and the classmates lack aesthetic ability. This is the main problem during music education in local colleges. In the digital multimedia VR age, all is media. Since the emergence of digital multimedia VR, many problems that cannot be solved in time can be solved through the Internet and various software. Digital multimedia VR makes people's life more convenient. In the same network environment, everyone can share the joys and sorrows of knowledge and life. The introduction of digital multimedia VR teaching methods into music education in local colleges will greatly improve the current situation of music education. At present, in the major of music education, music history, music, harmony, music theory, Solfeggio, and other courses are lack of integration, and there is no mutual connection between the courses. If there is digital multimedia VR participation, it will greatly promote the integration of the curriculum, not only in professional courses and nonprofessional courses, but also can make full use of digital multimedia VR, to achieve cross professional learning and effective integration between various majors.

2.5.2. Promote the Multiform Development of Teaching Mode. The simplification of teaching mode is also a major problem in the current music education curriculum of local colleges and universities. The existing teaching mode is mainly classroom teaching, and the classroom content is the process of dialogue between teachers and classmates, the process of constantly exploring and digging new knowledge, and the bridge of communication between teachers and classmates. Mainly, the teacher speaks at the podium and the students listen at their seats. The effect of speaking and listening depends on a test paper, which is not only tedious but also inefficient. Using digital multimedia VR can change this situation. Currently, web-based teaching has formed a new teaching mode. Teachers can interact with students in front of the screen through webcasting and explain the course anytime and anywhere. The beneficiary group is more general and there is no restriction on the time and place of teaching; they can start teaching at any time. In addition, developing online lessons is a way to develop music appreciation lessons through online music resources, giving students enough time to listen to different styles of music with an assignment and then share the experience with their classmates and teachers in class. This way of teaching saves classroom time, weakens the teacher's dominant position, enables students to participate in classroom teaching, and greatly improves teaching efficiency within the limited educational time. In addition, VR and the popular webcast in the digital multimedia era also provide students with opportunities to practice. Students can make full use of the Internet to show their talents, especially for music education majors, who can practice with various live streaming and singing software to enrich their practical experience and skills during normal times. At the same time, they can also use digital multimedia VR to provide not only limited to music but also a comprehensive quality training and improvement. Therefore, local universities should pay full attention to the application of digital multimedia VR in music education so that digital multimedia VR can contribute to the training of qualified music teachers.

2.5.3. Take Full Advantage of Internet to Spread Local Culture. The cultivation of music education talents in local colleges should not be limited to the study of general music theory and music skills. Local colleges should highlight local characteristics, take local music culture as the leading role, and cultivate music talents. Local music culture needs professional music talents to excavate and spread. The talents of music education in local colleges should be based on the local music culture, enrich the local music culture while improving their professional skills, and spread it through the network. Through the dissemination of local music culture, classmates majoring in music education can use the network to carry out popular science activities of local music culture knowledge and incorporate them into the curriculum assessment. On the one hand, it can promote the dissemination of music and let the public pay attention to music culture in different regions. On the other hand, in the dissemination practice, classmates majoring in music education can establish different links to exercise their own teaching water ping, during conversation with netizens, can further tap the local music culture.

3. Experiments

3.1. Experimental Dataset. This study's main goal is to explore the cognitive level of digital multimedia VR art and college music teachers, find out the existing problems, and analyze the causes of these problems. On this basis, it demonstrates the feasibility and necessity of integrating digital multimedia VR art into the development of school-based music curriculum, which paves the way for the development of school-based music curriculum.

This questionnaire survey is mainly distributed in city a, which is located in the Central Plains, and can represent the lower level of art education in China. It has certain backwardness in education idea and teaching method, but it has strong pertinence to the development of local school-based curriculum and really realizes the teaching idea of "from classmates to classmates." There are 10 questions in the questionnaire, all of which are objective choice questions.

Before the course learning, this study investigates the needs of learners, aiming to determine the real needs of learners according to the actual needs of learners so as to stimulate learners' interest in teaching design. This survey adopts the method of questionnaire. Through the reliability and validity test, the study needs of the experimental class learners were investigated. A total of 24 questionnaires were sent out, 24 were recovered, the recovery rate was 100%, and the effective rate was 100%. In order to maintain the consistency between the pretest and the post test, the subjects in this survey are learners' needs, and the subjects in the post test are the same group of classmates. Therefore, the number of questionnaires is small and targeted.

3.2. Basic Information of Research Object. The subjects were teachers and classmates in city a, 20 teachers in city a, 20 teachers in questionnaire survey, all aged 25–45, with master's degree or above. They are first-class and second-class titles, respectively. The basic information of the subjects is the first content of the questionnaire. The basic information can be filled in without thinking, which can help the subjects quickly enter the status of filling in the questionnaire. The basic information of the respondents mainly includes gender, grade, major, and family location. Differences in learning background may lead to differences in research results. Because it is the same major and the same class, there is no difference between the grades and majors of the subjects. The subjects of this survey are classmates of grade 19 (second year) of the school of education. In terms of gender, the proportion of men and women was 37% and 63%, respectively, about 4 : 6, which basically kept the gender balance of subjects. 58% of families were in cities, 17% in villages, and 25% in rural areas. Families are distributed in towns and villages, more than half of them are in cities, obviously more than towns and villages.

3.3. Research Object's Digital Multimedia VR Learning. In the second part of the questionnaire, it mainly investigates the basic situation of digital multimedia VR learning. It mainly includes digital multimedia VR learning experience, digital multimedia VR learning time per week, digital multimedia VR learning location, using digital multimedia technology to obtain learning resources, the impact of digital multimedia VR on teaching methods, and the initiative of digital multimedia VR independent learning. The main purpose of this part of question setting is to understand the basic situation of digital multimedia VR learning of the research object through the questionnaire survey, judge the proportion of digital multimedia VR learning in the current learning life of the research object, whether digital multimedia VR learning is feasible, and whether the research object is willing to accept digital multimedia VR learning.

4. Discussion

4.1. Analysis of Teachers' Arrangement of Digital Multimedia VR Teaching Content. 50% of music teachers will not strictly follow the content written in the book but will reorganize the content of the textbook in term of the concrete situation of the classmates and the actual application of the textbook. The remaining music teachers will also have their own views and adjust the content of the textbook to a certain extent according to the specific characteristics of the classmates, as shown in Figure 1.

In the various stages of the development and deepening of the new art curriculum reform, many music teachers' teaching concepts have gradually changed from the old teaching concepts to the new teaching concepts. In the digital multimedia VR teaching, music teachers also change the previous teaching methods into the teaching process that keeps pace with the times according to the characteristics of the digital multimedia VR teaching. In our past music classes, music teachers may focus on classmates' basic music knowledge and music skills, while music teachers often play the role of the leader and speaker, mostly using conventional education ways. In many teachers' classroom teaching, many teachers concentrate on the results of classmates' knowledge, but for classmates' basic music knowledge and music skills, the process and method of classmates' acquiring knowledge lack attention. Therefore, there are some bad teaching methods such as cramming. In terms of teaching methods, College music teachers basically use multimedia means such as computer and network to carry out teaching work so as to obtain a very rich teaching materials, and produce enough attraction for classmates.

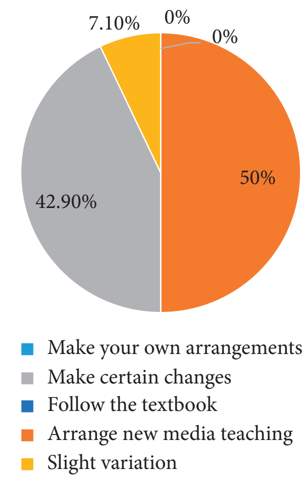


Figure 1: Arranging the teaching content of digital multimedia VR.

4.2. Implementation of Digital Multimedia VR Teaching

4.2.1. Implementation of Digital Multimedia VR Classroom Teaching. According to the survey data, 42.9% of music teachers pay more attention to the combination of VR theory and practice in the teaching process, and only 7.2% of music teachers realize that they cannot meet this standard in the teaching activities, as shown in Figure 2.

4.2.2. Training of Practical Ability of Digital Multimedia VR. As shown in Table 1, for developing classmates' practical skills, 62.7% and 28.6% of music teachers think that they are more absorbed in the cultivation of classmates' practical skills. Teachers and curriculum have become the basic guarantee for the smooth progress of music curriculum reform and the effective implementation of music digital multimedia VR teaching. The implementation of college music curriculum is not only influenced by teachers' teaching ability and time arrangement, but also has a lot to do with whether the teaching equipment is complete. The number and class hours of college music curriculum, that is, within one academic year, the first grade classmates arrange one class hour of music curriculum every week, and the second grade classmates arrange one class hour every semester or the whole academic year every week. After investigation and statistics, it is not difficult to find out that all schools can offer art courses in the first year of college, usually once a week. Due to the fact that sophomores are not far away from graduation and heavy burden of practice, the arrangement of music courses for sophomores in colleges is quite different. But generally speaking, compared with before the curriculum reform, the digital multimedia VR teaching effect of College Music Course under the new curriculum is better, and music course is seldom occupied by other disciplines. In terms of improving the level of teachers, according to the statistical results, it is not difficult to find that at present, there are basically one or two professional music teachers in colleges, generally two music teachers in urban schools, and one music teacher in rural areas. These teachers are relatively professional, and their ability to use digital multimedia VR technology is gradually enhanced. Although the digital multimedia VR full-time music teachers are not enough in reality compared with the teachers' course selection and arrangement required by the Ministry of education, compared with the weak music teachers in the

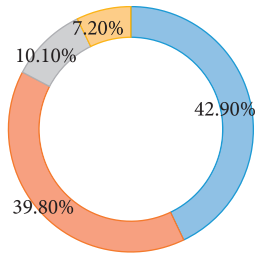


FIGURE 2: During the implementation of digital multimedia VR course, teachers and classmates combine learning with hands-on practice.

TABLE 1: Training classmates' practical ability of art digital multimedia VR in the specific teaching process.

Pay great attention to	28.6%
Pay more attention to	62.7%
Commonly	8.7%
Less emphasis	0%
Pay no attention to	0%

past, it is not difficult to find that the current music teachers have strong working ability.

4.3. Digital Multimedia VR Teaching Is More Advanced Than Traditional Teaching

4.3.1. Use of Digital Multimedia VR-Related Teaching Equipment. In the survey data, we found that up to 72.2% of classmates explained that their music teachers occasionally use digital multimedia VR teaching equipment to teach digital multimedia VR-related courses in music class, and this data is on the rise. However, 13.4 classmates said that teachers rarely use digital multimedia VR teaching equipment and equipment to teach classmates digital multimedia VR-related courses, and 6.1% of classmates have never seen music teachers use digital multimedia VR equipment to teach related digital multimedia VR courses in music class for various reasons and conditions, as shown in Figure 3.

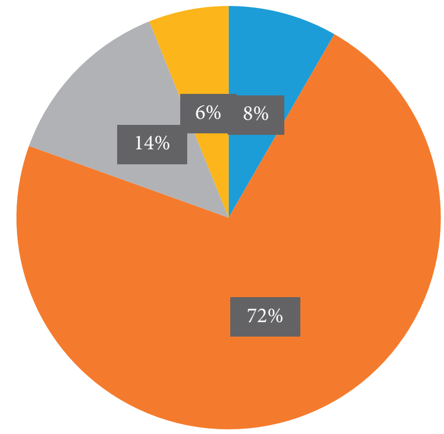


FIGURE 3: In music class, the situation of music teaching by teachers through digital multimedia VR equipment.

4.3.2. Utilization of Digital Multimedia VR Informatization Curriculum Resources. In the survey data, we are happy to find that most music teachers are able to take full advantage of the network and other wonderful resources to collect music digital multimedia VR education resources. At the same time, many music teachers can communicate with digital multimedia VR music teachers in other schools or provinces and cities and exchange their own student works and digital multimedia VR teaching results and experience flow. 30.8% of music teachers think that this kind of activity can be developed as a normal digital multimedia VR teaching activity, as shown in Figure 4.

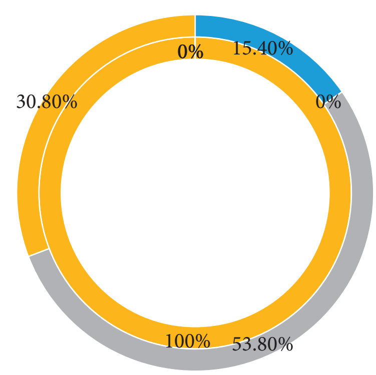


FIGURE 4: Teachers' digital multimedia VR teaching on the Internet.

Teaching method is a way chosen by teachers to complete teaching tasks, achieve teaching objectives, promote conversation between teachers and classmates, and improve classmates' learning ability. In the past, in the teaching process of digital multimedia VR in colleges, in the music digital multimedia VR classroom, the main teaching methods were teachers' oral teaching and heart to heart teaching, classmates were constantly indoctrinated, the conversation between teachers and classmates was less, it was difficult to cultivate classmates' interest in learning digital multimedia VR, and it was also difficult to improve classmates' ability and thinking level of self-learning digital multimedia VR. Therefore, the implementation of new music media Teaching can implement cooperative, autonomous, and research-based learning strategies, and also change the bad habits of passive acceptance of classmates in music learning in the past so that classmates can actively participate in music learning, which is different from the previous teaching methods. Some music teachers are not limited any longer to the usual teaching methods for many years. They are trying to integrate the teaching methods advocated by the new curriculum and concentrate on the cultivation of classmates' subjective initiative. In the learning process, classmates can not only gain their own experience but also master the learning methods of music. During teaching, teachers are reversing the trend of direct indoctrination. The post teaching method is to guide classmates to ask more questions and discuss more, so that they can give full play to their imagination. It is to guide and organize classmates to have group discussion and cooperative communication on specific contents with the continuous improvement of teaching strategies. As a result, classmates are more and more interested in learning. The research-based learning strategy and cooperative autonomous learning strategy advocated by the new curriculum gradually appear in the digital multimedia VR teaching in colleges.

5. Conclusions

According to the relevant research materials, this study draws on and adopts the new education and teaching ideas and new teaching achievements, adopts the methods of questionnaire survey, interview, and classroom observation, and takes the implementation of digital multimedia VR art course in city a as an example to make the effective implementation of digital multimedia VR art course. In this paper, while investigating the actual classroom, we investigate the situation of classmates and teachers, trying to find out the factors affecting the implementation of digital multimedia VR art courses and the relationship between the implementation of digital multimedia VR art courses and various influencing factors, as well as the investigation of the implementation of digital multimedia VR art courses, and put forward our own opinions or suggestions for the effective implementation of the new curriculum reform and the implementation of digital multimedia VR art courses in colleges and universities. Although the development of digital multimedia VR teaching in colleges has achieved some results, there are still many deficiencies. For example, the curriculum resources of art digital multimedia VR are insufficient, the implementation progress of art digital multimedia VR curriculum cannot keep up with the pace of the times, there is a gap between the implementation and development of art digital multimedia VR teaching, the operation level of teachers' digital multimedia VR is low, and the regional conditions are greatly different. Through the analysis of the causes of the problems, the corresponding countermeasures are put forward from different angles. For these shortcomings, experts are needed to keep abreast of the artistic development of the times, to update the curriculum resources and to improve the course content.

Through the investigation and study on the current circumstance of the implementation of music digital multimedia VR teaching, this research gives a more detailed basis for the reform of music curriculum in colleges, which helps us to understand the reasons and influencing factors for the smooth implementation of digital multimedia VR art curriculum in art digital multimedia VR teaching, and timely revise and adjust the implementation strategies of art digital multimedia VR teaching curriculum in colleges so as to make digital multimedia VR sports in college music. The implementation of the system tends to be improved.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this article.

References

[1] C. Randles, "A quest for the Perfect Tone: Luthiering, pedal Boards and curriculum Expansion," *Journal of Music, Technology & Education*, vol. 8, no. 2, pp. 183–197, 2015.

[2] O. Zandén and C. F. Thorgersen, "Teaching for learning or teaching for Documentation? Music teachers' Perspectives on A Swedish curriculum reform," *British Journal of Music Education*, vol. 32, no. 01, pp. 37–50, 2015.

[3] A. K. Singh, X. Liu, and H. Wang, "Recent advances in multimedia security and information hiding," *TRAnsactions on Emerging Telecommunications Technologies*, vol. 32, no. 2, p. e4193, 2021.

[4] Y. Zhang, Q. He, Y. Xiang et al., "Low-cost and confidentiality-preserving data acquisition for internet of multimedia things," *IEEE Internet of Things Journal*, vol. 5, no. 5, pp. 3442–3451, 2017.

[5] A. de Villiers, "The Transformation of music education: a South African Case study," *British Journal of Music Education*, vol. 32, no. 3, pp. 315–322, 2015.

[6] W. M. William Michael Perrine, "Bauchman v. West high school Revisited: Religious Text and context in music education," *Philosophy of Music Education Review*, vol. 25, no. 2, p. 192, 2017.

[7] A. Ockelford, G. Welch, and S. Zimmermann, "Focus of practice: music education for Pupils with Severe or Profound and Multiple Difficulties — current Provision and future need," *British Journal of Special Education*, vol. 29, no. 4, pp. 178–182, 2015.

[8] X. Gong, Y. Zhu, H. Zhu, and H. Wei, "Chmusic: A Traditional Chinese Music Dataset for Evaluation of Instrument Recognition," 2021, https://arxiv.org/abs/2108.08470.

[9] Y. T. Chen, C. H. Chen, S. Wu, and C. C. Lo, "A two-Step approach for Classifying music genre on the Strength of AHP weighted musical features," *Mathematics*, vol. 7, no. 1, p. 19, 2019.

[10] B. P. Nd, L. Daste, and T. Northern, "Multigenagetional challenges and the future of graduate Medical education," *The Ochsner Journal*, vol. 16, no. 1, p. 101, 2016.

[11] D. E. Myers, "Creativity, Diversity, and integration: Radical change in the Bachelor of music curriculum," *Arts & Humanities in Higher Education An International Journal of Theory Research & Practice*, vol. 15, no. 3-4, pp. 293–307, 2016.

[12] Önder and G. . Cüceoglu, "Classmates' attitudes towards individual musical instrument courses in music education graduate programs in Turkey," *Australian Journal of Teacher Education*, vol. 40, no. 40, p. 12, 2015.

[13] J. Jagodzinski, "The challenges of art education in Designer capitalism: collaborative practices in the (new media) arts," *International Journal of Art and Design Education*, vol. 34, no. 3, pp. 282–295, 2015.
[14] G. Reid and S. P. Norris, "Scientific media education in the classroom and beyond: a research agenda for the next decade," *Cultural Studies of Science Education*, vol. 11, no. 1, pp. 147–166, 2016.
[15] Q. Wang and Z. Mu, "Application of music in relief of driving fatigue based on EEG signals," *EURASIP Journal on Applied Signal Processing*, vol. 2021, no. 1, 2021.
[16] C. Grange and H. Barki, "The nature and role of user Beliefs regarding a website's Design quality," *Journal of Organizational and End User Computing*, vol. 32, no. 1, pp. 75–96, 2020.
[17] Z. Lv, X. Li, and W. Li, "Virtual reality geographical interactive scene semantics research for immersive geography learning," *Neurocomputing*, vol. 254, pp. 71–78, 2017.
[18] Z. Lv and H. Song, "Trust Mechanism of feedback Trust weight in multimedia network," *ACM Transactions on Multimedia Computing, Communications, and Applications*, vol. 17, no. 4, pp. 1–26, 2021.
[19] X. Li, H. Jianmin, B. Hou, and P. Zhang, "Exploring the innovation modes and Evolution of the Cloud-based service using the activity theory on the basis of Big data," *Cluster Computing*, vol. 21, no. 1, pp. 907–922, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 3900615, 12 pages
https://doi.org/10.1155/2022/3900615

Research Article

Metro Engineering Project Schedule Optimization Based on Wireless Network Communication and BIM Model Algorithm

Haidong Jiang,[1,2] Manli Tian ,[3] Yonggui Chen,[2] Guofa Zhang,[4] and Xiaoyong Peng[4]

[1]*Resources and Environmental Engineering, Guizhou Institute of Technology, Guiyang 550003, Guizhou, China*
[2]*Key Laboratory of Geotechnical and Underground Engineering of Ministry of Education, Department of Geotechnical Engineering, Tongji University, Shanghai 200092, China*
[3]*College of Road, Bridge and Architecture, Chongqing Vocational College of Transportation, Jiangjin 402247, Chongqing, China*
[4]*Guizhou Traffic Planning Survey and Design Research Institute Co., Ltd., Guiyang 550081, Guizhou, China*

Correspondence should be addressed to Manli Tian; tianmanli@cqjy.edu.cn

Received 22 April 2022; Revised 24 May 2022; Accepted 31 May 2022; Published 5 July 2022

Academic Editor: Ahmed Farouk

BIM (Building Information Modeling) is to create models based on various related information in construction projects and use simulation virtual technology to model actual building information. It is not only the integration of digital information but also the application of digital information in engineering construction. Digital models can be used to plan and simulate the whole process of construction projects scientifically and accurately. In the process of project construction, wireless network communication technology can provide a good basis for collaboration, which is essential for the control of project progress, task scheduling, and systematic communication between all parties. This article introduces the LTE wireless network communication technology and network coverage plan, summarizes the cost and schedule control principles of construction projects, analyzes the factors that affect the construction schedule in subway construction, and introduces the application of BIM technology in subway construction schedule control. Taking the construction of Section XX of Line 1 of City A as an example, a simulation experiment was carried out, and the optimization effect was evaluated with SPI and CPI indicators. The final experimental results show that it is meaningful to use the BIM model algorithm to optimize the subway project. In the simulation experiment, the corresponding construction period saving rate after completion of the project is 6.94%.

1. Introduction

1.1. Background. Urban rail transit projects are difficult to construct, have high technical requirements, and have huge investments. They are the key investment directions for urbanization. If there is a lack of effective management of engineering projects, it will cause huge economic waste, especially the control of progress. The construction of urban rail transit was originally designed to relieve the pressure of urban traffic, but the construction process will take up a lot of valuable surface transportation lines. If the progress is not effectively controlled, it will aggravate urban traffic congestion. At the same time, due to the large construction area of the subway project, the complex location, and the different signal receiving environments in different places, it is necessary to implement different communication signals laying according to different conditions to meet the full coverage of the signal in the construction area. Therefore, it is necessary to conduct special research on the progress control in the process of urban rail transit construction to reduce the impact on urban traffic to the lowest level.

1.2. Significance. Schedule management has an important position in project management. The quality of subway project schedule control will directly affect the industrial competitiveness of construction companies and their own profitability. Strengthening the control of the construction process is the key to rapid and high-quality construction of subway projects. Therefore, research on the construction period control of shield construction of subway projects has important practical guiding significance. In the construction, the quality and management level can be improved by using wireless network communication technology and BIM technology, and the good implementation of the construction project can be realized. Supported by wireless network information technology and BIM model algorithms, a high degree of information sharing is realized in a collaborative platform, which reduced the ambiguity and prevarication of the parties involved, and improved the efficiency of the parties involved in obtaining schedule information in the construction of subway stations and provided support for schedule control decision-making.

1.3. Relating Work. Ansari has developed a hybrid modeling and algorithm framework to analyze the mutual influence of multiple sources of uncertainty on the quality and robustness of the construction schedule. This model combines variable neighborhood search (VNS) with an event-driven simulation framework. The simulation experiment adopted a dual-objective optimization model to minimize the project completion time and maximize a new agent robustness function at the same time [1]. The sustainability calculation algorithm is indeed very effective in optimizing the project completion time, but generally, such research will ignore the control of project quality and cost, which will lead to the two extremes of the project, either the quality is not good enough, or the cost is high. Most construction simulation tools require an integrated platform to combine with optimization techniques. In order to alleviate these limitations, Salimi et al. developed a simulation-based integrated optimization framework on a high-performance computing (HPC) platform and analyzed its performance through a case, using a master-slave (or global) parallel genetic algorithm (GA) to reduce calculation time and effectively use all capacity [2]. The advantage of the algorithm is that the hardware environment required for the construction of the integrated platform is not high, but the algorithm model has not been used in practical applications, and its true performance is unknown. Houssein et al. proposed a framework that combines building information modeling (BIM) with least squares support vector machine (LSSVM) and nondominated sorting genetic algorithm II (NSGA-II) to study the influence of building envelope structure parameters on building energy consumption and find the best schedule design plan [3]. The combination of the BIM model and the deep learning framework has become a research hot pot because with the help of deep learning models, not only can an adaptive schedule optimization control model be constructed, but also the cost of various human learning and manipulation can be simplified. Hwang et al. compare two sets of projects (implemented BIM and nonimplemented BIM) to assess and compare the current status of rework, as well as the scale and impact of rework divided by project type and source of rework. He also proposed a set of practical strategies to help prevent rework in projects that use fuzzy set theory-based models to implement BIM and greatly improve the efficiency of project construction [4]. According to research, rework is indeed an important factor affecting the construction progress of construction projects. The research is of great significance to the progress control of construction projects, but its model is not well applicable to all types of construction projects. Ajewole et al. studied the performance of Orthogonal Frequency Division Multiplexing (OFDM) free-space optical communication systems under gamma-gamma turbulence channels. Various fluctuations in irradiance and atmospheric turbulence hinder the performance of the system. OFDM-FSO channel adopts two traditional modulation schemes, namely, binary phase-shift keying (BPSK) and M-ary quadrature amplitude modulation (QAM) to reduce the influence of channel damage [5]. The research is mainly aimed at solving the problem of channel damage in signal propagation, and no further solutions are proposed for how to better solve signal interference and improve network throughput. Ma and Liu designed a project schedule control algorithm based on communication strategy and communication strategy and combined the algorithm with BIM to provide a visual overlap planning and dynamic control platform framework. This research is valuable to practitioners because it provides a dynamic overlapping plan [6]. This is a comprehensive plan to control the project process, including communication strategy optimization and BIM model technology, but it is only a plan proposed and not used for empirical analysis.

1.4. Innovation. Construction projects are increasingly developing in the direction of complexity and scale, higher requirements are put forward for the progress control of engineering projects, and the continuous updating of information technology methods creates prerequisites for them. In this paper, the innovations of the research on the schedule optimization of subway projects based on wireless networks and BIM model algorithms are as follows. First is the introduction of LTE wireless network technology and RFID radio frequency identification technology to improve the efficiency of project construction collaboration and the tracking efficiency of building products. The second is to use a series of network congestion control algorithms to solve the signal interference and network congestion problems. The third is to propose a schedule optimization plan that combines communication strategies and project schedule control strategies, and its optimization effect has been confirmed in the article.

2. Metro Project Schedule Optimization Based on Wireless Network Communication and BIM Model Algorithm

2.1. Wireless Network Communication Technology. Wireless network communication refers to a way to achieve communication through wireless protocols, including various fixed, mobile, and portable applications, such as cellular networks, WiFi, and mobile satellite communications that are now widely used [7–9]. For a large-scale project such as subway construction, its engineering control and task scheduling are inseparable from a wireless communication system with strong anti-interference ability and high signal connectivity. The wireless network communication technology involved in this research is introduced below [10, 11].

From a performance point of view, WLAN, EUHT, and LTE can all meet the needs of rail transit vehicle-ground wireless communication. WLAN technology will have a relatively large control information overhead. The application of EUHT technology is advancing, and the technological development is not comprehensive and not stable enough. The application of LTE wireless technology is feasible.

2.1.1. LTE Technology. The principle of LTE technology is mainly based on OFDM and MIMO as the core for wireless communication, which can improve the information transmission rate and spectrum efficiency, and can also allocate spectrum flexibly, which can ensure low communication delay of the system and improve the anti-interference characteristics of the system. The LTE system uses a three-level architecture, namely, the core network, base station, and user equipment. Among them, EPC is the core network part, responsible for UE control and bearer establishment. The network structure of LTE is shown in Figure 1.

3GPP defines two methods for the LTE system, namely, Frequency Division Duplex (FDD-LTE) and Time Division Duplex (TDD-LTE). The comparison between the two is shown in Table 1.

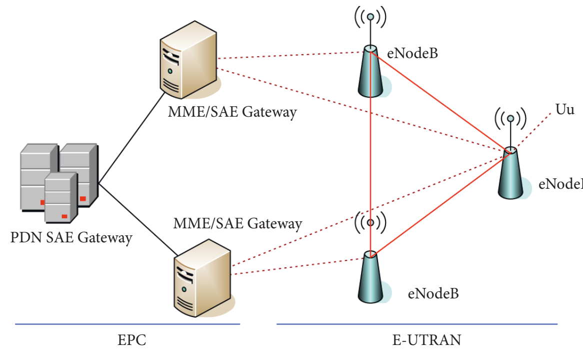


Figure 1: LTE network system structure.

Table 1: Comparison between FDD-LTE and TDD-LTE

	FDD-LTE	TDD-LTE
Working principle	Frequency division duplex	` duplex
Uplink rate	150 Mbps	40 Mbps
Downlink rate	100 Mbps	50 Mbps
Frame structure	10 subframes*2	5 ms half-frames*2
Asymmetric service support	Poor	Preferably

(1) LTE Network Protocol. There are two LTE wireless interface protocols, namely, control plane protocol and user plane protocol. According to the trend of data flow and signaling flow, the LTE protocol structure is composed of four parts: UE, eNodeB, MME, and S-GW. The LTE system architecture is divided into two parts: the evolved core network EPC (MME/S-GW) and the evolved access network E-UTRAN. The evolved system only has the packet switching domain. The LTE access network is only composed of evolved NodeB (evolved NodeB), which provides the termination point of the E-UTRA control plane and user plane protocol to the UE. The LTE network protocol stack is shown in Figure 2.

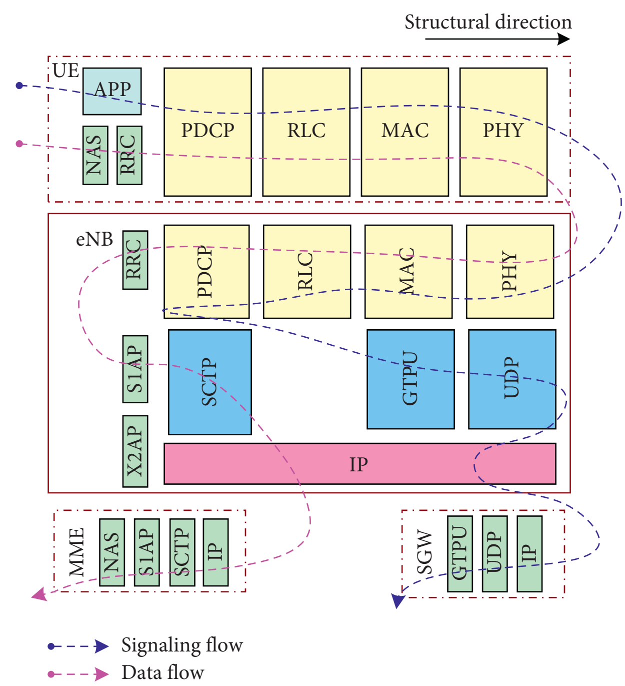


Figure 2: LTE network protocol stack architecture diagram.

(2) OFDM Technology. OFDM uses orthogonality between carriers for data transmission. Compared with the technology used in 3G, it can improve spectrum utilization and save half of the spectrum. OFDM divides the signal source into N subsignal sources and modulates these subsignal sources on N orthogonal subcarriers. In this way, higher spectrum utilization is achieved. OFMD can also solve the problem of multipath fading [12, 13]. OFDM has the following advantages: (1) high spectral efficiency, (2) strong bandwidth expansion, (3) anti-multipath fading, (4) frequency domain scheduling and self-adaptation, and (5) being relatively simple to implement MIMO technology. LTE uses DFT-S-OFDM as the uplink multiple access method, and its schematic diagram is shown in Figure 3.

(3) MIMO Technology. MIMO technology is a multiantenna transmission technology: the base station transmitter transmits multiple data through multiple antennas at the same time, and the receiving section uses multiple antennas to simultaneously receive multiple data streams, and according to the spatial characteristics of each parallel data stream, using demodulation technology, the original data stream is finally restored. Multiple antennas are used at the transceiver end. Compared with the single-transmit-single-receive link of the same bandwidth, the channel resources of

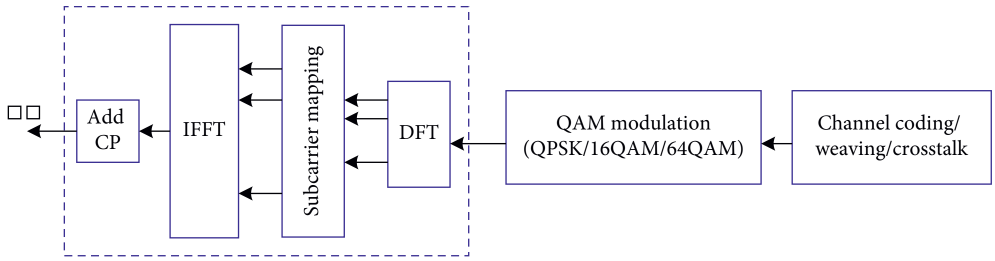


Figure 3: Schematic diagram of LTE uplink multiple access mode.

MIMO are doubled [14]. The form of the MIMO smart antenna is shown in Figure 4.

MIMO technology essentially provides the system with spatial multiplexing gain and spatial diversity gain. Spatial multiplexing technology can greatly increase channel capacity, while spatial diversity can improve channel reliability and reduce the channel error rate. The manifestation of the wireless signal received by the MIMO system is expressed as a mathematical model:

$$E = M * L + A,$$
$$M = \begin{bmatrix} e_1 \\ e_2 \\ \cdots \\ e_{N_r} \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & \cdots & m_{1N_t} \\ m_{12} & m_{22} & \cdots & m_{2N_t} \\ \cdots & \cdots & \cdots & \cdots \\ m_{N_r1} & m_{N_r2} & \cdots & m_{N_rN_t} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ \cdots \\ s_{N_r} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \cdots \\ a_{N_t} \end{bmatrix}. \quad (1)$$

Among them, A is the additive white noise, M is the transmission channel matrix, L is the transmitted signal, and E is the received signal. The transmitter end is equipped with N_t transmitting antennas, and the receiving end is equipped with N_r receiving antennas. s_i represents the signal transmitted by the i-th transmitting antenna, a_j represents the signal received by the j-th receiving antenna, and m_{ij} represents the signal fading coefficient.

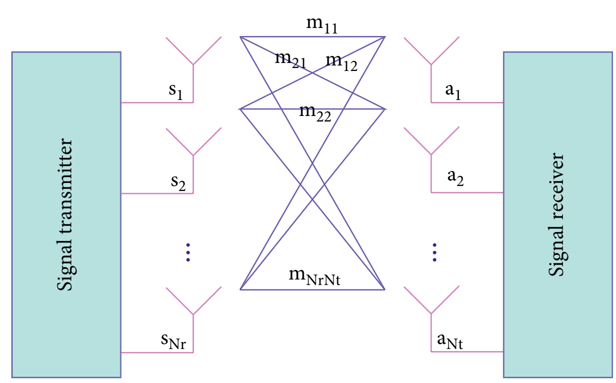


Figure 4: The form of MIMO smart antenna.

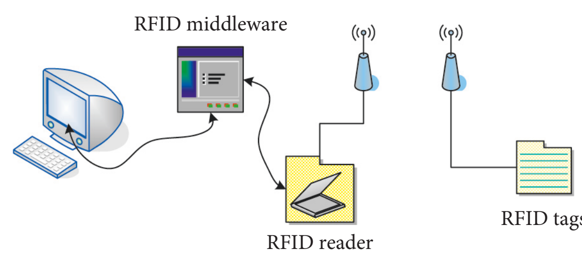


Figure 5: RFID identification system.

2.1.2. Radio Frequency Identification Technology (RFID). Radio frequency identification technology (RFID) is a short-range wireless communication system. It recognizes specific targets through wireless communication signals, does not require mechanical or optical contact with the target, collects corresponding data, and can be applied to the identification and tracking of construction products [15, 16]. RFID technology consists of four parts: RFID tags, RFID readers, supporting software, and RFID application software systems, as shown in Figure 5.

The technical principle is as follows: the electronic tag receives the radio frequency signal sent by the reader in the magnetic field, the energy is obtained by the induced current, and the reader collects relevant information stored in the internal chip of the electronic tag. The reader sends the collected information to the central processing unit for the processing to deal with.

In more complex and large-scale construction projects, RFID technology can be used to establish a material management tracking system model to track the material storage location and dispatch method of the construction site and improve construction efficiency. In the system supported by information tools, the workload is greatly reduced, saving labor costs for enterprises, and bringing great convenience to construction enterprises.

2.1.3. Wireless Network Congestion Control Algorithm. A major problem of wireless networks is channel interference [17–19]. Excessive channel interference will reduce the quality of network transmission and aggravate the congestion of each transmission node, which is also causing network congestion. In addition to channel interference, node load and link load are also factors that cause network congestion. Considering dividing the degree of congestion from the above three aspects:

$$CCM = \omega_1 \sum LN_i + \omega_2 \sum LL_i + \omega_3 \sum LC_i. \quad (2)$$

LC_i, LL_i, and LN_i, respectively, indicate the degree of channel interference, link load degree, and node load degree. ω_1, ω_2, and ω_3 are the weights of network congestion caused by node load, link load, and channel interference, and their sum is 1.

According to the transmission rate of the node in the wireless network, the expected transmission time (ETT) and the expected number of transmissions (ETX), the load degree of the node, the load degree of the link, and the interference degree of the channel can be quantified.

In the wireless network transmission queue, the load of any node is associated with its previous-hop node and next-hop node. The load degree of node i can be represented by the length of the transmission queue of the node. The congestion degree of all nodes on each transmission path is

$$LN_i = ETX_i * \frac{Q_i + \sum r_j \cdot ETT_j - \alpha \sum r_n \cdot ETT_n}{r_i}. \tag{3}$$

Q_i represents the length of the waiting transmission queue of node i. r_j is the receiving rate of node i. r_n is the potential receiving rate of the next node of node i. α is the latent factor, and the value is 0 or 1. r_i is the sending rate of node i.

There are different limit rates for the sending rate of nodes. Assuming that the node's limit sending rate is R_i, then the limit formula is

$$\lim_{\substack{r_i \longrightarrow R_i \\ \sum r_j \cdot ETT_{j \longrightarrow N}}} \frac{Q_i + \sum r_j \cdot ETT_j - \alpha \sum r_n \cdot ETT_n}{r_i} * ETT_n = M. \tag{4}$$

When the rate of node i approaches the limit rate, because the load value N from the previous node is too large, the limit approaches a value M much larger than ETT_i. At this time, no matter how to adjust the sending rate or the potential factor, it will cause congestion.

When $\alpha = 0$, transmission at normal speed r_i can meet the time:

$$\begin{aligned} \frac{Q_0 - Q_i + \sum r_j \cdot ETT_j}{r_i} &= ETT_i, \\ Q_0 &= ETT_i * r_i + Q_i - \sum r_j \cdot ETT_j. \end{aligned} \tag{5}$$

At this time, the queue occupancy rate is

$$P_0 = \frac{Q_0}{Q}. \tag{6}$$

When $\alpha = 0$, transmission at the limit rate R_i can meet the time:

$$\begin{aligned} \frac{Q_1 - Q_i + \sum r_j \cdot ETT_j}{R_i} &= ETT_i, \\ Q_1 &= ETT_j * R_i + Q_i - \sum r_j \cdot ETT_j. \end{aligned} \tag{7}$$

At this time, the queue occupancy rate is

$$P_1 = \frac{Q_1}{Q}. \tag{8}$$

When $\alpha = 1$, transmission at the limit rate R_i can meet the time:

$$\begin{aligned} \frac{Q_2 - Q_i + \sum r_j \cdot ETT_j - \alpha \sum r_n \cdot ETT_n}{R_i} &= ETT_i, \\ Q_2 = ETT_i * R_i + Q_i - \sum r_j \cdot ETT_j + \alpha \sum r_n \cdot ETT_n&. \end{aligned} \tag{9}$$

At this time, the queue occupancy rate is

$$P_2 = \frac{Q_2}{Q}. \tag{10}$$

When $P_i < P_0$, it means that the node has a good transmission status. When $P_0 < P_i < P_1$, it means that the transmission rate can be adjusted appropriately to ensure transmission. When $P_1 < P_i < P_2$, it means that the potential next node needs to be scheduled to ensure transmission quality. When $P_i > P_2$, it means that the node is heavily congested and the routing link needs to be reselected.

The link load level LL_i can be measured by the load transmission capacity of the link:

$$\begin{aligned} LL_i &= \frac{Q_{ij}}{R_i - M} * ETX_{ij}, \\ M &= \sum_{k \in N_i} R_{ik}. \end{aligned} \tag{11}$$

$$R_i - M = 2R_0 \tag{12}$$

R_i represents the total transmission rate. R_{ik} represents the actual shunt rate. Q_{ij} represents the total amount of information to be transmitted from node i to j. ETX_{ij} represents the expected number of transmissions from i to j. N_i is the next node of node i. When the value of M keeps increasing, it will cause congestion. In order to avoid this problem, it can be stipulated that when in the state of formula (12), congestion handling must be adopted, and R_0 is the minimum transmission rate of node i.

The channel interference level LC_i can be expressed as

$$\begin{aligned} LC_i &= CST_i + \underset{k \in N_k}{MAX} \left\{ \frac{\gamma}{d_k} * LCIT_k \right\}, \\ LCIT_k &= \sum_{k \in N_k} ETTk. \end{aligned} \tag{13}$$

γ is the channel interference factor. d_k is the interference distance of each interfering link. $LCIT_k$ is the link channel interference time. CST_i is the channel switching time. When LC_i increases, excessive channel interference will cause serious network congestion. Therefore, a limit value must be set. When the channel interference is close to the limit value, congestion processing must be adopted.

2.2. Comprehensive Target Forecast Model of Engineering Project Progress

2.2.1. Statistical Forecasting Method. The influencing factors of the project schedule should be regarded as random variables, and each activity factor obeys its own probability distribution. Project management personnel can carry out risk analysis and effective control close to the actual project schedule, time, resources, and costs. The reliability method of the construction schedule is to regard the various variables that affect the construction schedule as random variables, such as human factors, material supply, capital supply, technical level, management level, construction conditions and environment, design changes, and risk factors. And the laws of these complex variables can be studied by probability and statistics methods [20]. In actual engineering, the impact of construction schedule is a complex issue, and actual schedule prediction may involve a variety of complex probability distribution methods, such as normal distribution, logarithmic distribution, and exponential distribution. The probability density curve and function curve of the standard normal distribution are shown in Figure 6.

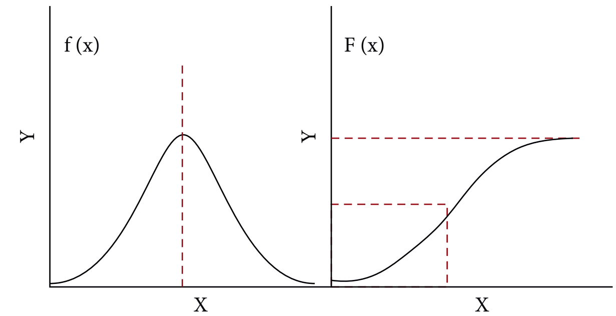


Figure 6: Standard normal distribution probability density curve and function curve.

2.2.2. Basic Relational Model. For engineering projects, under certain constraint conditions, consider the interrelationship between the goals, establish a multiobjective collaborative optimization model, effectively implement project goal control, and achieve the shortest schedule, the lowest cost, the highest quality, and other goals and the best overall system. The overall structure is shown in Figure 7.

(1) Cost-Schedule Relationship Model. Costs include direct costs and indirect costs. The direct cost is the sum of the direct cost required to complete the various activities of the project; the indirect cost includes the salary of the management staff, office expenses, etc. Direct costs increase with the shortening of the schedule, and indirect costs increase with the continuous increase of activities. The relationship between cost and schedule is the superposition of the above two relationships, and the graph is shown in Figure 7(a).

(2) Quality-Schedule Relationship Model. In the construction of engineering projects, as the duration is compressed, the quality of activities is affected, and different completion times result in different degrees of quality. The activity corresponds to the normal construction quality (z_{i0}) under the normal duration x_{i0} and corresponds to the accelerated construction quality (z_{im}) under the limit time x_{im}. The quality-schedule change curve of the activity is obtained, as shown in Figure 7(b).

2.3. BIM Model Engineering Project Schedule Forecast Integrated System. The BIM model can realize the digital information and visual expression of the physical and functional characteristics of the project. In the implementation of BIM technology, various model information is shared through the data information resource platform. And the application of BIM technology runs through the entire life cycle of decision-making, design, construction, operation and maintenance, and collaborative work and management. The computer-integrated architecture of BIM and construction schedule prediction model is shown in Figure 8.

The application of BIM in the preparation of the schedule is essentially the addition of a four-dimensional construction simulation function on the basis of the three-dimensional model. Relevant tasks decomposed by the project schedule can be automatically associated with BIM software, and engineering simulations can also be carried out before construction. The visualization of the project schedule information and construction process helps to predict and judge possible problems in advance, thereby improving the schedule plan. The introduction of BIM technology has a major impact on the schedule optimization of engineering projects, which is mainly reflected in the visualization of schedule control, abundant information, improving schedule management efficiency, and optimizing process control.

2.4. Construction Schedule Optimization Model Based on Wireless Network Communication and BIM Model Algorithm. The BIM schedule optimization management first requires the preparation of the overall schedule plan, including design models, statistical engineering quantities, determination of the construction period, and start and completion time to form a BIM 4D model. The second is the preparation of the secondary schedule plan, using WBS work structure analysis, defining the working space, linking the construction drawing budget and the associated list model, determining the schedule-cost model, and obtaining the consumption of labor, materials, machinery and equipment, and funds. Then, the weekly schedule is prepared with LPS (LPS is a final planning system that can provide refined management and lean operation solutions and decompose tasks according to the contract duration) as the core, and the heads of each group will work together to refine and decompose the tasks, reasonably carry out BIM construction simulation, determine the important and difficult points of the project, and carry out prefabrication to ensure the implementation of the plan. The last is the formulation of daily work, including material supply, quality acceptance, daily work report, problem-solving, and adjustment [21, 22].

Considering that the subway construction is more complicated and the amount of work is compared with the traditional building construction, and the traditional schedule control system is difficult to adapt to the construction of the subway project, this paper chooses the modular construction mode. A construction schedule optimization model based on wireless network communication technology and the BIM model algorithm is established for

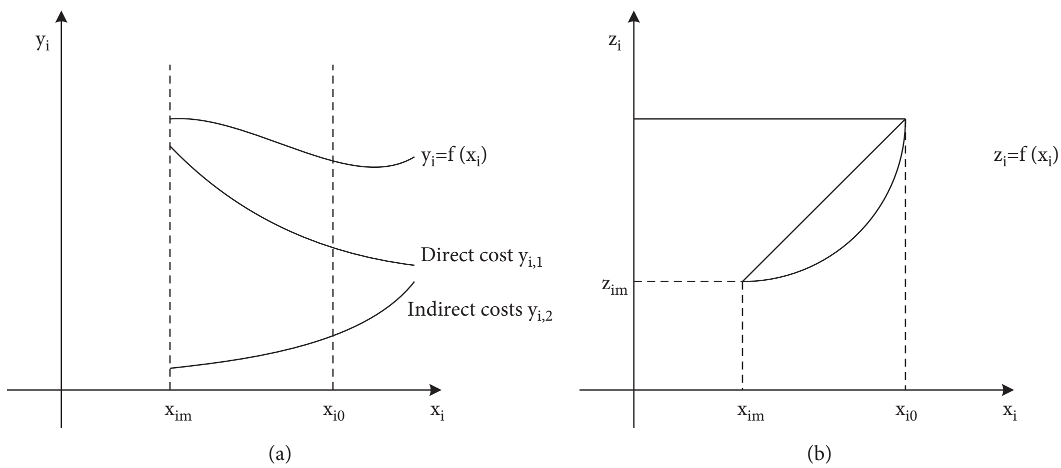


Figure 7: Basic relational model.

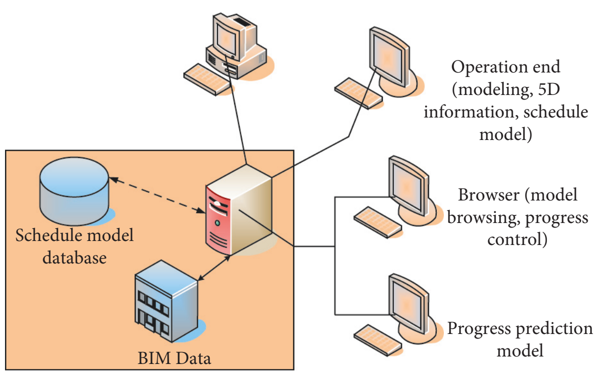


Figure 8: BIM project schedule prediction model.

the three aspects of the optimization of information acquisition quality, the optimization of personnel task scheduling, and the optimization of quality control in the modular construction of subway stations. The specific physical model is shown in Figure 9.

The introduction of the BIM collaboration platform can predict possible problems in the project in advance through virtual construction simulation and reduce conflicts and collisions and help professional engineers to optimize the design plan. LTE wireless network communication technology can ensure the communication environment of the project and improve various tasks' coordination of progress. RFID can collect construction progress information in time and transmit it to the BIM platform and then show the deviation between actual progress and planned progress in the BIM model.

3. Metro Engineering Project Schedule Optimization Model Test and Scheme Verification Based on Wireless Network Communication and BIM Model Algorithm

3.1. A Summary of the Subway Traffic Engineering Project of Line 1 in City A. Metro Line 1 of City A is the only circular metro line with the longest line and the most cross-transfer metro lines in the metro line planning of the city where it is located. The total length is 38 km, all of which are underground lines. There are a total of 25 stations, including 4 transfer stations, all of which are located in the main urban area of city A. Take the XX depot as an example. The depot is responsible for parking, cleaning, daily inspections, technical management, and crew work of the attached vehicles. The main engineering content of the vehicle scope includes earthwork engineering, foundation treatment engineering, track engineering, power lighting, fire-fighting drainage, and ventilation engineering. The main project quantity table is shown in Table 2. The major and difficult points of the construction of this project are as follows: it involves many professional fields, strong professionalism, and high requirements on the construction ability of the construction unit, and the construction procedures are easy to affect each other and slow down the progress. The project volume is relatively large, and there are many topics involved. It is necessary to scientifically and rationally plan the procedures of various professional projects and strengthen on-site coordination within the specified construction period.

3.2. Simulation Application of LTE Wireless Network Communication in Schedule Optimization of Subway Engineering Projects

3.2.1. Wireless Network Design

(1) Wireless Coverage Design. Design the wireless communication coverage during the construction process of the A city subway Line 1 project. Setting up base station equipment and radio frequency units in the constructed stations, the radio frequency units are deployed in the track tunnel near the leaky cable, and the base station equipment is deployed in the station of the communication equipment room, which can guarantee the coverage of wireless signals to the greatest extent.

(2) Link Budget Design. In the urban subway transportation wireless communication system, a dual-network structure of 5 Mhz for A network and 15 Mhz for B network is generally adopted. When adapting to radio frequency units with the

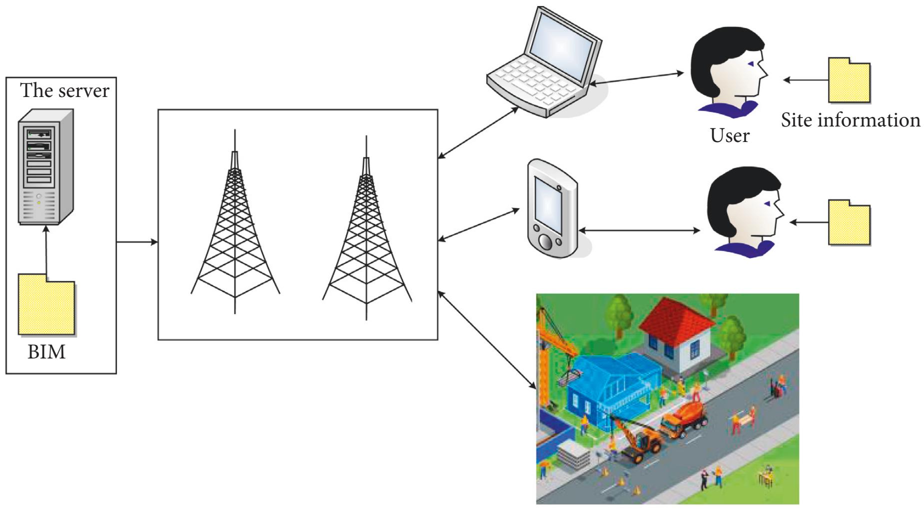


Figure 9: Physical model of construction schedule optimization.

Table 2: Number of main projects.

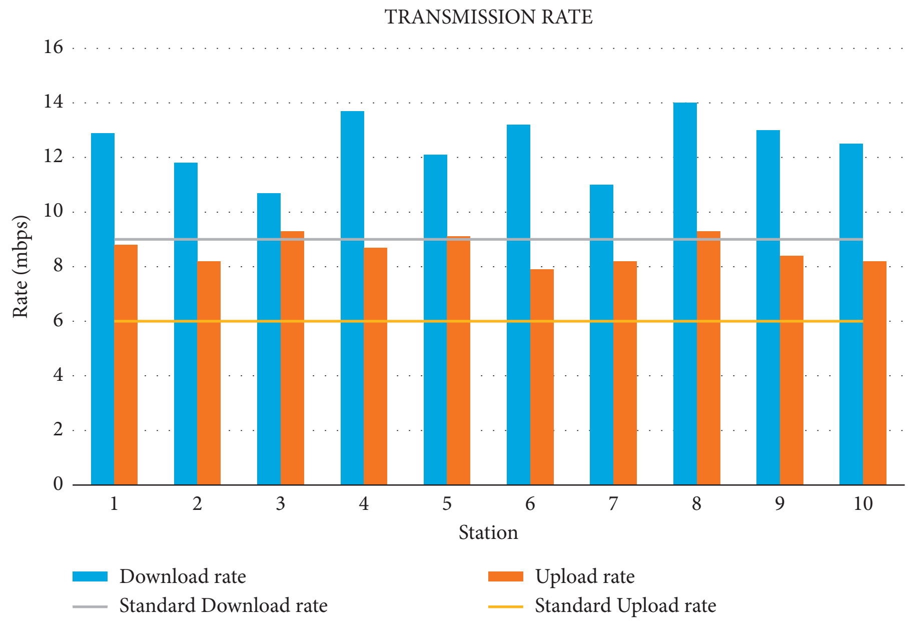
	Engineering	Unit	Quantity
Earthwork engineering	Excavation Fill Desilt Subgrade earthwork	m^3	612977 835820 698211 931880
Foundation treatment engineering	Precast concrete pipe pile Track jet grouting pile	m	105523 138480
Track engineering	Track laying Lay a railway track Integral track bed Gravel track bed	km Group m^3 m^3	7.9 28 964 12869
—	Dynamic lighting Fire-fighting Drainage Ventilation works	m^2	156800

Table 3: Link calculation table within the construction section of LTE subway project.

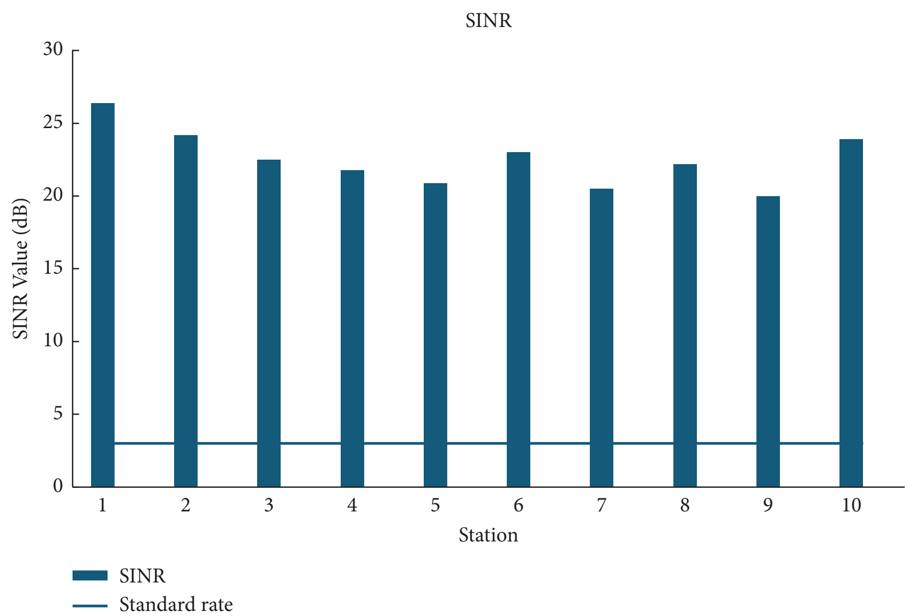
Channel type	A uplink	A downlink	B uplink	B downlink
System broadband (MHZ)	6		15	
MIMO	1*2	2*2SFBC	1*2	2*2SFBC
Maximum total transmit power (DBM)	26	52	25	52
Subcarrier transmission power (DBM)	−1.2	23.4	−6.63	18.82
Feeder loss (DB)	0	6	0	6

same power, network A is larger than network B with regard to the transmission power of subcarriers, and the coverage of the network with higher transmission power is also relatively larger. When performing link calculations, network B should be used as a reference. The calculation of wireless links in the tunnel scenario can be shown in Table 3. The use of this link design scheme is reasonable and can reduce the number of equipment in the station section and reduce costs.

(3) Anti-Interference Design. The anti-interference system of the wireless communication network will mainly be applied to the network congestion control algorithm mentioned above. Since the subway LTE system used is closer to the frequency band of the civil mobile communication system, the design of the same frequency anti-interference solution and the solution to the multipath interference problem are more important [23, 24]. When designing the corresponding scheme, the last part of the OFDM symbol can be copied and inserted into the starting position. At this time, certain continuous orthogonality can be maintained between the subcarriers, which will avoid interference to a greater extent. Because this is equivalent to adding a cyclic prefix, if the cyclic prefix is always longer than the service signal delay, continuous orthogonality can be guaranteed.

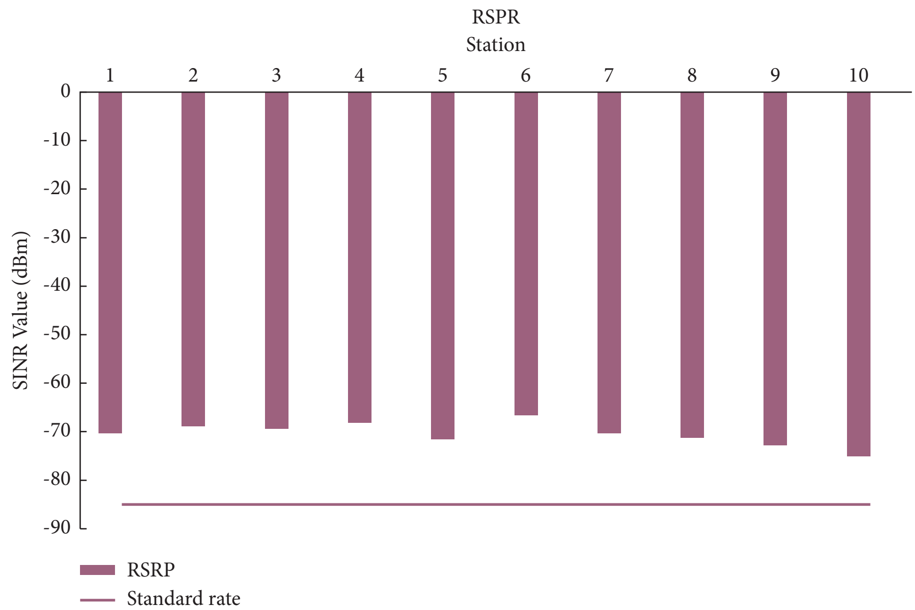


(a)



(b)

Figure 10: Continued.



(c)

Figure 10: Wireless communication test results. (a) Transmission rate. (b) SINR. (c) RSPR.

3.2.2. Wireless Communication Result Test. The wireless communication network system of this project was tested, and 10 station construction points on Line 1 of City A were randomly selected and numbered 1~10. The test indicators include the download rate, upload rate, SINR value, and RSRP value of each station construction module. SINR refers to the ratio of the strength of the received useful signal to the strength of the received interference signal (noise and interference); it can be simply understood as the "signal-to-noise ratio". RSRP is the reference signal received power, which can represent the signal strength, and is the average value of the signal power received on all REs (resource particles) that carry the reference signal in a certain symbol in the LTE network. The test result is shown in Figure 10. The qualified values have been marked with horizontal lines in the figure, and the index evaluation values are RSRP > −85 dBm, SINR > 3 dB, download rate > 9 Mbps, and upload rate > 6 Mbps. It can be concluded that the test results of various index values are greater than expected values, and the signal conversion between 10 stations is normal. The data obtained from this test proves that the application of LTE to the wireless communication of subway project construction can meet the system requirements.

3.3. The Application Benefit of BIM in XX Road Section Construction Schedule Optimization. First carry out temporary site layout, civil engineering, and electromechanical modeling of the project, import the deepened model into the BIM application platform, then import the construction schedule into the platform, and associate the construction model to simulate and analyze the construction process. In addition, it is necessary to import a budget file, associate the three-dimensional model with it according to the project quantity, check the compatibility of the list and the schedule plan, and realize the collaborative management of the construction schedule and cost. According to the overall construction schedule plan, determine the key routes and work, comprehensively consider the resource constraints, formulate hierarchical monthly schedules and weekly schedules, and arrange daily work schedules to achieve effective control of the construction schedule and refined construction management to improve project profit and industry informatization level [25, 26]. Autodesk Autocad and Autodesk Revit 2016 are used for temporary site layout, civil engineering, and electromechanical modeling; Fuzor, Lumion, and Naviswork are used for roaming, construction simulation, and construction animation production. The evaluation of the schedule optimization of a subway project cannot only rely on the index of how much the schedule has been optimized but also comprehensively analyze the cost index of the method. Therefore, this article uses the schedule performance index SPI and the cost performance index CPI to evaluate the level of the project's use of BIM technology management to optimize the construction schedule.

The progress performance index SPI represents the ratio of earned value to planned value, that is, the ratio of the completed work budget to the planned work budget. When SPI is greater than 1, the progress is advanced, and less than 1 is the delay. The cost performance index CPI is the ratio of the budget cost of the completed work to the actual cost of the completed work (total of direct and indirect costs). A CPI value less than 1 indicates that the actual cost exceeds the budget, and a CPI value greater than 1 indicates that the actual cost is lower than the budget. The actual value can be obtained by directly selecting the time point on the BIM platform, and the earned value can be obtained by multiplying the percentage value of the project completion

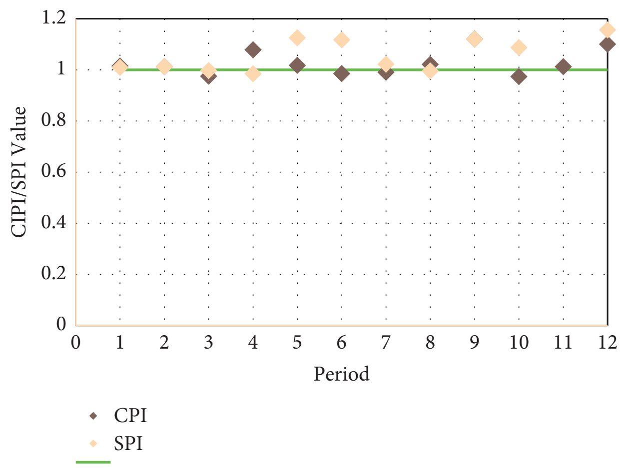


Figure 11: Cost and schedule performance indicator statistics.

amount by the completion budget. It took 24 months from the actual start to completion of the XX section of the project. The actual completion time of the project was divided into 12 cycles, two months as a cycle, and the CPI and SPI values were counted. The results are shown in Figure 11. It can be seen that the CPI value and SPI value of most cycles are greater than 1, indicating that the project has been optimized in terms of cost and time.

The XX section subway station project lasted 24 months in total. After the completion of the project, it was concluded that the construction period was shortened by 50 days, the construction period saving rate was 6.94%, and the engineering cost-saving rate was 1.63%, indicating that the project goal was completed ahead of schedule and not exceeded according to the original plan original budget. And from the perspective of overall quality and safety management, the project can reasonably control the progress, organize the work in an orderly manner, maximize the use of resources, strictly control the quality links, and meet the acceptance standards.

4. Discussion

This paper takes the optimization of the subway project schedule as the main research object, takes LTE wireless network communication technology and BIM model technology as the main technical support, and takes the cost control and schedule control theory of construction engineering as the theoretical support. It deeply studies the modular construction of subway stations' schedule optimization problem of modular construction. The article first summarizes the relevant research background and research significance of the development background of BIM technology and the role of wireless network information technology in the construction of engineering projects and summarizes the research results of predecessors on project schedule optimization and the significance of their research to the realization of this paper. Secondly, some professional theoretical knowledge and methodology that the article may or should be involved in are elaborated, such as LTE wireless network communication technology and its key technologies (MIMO technology and OFMD technology). Some solutions are proposed for the interference and congestion problems that may occur in the communication process. We introduce the comprehensive predictive control models of engineering projects, such as statistical forecasting methods, cost-schedule and quality-schedule relationship models, and description of the BIM model engineering project schedule forecast integrated system. The construction schedule optimization model based on the wireless communication network and BIM model algorithm is designed in this paper. Finally, it is the simulation test part of the scheme. With the subway traffic engineering project of Line 1 in City A as the main test object, a specific wireless coverage scheme for the thread project is designed and tested. The results verify that the scheme has a good effect. The anti-interference ability and the ability to deal with network congestion have good real-time performance, which can fully meet the task scheduling and communication needs during the construction period. Using SPI and CPI as performance indicators, the construction status of the XX section of Line 1 in City A was evaluated. Under this plan, the simulation experiment results showed that the introduction of the BIM model can save the construction period and the cost did not exceed expectations.

5. Conclusions

Based on the foundation of BIM technology and wireless network communication technology, this paper proposes an integrated system for predicting and optimizing the utilization of subway project construction schedule and explores the integration method between subway project construction schedule prediction model and construction management system in BIM technology. This method can identify the factors that affect the completion schedule of any subway project, predict the schedule, quantitatively analyze the actual completion prediction, automatically modify the actual completion schedule in the BIM technology foundation, analyze the deviation from the schedule, and modify the subsequent schedule plan. Wireless network communication technology plays an important role in improving the collaboration and real-time and scientific nature of the construction of engineering projects. The technology application research in BIM has been expanded and deepened, thereby improving the scientific accuracy of predicting short-term progress and general risks, and improving refined management and scientific management of engineering projects has been achieved. Judging from the results of the simulation experiment, the scheme proposed in this paper is not excellent in cost-saving, but there is still some research progress in schedule optimization. However, because of the limited research content of this article, the application analysis of BIM in various aspects of schedule control, such as cost and quality control, is still limited. In the future, BIM technology will be further combined with modern advanced information technology.

Data Availability

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

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Acknowledgments

This work was supported by the research on the application of BIM in the whole life cycle of urban rail transit (Foundation of Guizhou Science and Technology cooperation (2019) No. 1420) and the special projects for promoting the development of big data of Guizhou Institute of Technology and funded by Geological Resources and Geological Engineering, Guizhou Provincial Key Disciplines, China (ZDXK [2018]001).

References

[1] R. Ansari, "Dynamic optimization for analyzing effects of multiple resource failures on project schedule robustness," *KSCE Journal of Civil Engineering*, vol. 25, no. 5, pp. 1515–1532, 2021.

[2] S. Salimi, M. Mawlana, and A. Hammad, "Performance analysis of simulation-based optimization of construction projects using High Performance Computing," *Automation in Construction*, vol. 87, no. MAR, pp. 158–172, 2018.

[3] E. H. Houssein, M. R. Saad, K. Hussain, W. Zhu, H. Shaban, and M. Hassaballah, "Optimal sink node placement in large scale wireless sensor networks based on harris' hawk optimization algorithm," *IEEE Access*, vol. 8, no. 99, pp. 19381–19397, 2020.

[4] B. G. Hwang, X. Zhao, and K. W. Yang, "Effect of BIM on rework in construction projects in Singapore: status quo, magnitude, impact, and strategies," *Journal of Construction Engineering and Management*, vol. 145, no. 2, Article ID 04018125, 2019.

[5] B. D. Ajewole, K. O. Odeyemi, K. O. Odeyemi, P. A. Owolawi, and V. M. Srivastava, "Performance of OFDM-FSO communication system with different modulation schemes over gamma-gamma turbulence channel," *Journal of Communications*, vol. 14, no. 6, pp. 490–497, 2019.

[6] G. Ma and X. Liu, "Model and algorithm for dependent activity schedule optimization combining with BIM," *Advances in Civil Engineering*, vol. 2020, no. 10, pp. 1–14, 2020.

[7] N. Veeraiah and O. C. V. P. R. Y. A. S. A. N. Ibrahim Khalaf, "Trust aware secure energy efficient hybrid Protocol for MANET," *IEEE Access*, vol. 9, pp. 120996–121005, 2021.

[8] G. M. Abdulsahib and O. I. Khalaf, "An improved cross-layer proactive congestion in wireless networks," *International Journal of Advances in Soft Computing and Its Applications*, vol. 13, no. 1, pp. 178–192, 2021.

[9] F. Zhu, C. Zhang, Z. Zheng, and A. Farouk, "Practical network coding technologies and softwarization in wireless networks," *IEEE Internet of Things Journal*, vol. 8, no. 7, pp. 5211–5218, 2021.

[10] M. Ai, P. Wang, and W. Ma, "Research and application of smart streetlamp based on fuzzy control method," *Procedia Computer Science*, vol. 183, no. 4, pp. 341–348, 2021.

[11] Q. Li and N. Liu, "Monitoring area coverage optimization algorithm based on nodes perceptual mathematical model in wireless sensor networks," *Computer Communications*, vol. 155, no. Apr, pp. 227–234, 2020.

[12] M. Mancini, X. Wang, M. Skitmore, and R. Issa, "Editorial for IJPM special issue on advances in building information modeling (BIM) for construction projects," *International Journal of Project Management*, vol. 35, no. 4, pp. 656-657, 2017.

[13] A. Salem and M. M. A. Azim, "The effect of RBCs concentration in blood on the wireless communication in Nano-networks in the THz band," *Nano Communication Networks*, vol. 18, no. DEC, pp. 34–43, 2018.

[14] T. W. Hazlett, S. Oh, and B. Skorup, "Mobile phone regulation: the effects of prohibiting handset bundling in Finland," *Journal of Competition Law and Economics*, vol. 14, no. 1, pp. 65–90, 2018.

[15] M. Stelzer, N. Radoncic, P. L. Iserte Llacer, and A. M. Tatar, "BIM processes and workflows using the example of the subway extension in Stockholm," *Geomechanics and Tunnelling*, vol. 11, no. 4, pp. 340–347, 2018.

[16] J. . Cui, "Model research of project schedule management system based on particle swarm optimization algorithm," *Revista de la Facultad de Ingenieria*, vol. 32, no. 15, pp. 122–127, 2017.

[17] A. F. Subahi, Y. Alotaibi, O. I. Khalaf, and F. Ajesh, "Packet drop battling mechanism for energy aware detection in wireless networks," *Computers, Materials & Continua*, vol. 66, no. 2, pp. 2077–2086, 2020.

[18] C. Li, S. Zhang, P. Liu, F. Sun, J. M. Cioffi, and L. Yang, "Overhearing protocol design exploiting intercell interference in cooperative green networks," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 1, pp. 441–446, 2016.

[19] B. Han, J. Li, J. Su, and J. Cao, "Self-supported cooperative networking for emergency services in multi-hop wireless networks," *IEEE Journal on Selected Areas in Communications*, vol. 30, no. 2, pp. 450–457, 2012.

[20] D. Ding, "Deformation detection model of high-rise building foundation pit support structure based on neural network and wireless communication," *Security and Communication Networks*, vol. 2021, no. 4, pp. 1–10, 2021.

[21] H. Zhou, K. Liu, D. Zhou, W. G. Qiao, Y. Y. Yang, and X. T. Zhang, "Project construction process optimization management based on BIM modelling technology," *IPPTA: Quarterly Journal of Indian Pulp and Paper Technical - A*, vol. 30, no. 7, pp. 360–370, 2018.

[22] X. J. An, J. F. Song, J. Wei, Y. M. Zhang, and Y. X. Su, "Total hip arthroplasty for post-traumatic arthritis after internal fixation of acetabular fracture," *Revista de la Facultad de Ingenieria*, vol. 30, no. 3, pp. 233–235, 2017.

[23] W. Hong, Z. H. Jiang, C. Yu, and J. P. Z. H. B. X. M. Y. M. K. T. Y. J. S. Zhou, "Multibeam antenna technologies for 5G wireless communications," *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 12, pp. 6231–6249, 2017.

[24] S. K. Sharma, T. E. Bogale, L. B. Le, and S. X. B. Chatzinotas, "Dynamic spectrum sharing in 5G wireless networks with full-duplex technology: recent advances and research challenges," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 1, pp. 674–707, 2018.

[25] P. Gandotra and R. K. Jha, "A survey on green communication and security challenges in 5G wireless communication networks," *Journal of Network and Computer Applications*, vol. 96, no. oct, pp. 39–61, 2017.

[26] L. Chettri and R. Bera, "A comprehensive survey on internet of things (IoT) toward 5G wireless systems," *IEEE Internet of Things Journal*, vol. 7, no. 1, pp. 16–32, 2020.

Hindawi
Scientific Programming
Volume 2022, Article ID 2465095, 10 pages
https://doi.org/10.1155/2022/2465095

Research Article

Practical Skills of Business English Correspondence Writing Based on Data Mining Algorithm

Danqing Liu[1,2] and Hadina Habil[1]

[1]*Language Academy, Universiti Teknologi Malaysia, Johor Bahru 81310, Johor, Malaysia*
[2]*School of English Language and Literature, Xi'an Fanyi University, Xi'an 710105, Shaanxi, China*

Correspondence should be addressed to Danqing Liu; liudanqing@xafy.edu.cn

Received 14 February 2022; Revised 21 March 2022; Accepted 1 June 2022; Published 4 July 2022

Academic Editor: Ahmed Farouk

English correspondence writing has become a necessary skill for every scientific researcher and high-tech talents. An English correspondence writing auxiliary writing system can help nonnative English speakers make up for the lack of professional expression. The key factor of business English correspondence writing system is the construction of knowledge base. To improve the business English correspondence writing knowledge base, we need to mine frequent patterns of sentences in each category. The purpose of this topic is to improve and supplement the knowledge base for the business English correspondence writing system and propose frequent pattern mining for sentences in each category, so as to improve the writing knowledge base for the business English correspondence writing system. Firstly, we crawl a large number of business English letters and telegrams from the Internet, extract the relevant summary information, then store it, and preliminarily construct a corpus based on sentences. Then, we do some research on the structure of business English correspondence abstracts, mark the sentences in the corpus and count the relevant information, and have a certain understanding of their writing methods. Finally, we mine frequent patterns for sentences in each category, so as to improve the knowledge base of summary writing for the business English correspondence writing system. In the experiment, we use the classical FP growth algorithm as the mining method. The experiment shows that the frequent patterns between 3 and 6 words have been mined to a certain extent. By gradually improving the mining strategy, the quality of mining results has been improved and the writing effect of business English correspondence of scientific researchers has been improved.

1. Introduction

With the growth of productivity and economy, more and more people begin to devote themselves to various scientific research in modern society, followed by the increasing number of papers, journal meetings, and papers published [1]. According to the research, the process of writing scientific research results into papers is more painful than theoretical derivation and experimental analysis. Similarly, students studying for a degree in China also have the need to publish papers. For nonnative English speakers, it is more difficult to write English papers. They are not only faced with the problem of how to express the experimental results clearly but also faced with problems such as English expression. To solve the above problems, this paper attempts to write with the latest frequent mining pattern [2]. The goal of natural language generation task is to enable the machine to express and create on the basis of understanding text, numbers, structured data, charts, and other data. Therefore, we should focus on how to effectively serve users with automatic text generation technology in a systematic form. Under the above background, it is a pioneering attempt to apply the relevant technologies of English correspondence writing auxiliary writing system to the applied thesis writing system, which can effectively improve the quality and efficiency of thesis writing. This paper studies the automatic text generation system based on the nature-oriented English correspondence writing auxiliary writing system [3]. Based on a large amount of paper data in the field of scientific and technological papers, with the help of deep learning model, the system uses document summary algorithm, graph structure based text generation algorithm, word vector algorithm, and text editing algorithm, and the user's writing experience can be improved from two aspects: automatically generating paper content and providing word suggestions. At the same time, in view of the continuous generation of new papers and the update of natural language generation model, the system provides a functional module for sustainable data capture and supports the iterative update of generation model. The system also provides a background management module for managing paper data and generating model, which provides strong support for the maintenance of the system. Based on the basic data of scientific and technological papers, the system designs a series of text generation models for paper writing, which can help users quickly and conveniently generate paper titles, abstracts, and touch-up sentences and reduce users' writing burden [4, 5]. The scientific contribution is the construction of the corpus. Since there is no ready-made corpus for writing abstracts of scientific papers, we need to build a corpus by ourselves. The main work includes web crawling, abstract information extraction of papers, corpus preprocessing, corpus research, and corpus labeling and storage. This work not only lays the groundwork for the follow-up work but also lays the foundation for other related works in the future. The system provides a user-friendly interaction mode, so that users can concentrate more on writing and provide work efficiency, as shown in Figure 1.

2. Literature Review

In the process of human-computer interaction, auxiliary writing system is a very broad concept. Kirubha and others found that many famous software can be classified into the category of auxiliary writing system, such as "MS Word" of Microsoft Corporation of the United States, "WPS" of China Kingsoft Corporation, and writing assistance software [6]. The original research orientation of natural language education is based on rule and conditional probabilities. Markov models are more representative. The Markov model regards the language generation process as different sequence states, calculates the transition direction of the next generation state based on the current word, and predicts the next word in the text in turn. However, with the in-depth research and theoretical development, especially in the 21st century, with the significant improvement of computer ability, learning natural language based on deep learning technology has gradually matured. In 2013, Wang and others proposed the word2vec algorithm and a bag-of-words model was constructed using neural network, and the word vector representation of the target language was calculated according to the context word distribution of the target language in a large-scale corpus [7]. Word2vec algorithm completes the transformation from text representation to static number vector. The algorithm maps words with similar meanings to the same region of the vector space and helps the computer understand the meaning of the text itself. When neural network is used to solve natural language problems, cyclic neural network transmits the information of one of the earliest neurons in the network to the next neural cell. Because the text information in natural language is usually orderly, recurrent neural network is naturally suitable for the task of text sequence. Using recurrent neural network to create image subtitles and machine translation has produced satisfactory results [8]. In Rajesh's work, the simulation of text production style is realized by using long-term and short-term storage networks, and a dialogue system is constructed. Based on recurrent neural network [9], in the work of Duan and Gao, the encoder-decoder framework was first proposed when solving machine translation problems. At the encoder end, recursive neural network is used to encode the input text sequence into fixed-length meaning vector. At the decoding end, other networks are used to generate text sequence according to the output of meaning vector [10]. The powerful performance of attention mechanism has been paid attention to. In 2014, Nwet and Darren used the attention mechanism to solve the image classification problem in order to reduce the complexity of the task, allowing the model to process the pixels of the attention part [11]. In addition, the Google team proposed an automatic attention mechanism to replace the traditional neural network layout for the end of the model and a unit converter composed of multiple multihead and multifunctional mechanisms. Although the traditional recurrent neural network is suitable for the development of language sequence, it cannot calculate in parallel and capture the global structure information. Through the self-attention mechanism, the attention distribution of each word in the sentence and all words in the sentence is calculated, which can solve the problem of dependence at a distance. As it can calculate in parallel, the efficiency of training has also improved considerably. In addition, on the basis of the structure of the transformation module above, in the follow-up, you only need to use a small amount of downstream work data to get rewarding results on different tasks. Huang and others proposed paper model for biomedical and computer documents. Firstly, the model comprehends a large number of documents on the ground and builds a specific and complete graph of basic knowledge. Through the connection prediction algorithm, other nodes that can be associated with the graphics nodes are found [12]. In terms of the current popular pretraining language model, Yu used hundreds of millions of words of biomedical text mixed general language text to train the biomedical corpus [13]. Molchanova and others used 1.14 million biomedical and computer science and technology documents for the training of sciences, which is best suited to the management of scientific and technological documents in China; some researchers have formed the Chinese pretraining model of SciBERT CN using the corpus of Chinese scientific and technological documents [14]. Hasheminejad and Khorrami found that, at present, the researchers tried to produce documents using the pretraining model. The University of California, Berkeley, conducted an experiment to generate documents using the gpt-3i5j pretraining model. In the experiment, Researchers input the title and introduction of the experimental paper and generate the model and other paper contents [15]. The experimental results of Xin show that

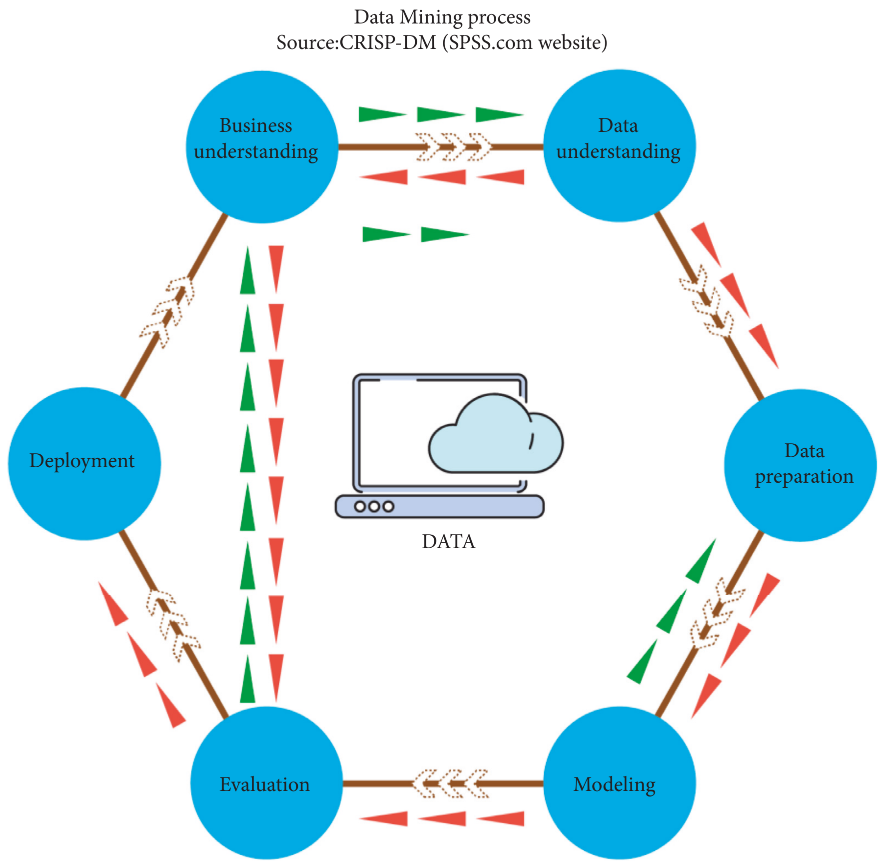


Figure 1: System flow.

even if the sentences generated by the model lack logic, they can use a large number of professional words to create sentences that confuse true and false [16]. Similarly, educational institutions allow graduates to write the same paper content with gpt-3. Finally, gpt-3 shows a level of writing similar to humans and reflects incredible creative ability in writing technical documents. To sum up, the use of natural language generation technology to produce documents is highly feasible and worthy of thorough research, but research in this direction, both at home and abroad, is still somewhat inadequate. Compared with other translation software, an English business-assisted writing system can help make up for the deficiencies in these aspects, and the construction of a knowledge base has become a key factor supporting an English-assisted writing system [17].

3. Method

At present, the Internet technology is relatively developed and the network resources are very rich. The network has become an important source for obtaining corpus [18, 19]. Moreover, with the increasing standardization of HTML files, it is more convenient, accurate, and fast to obtain information from HTML files than from PDF, CAJ, DOC, and other formats. Therefore, obtaining corpus from Internet web pages is the most appropriate choice. The work of this paper to obtain the corpus is to use the special crawler tool "NetCrawler" to obtain the corpus web page from the famous foreign academic retrieval website "http://www.sciencedirect.com/." The advantage of crawling papers from the same academic website is that most URIs (uniform resource identifiers) have the same or similar field format, which is convenient for batch crawling. In addition, most HTML files have the same or similar organizational structure format, which is convenient for unified information extraction [20]. The corpus of this subject includes 15 university subjects such as computer science, life science, medicine, and chemistry. Each university subject also includes several specific research fields. Generally speaking, the number is relatively sufficient. The crawled corpus is a file in HTML format and needs further processing. Through the investigation of a large number of corpus files, it is found that the HTML tag organization of this website is relatively standardized. The information related to paper abstracts (including) is usually between the tags "<HR id = " a (a) bstract> "and" <HR>," while the specific content of paper abstracts is usually between the tags "<p id = "∗∗">" and "</P>," which brings great convenience to the batch extraction of summary information. The extraction method based on regular expression can be used for batch extraction easily, and the extraction accuracy is very high. Only a few HTML files cannot extract summary information because of the "uniqueness" of tag organization [21].

The manually labeled corpus of this subject comes from the abstract part of 400 papers, a total of 4555 sentences. After English word segmentation, there were a total of 127710 words (including punctuation, person name, special symbols, misclassification, etc.), with an average of 28 words per sentence unit (including punctuation, person name, special symbols, misclassification, etc.), and a vocabulary size of 10345 (including punctuation, person name, special symbols, misclassification, etc.). The in-depth statistics are shown in Table 1.

In the words and thesaurus counted above, there are some redundant information and nonstandard information, such as word inconsistency caused by case of letters, word inconsistency caused by changes in singular and plural numbers, word inconsistency caused by changes in word form, and widely used punctuation marks. Therefore, further text standardization is needed [22]. The commonly needed text normalization processing steps include lowercase, stem extraction, and word form merging [23]. The related technologies listed above are introduced. After several steps of text normalization, such as lowercase, stem extraction, word form merging, and elimination of useless punctuation, the size information of the word list is shown in Table 2, and the word frequency distribution is shown in Figure 2.

Figure 2 lists the word frequency distribution of the words with the word frequency in the top 50. It can be seen that the overall word frequency distribution on the marked dataset generally obeys Zipf's law. Zipf's law states that, in a given corpus expressed in natural language, the frequency of a word is inversely proportional to its ranking from high to low in the corpus. We have the following formula:

$$R \times F \approx C. \tag{1}$$

Here, R is ranking of the frequency of a word in the corpus (from high to low), F is frequency of this word, and C is a constant.

Currently, research into the level of phrases is of great importance in the fields of natural language processing, information retrieval, automatic translation, and so on. The purpose is to divide the abstract sentences of English scientific papers in the corpus constructed by ourselves in the previous work into four categories: "research background," "subject content," "experimental method," and "results and conclusions," so that these classified abstract sentences of English scientific papers can be used for the next research work, that is, the frequent pattern mining of various categories of abstract sentences and the construction of knowledge base of English scientific paper auxiliary writing system. The sentence categories in the abstracts of 400 English scientific papers are manually labeled, with a total of 4555 abstract sentences, which are divided into two parts. 2400 labeled corpora in the first part are used as the training set of the classifier and 2155 labeled corpora in the second part are used as the test set. The specific statistical information of each category is shown in Table 3.

Selection and extraction of characteristics is one of the necessary steps in the classification. In the task of classifying the text, "word bag" and vector space model (VSM) are the most commonly used methods of representation of text [24]. The document frequency of a word is the number of documents in which the word appears in the corpus. This feature selection method assumes that rare words have little effect and impact on classification. Therefore, a threshold is set in advance to filter out the words whose document frequency is lower than this threshold, so as to reduce the feature dimension. In addition, if a filtered word Yiqiao is a noisy word, this method will improve the classification effect. In general, document frequency is the simplest and least computational feature selection method. The information gain of a word is a measure of the information increment brought by the word to the classification, which reflects the ability of the word to distinguish this category from other categories [25]. It performs category prediction by calculating the number of instances in which a word is included and the number of instances in which it is not included. The calculation method is as follows:

Table 1: Information statistics of each category.

	Category 1	Category 2	Category 3	Category 4
Number of sentences	1055	780	1715	996
Proportion of sentences	0.24	0.17	0.38	0.2
Total words	29036	23126	47163	28395
Thesaurus size	4545	3965	6415	4675

$$\begin{aligned} IG(t) = &-\sum_{i=1}^{m} p(c_i) + p(t)\sum_{i=1}^{m} p(c_i|t)\log\, p(c_i|t) \\ &+ p(t)\sum_{i=1}^{m} p(c_i|t)\log\, p(c_i|t), \end{aligned} \tag{2}$$

where M is number of categories, $p(c_i)$ is probability of occurrence of class instances in the corpus, $p(t)$ is the probability that instances containing word t appear in the corpus, $p(c_i|t)$ is conditional probability that the instance containing word t belongs to category I, $p(t)$ is the probability that instances without word t appear in the corpus, and $p(c_i|t)$ is conditional probability that an instance without word t belongs to category I.

The information gain determines the category discrimination ability of the word to a certain extent. Using this feature selection method to select the word whose information gain is higher than a preset threshold as the feature can effectively reduce the feature dimension and improve the quality of the feature set. In a broad sense, mutual information refers to the correlation between two event sets. In the feature selection of text classification, it reflects the correlation between a word and a category. The calculation method is shown in the following formula:

$$I(t,c) \approx \log\frac{A \times N}{(A+C)\times(A+B)}, \tag{3}$$

where A is number of cases in the corpus containing word t and belonging to category C; N is the total number of instances in the corpus; B is the number of cases in the corpus containing word t but not belonging to category C; C is the number of instances in the corpus which do not contain word t but belong to category C.

Table 2: Thesaurus statistics after text normalization.

Statistical information	Population	Category I	Category II	Category III	Category IV
Number of words	114430	26016	20701	41955	25758
Thesaurus size	6310	2902	2695	4128	3128

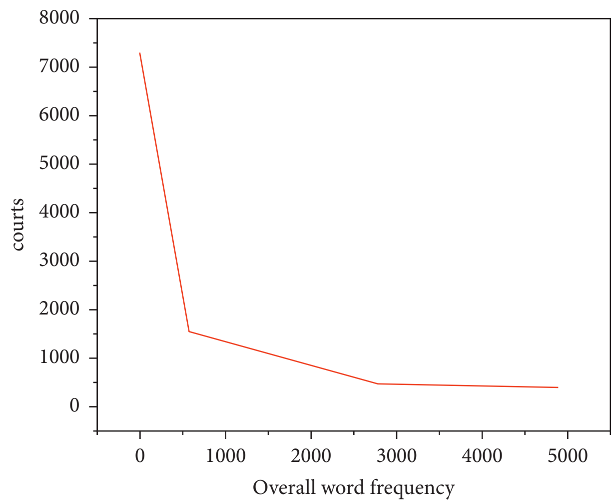


Figure 2: Overall word frequency distribution.

Table 3: Sample statistics of training set and test set.

	Training set	Test set
Total number of labeled samples	2405	2145
Number of samples in category I	535	520
Category I sample proportion	0.22	0.24
Number of samples in category II	415	365
Category II sample proportion	0.16	0.16
Number of samples in category III	920	795
Category III sample proportion	0.32	0.36
Number of samples in category IV	530	466
Category IV sample proportion	0.22	0.21

In the global feature selection of multiclass problems, the mutual information of a word is usually calculated by selecting the weighted average of the mutual information of the word in each class (formula (4)) or the maximum mutual information (formula (5)).

$$I_{\text{avg}}(t) = m \sum_{i=1} I(t, c_i), \quad (4)$$

$$I_{\max}(t) = \max_{i=1}^{m} \{I(t, c_i)\}, \quad (5)$$

where M is number of categories, $p(c_i)$ is the proportion of instances belonging to category I in the corpus, and $I(t, c_i)$ is mutual information of word t in corpus for category I.

The size of mutual information reflects the relevance of a word and a category to a certain extent. However, its defect is that its value is greatly affected by the edge probability, which makes the mutual information value of a rare word greater than that of an ordinary word when the conditional probability of word t belonging to category C is the same. It is also an effective feature selection method to select words whose mutual information value is higher than a preset threshold as features [26].

X^2 statistic is used to measure the lack of independence between a word and a category in text classification. The greater the value, the smaller the independence between the word and the category, that is, the greater the correlation. The calculation method of X^2 statistics of a word for a category is shown in the following formula:

$$x^2(t, c) = \frac{N \times (AD - BC)^2}{(A + C)(B + D)(A + B)(C + D)}, \quad (6)$$

where N is the total number of instances in the corpus; A is the number of instances in the corpus which contain word t and belong to category C; B is the number of instances in the corpus which contain word t but do not belong to category C; C is the number of instances in the corpus which do not contain word t but belong to category C; and D is the number of instances in the corpus which do not contain word t and do not belong to category C.

In the global feature selection of multiclass problems, the X^2 statistic of a word is usually calculated by selecting the weighted average (formula (7)) or maximum (formula (8)) of the mutual information of the word in each class.

$$x^2\text{avg}(t) = \sum_{i=1}^{m} P(c_i) x^2(t, c_i), \quad (7)$$

$$x^2 \max(t) = \max_{i=1}^{m} \left\{x^2(t, c_i)\right\}. \quad (8)$$

Like mutual information, X^2 statistic reflects the correlation between words and categories to a certain extent. The difference is that X^2 statistic is a normalized value. Therefore, for words in the same category, the correlation between words and categories can be compared according to the value, but, for low-frequency words, the confidence of this correlation is not strong enough. It is also an effective feature selection method to select words whose X^2 statistics are higher than a preset threshold as features [27].

Supervised statistical learning method is widely used in classification tasks. Its basic idea is to use labeled data to train the classifier and then use the classifier to predict the target samples of unknown categories. There are many models and methods that can be used for text classification, such as naive Bayesian model, k-nearest neighbor model, maximum entropy model, artificial neural network model, and support vector machine model. Among them, support vector machine model is recognized as the most suitable model for text classification task. At present, nonlinear support vector machines have been widely used in various classification tasks, especially in text classification tasks [28]. The nonlinear support vector machine takes the labeled samples as the input and solves the class II classification problem by constructing the target classification decision function, as shown in

$$\min_{\partial} \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \partial_i \partial_j y_i y_j K\left(x_i, x_j\right) - \sum_{i=1}^{N} \partial_i, \tag{9}$$

$$s.t. \sum_{i=1}^{N} \partial_i y_i = 0, \tag{10}$$

$$0 \le \partial_i \le C, \quad i = 1, 2\ldots, N, \tag{11}$$

$$K(x, \Xi) = \exp\left(-\sigma \cdot \|x - \Xi\|^2\right). \tag{12}$$

SVM uses kernel function to map the feature space to a higher dimensional space. Therefore, when using SVM model, it is generally not necessary to reduce the dimension to control the complexity of the model. But this does not mean that thesaurus can be used as the full feature in the classification of abstract sentences of scientific papers in this paper, because, as described in the feature selection section above, if some noise words are not filtered, the classification effect will be affected. The data used in the classification experiment of abstract sentences here are from the corpus of abstract sentences of English scientific papers constructed by ourselves in the previous work, including 4555 annotated abstract sentences and a large number of unmarked abstract sentences. The 4555 labeled data samples are divided into two parts, of which 2400 data samples are used as the training set and 2155 are used as the test set. Firstly, we use the supervised learning model support vector machine to do a preliminary control experiment in order to have a preliminary understanding of the problems and challenges. The experimental method adopts the word bag method used in the general text classification experiment, takes the words after lowercase, word stemming, and word form merging as the feature set, selects the features with the word frequency threshold and X^2 statistic threshold, respectively, takes the value of 0-1 as the feature value, classifies with the SVM model, trains with all 4550 labeled data samples, and makes a 50-fold cross validation. The highest accuracy results obtained are shown in Table 4.

The frequent pattern mining in this paper is different from the general frequent pattern mining or frequent itemset mining. Common frequent pattern mining tasks, such as the classic frequent pattern mining and association rule mining in supermarket shopping, generally only need to investigate the cooccurrence relationship of different items and the association support. In the frequent pattern mining of various abstract sentences of scientific papers in this chapter, in addition to mining the cooccurrence relationship between words in various sentences, we should also consider the collocation order of cooccurrence words and whether they are representative of categories. The so-called collocation sequence refers to, for example, the fact that, through frequent pattern mining, it is found that words A, B, and C appear at the same time with high support, but the total arrangement order of these three words is the six cases "ABC," "ACB," "BAC," " BCA," "CAB," "CBA." What kind of situation is more in line with the actual expression is a problem that needs to be investigated. The so-called category representativeness means that the mined frequent patterns are easier to distinguish from other categories. The smaller the intersection between the frequent pattern sets of various categories, the better. For example, in the "background meaning" sentence of English correspondence writing, there are more symbolic expressions such as "the background o...," "recent years...," and "have been proposed"; in the "subject content "sentences of English correspondence writing, there are more symbolic expressions such as "in this paper/article," "this paper introduction/descriptions," and "here we present/propose." In the "experimental method" sentence of English correspondence writing, there are more symbolic expressions, such as "we use..," "the data/datasets," and "step one/two/three." In the sentence of "results and conclusions" in English correspondence writing, there are more symbolic expressions, such as "the results of for," "the result(s) indicate that...," and "we conclude/demonstrate that...." All of the previously mentioned statements have great category representativeness. On the other hand, according to Zipf's law and the previous statistical information on the distribution of words in the corpus, the frequency of function words (including stop words, some prepositions, articles, etc.) is high both in the types of abstract sentences of English scientific papers and in the overall expression of English language. The frequency of cooccurrence between them is much higher than that between other meaningful words, and the regularity of cooccurrence is poor. Therefore, the frequent pattern mining of these function words has little significance. Since the number of various sentences involved is not very large, the establishment of inverted index can be completed in memory. The memory based inverted index establishment algorithm is shown in Table 5 [29]. For the full arrangement of words in a frequent pattern, you can count the number of times of each full arrangement by returning to the sentence containing the frequent pattern and finally decide the arrangement with the largest number of votes by voting, which is the prototype of the frequent pattern. In addition, by calculating the expectation and variance of the relative distance between words in the sample, it can also be used to determine the prototype of frequent patterns.

At present, there is no unified evaluation index for the result quality of frequent pattern mining. According to different specific problems, evaluation indicators that can be roughly applicable to specific problems can be formulated. For the frequent pattern mining of words in the sentence set, on the one hand, the support of the discovered frequent pattern needs to be investigated, because the support is about equal to the number of occurrences of the frequent pattern in the sentence set. The greater the support, the greater the probability of cooccurrence of each word item in the frequent pattern. On the other hand, we should also examine the stability of its structure. The so-called stability refers to whether the frequency distribution of the full arrangement of words in a frequent pattern is stable according to the order of occurrence; that is, if each full arrangement appears more evenly in the sentence set, it becomes more unstable. On the contrary, if it appears in

Table 4: Comparison of accuracy under different dimensions and different feature selection methods.

	Threshold = 0.05 (%)	Threshold = 0.03 (%)	Threshold = 0.02 (%)	Threshold = 0.01 (%)
Word frequency	48	53	57	59
X^2 statistic	53	58	59	62

Table 5: Memory based inverted index establishment algorithm.

Input	Sentence set
Output	Inverted index based on sentence set (1) Initially traverse the sentence set. For each word, count the number of sentences containing the word f_w. (2) Create an array of length $\sum f_w$, and for each word W, generate a pointer p_w to the beginning of its record table block. (3) Traverse the sentence set again, for each word w in each sentence d, add the sequence number of sentence d to p_w, and move p_w backward.

one arrangement, then this arrangement can be considered a stable frequent pattern.

We directly use the *FP* growth method to mine frequent patterns of summary sentences of various classes, and the experimental results show that the effect is poor. Most of the frequent patterns with high support are composed of function words (including stop words, prepositions, numerals, etc.), as shown in Table 6. Even if some words with actual meaning appear in some frequent patterns with low confidence, the frequent patterns are usually composed of only a small number of notional words and a large number of functional words, as shown in Table 7.

Among the frequent patterns mined, the three frequent itemsets have increased significantly. Because the sentence representation is in the form of bigram, it can be said that the frequent patterns between 3 and 6 words have been mined to some extent, which is better than before. From the perspective of English assisted writing, the more words the frequent pattern contains, the more it can reflect the value of assisted writing. In general, using bigram sentence representation method for frequent pattern mining, the mining effect and results have been greatly improved, but there is still a certain gap with the expectation, which is related to the limited size of sentence set and the limitation of mining methods.

Table 6: Examples of frequent patterns with support greater than 200 in category 1.

Support	Frequent mode
530	The of
400	Of and
365	The and
305	Of the and
365	Of the
205	The of
355	Of to
275	Of the to
200	The and to

Table 7: Examples of frequent patterns containing the notional word "information" in category 1.

Support	Frequent mode
42	The is information
40	Of is information
30	To is information
35	The of is information
36	And in information
32	Of in information
25	To in information

4. Experiment and Discussion

As can be seen from the experimental results in Figure 3, with the increase of feature dimension, the classification accuracy increases, but the increase tends to be gentle. In addition, the effect of feature selection using X^2 statistics is better than that using word frequency, which proves that words with strong classification ability play a better role in classification. However, from the perspective of accuracy value, even if cross validation is adopted on the training set itself, the results are still not ideal [30]. This is directly related to the feature sparsity of sentences. Then, the following groups of experiments are carried out using SVM model to verify the impact of feature selection on classification effect. The results are shown in Table 8.

In this experiment, the kernel function of support vector machine adopts linear kernel function, and the penalty term factor C is set to 1. The parameters P and f shown in Table 4 represent different feature selection methods. P mainly selects different methods from the perspective of text features, and its significance is shown in Table 9. F selects different methods from the perspective of main feature representation methods, and its significance is shown in Table 10.

From the above results, it can be seen that the representation of text features has a great impact on the accuracy of classification, while different feature selection methods have little impact on the accuracy of classification, and there is almost no significant difference. Among them, the classification accuracy of retaining stop words ($P = 0$, 1, 2, 3) is significantly higher than that of removing stop words ($P = 4$, 5, 6, 7). On this basis, the classification accuracy of bigram text feature ($P = 1$, 3) is higher than that of unigram ($P = 0$, 2). Without word stemming and word form merging ($P = 0$, 1, 4, 5), the effect is not more obvious than that of word stemming and word form merging ($P = 2$, 3, 6, 7). To some extent, this is due to the common writing methods and expression characteristics of various parts of the abstract

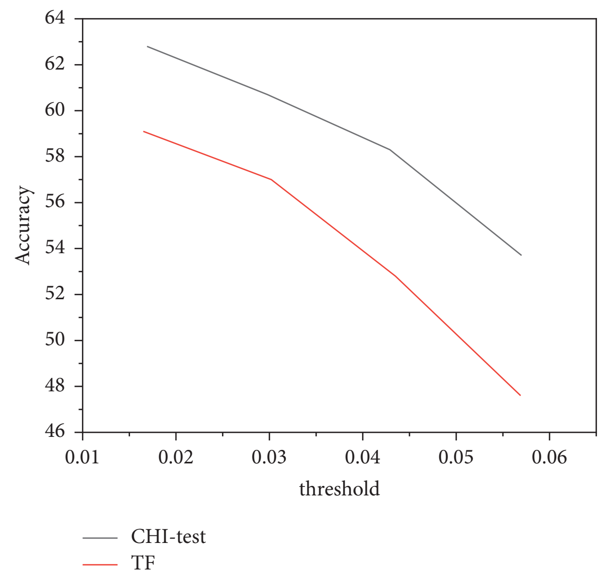


Figure 3: Comparison of preliminary experimental results.

Table 8: Influence of feature selection on classification accuracy.

P/F	0	1	2	3
0	62.3	62.4	52.4	60
1	66	65.4	65.4	64.3
2	61.2	61.6	61.4	59.5
3	65	64.8	64.8	65
4	56.5	55	55	55.8
5	57.3	58	58	58.2
6	55.2	53.8	53.8	54.2
7	57.3	55.8	55.8	57.9

Table 9: Text feature pattern represented by parameter P.

P	Text feature mode
0	Retain stop words without word stemming and morphological merging, unigram
1	Retain stop words without word stemming and morphological merging, bigram
2	Retain stop words, carry out word stemming and word form merging, unigram
3	Retain stop words, carry out word stemming and word form merging, bigram
4	Remove stop words without word stemming and morphological merging, unigram
5	Remove stop words without word stemming and morphological merging, bigram
6	Remove stop words, carry out word stemming and word form merging, unigram
7	Remove stop words, perform word stemming and word form merging, bigram

Table 10: Feature representation represented by parameter F.

F	Feature representation method
0	Binary
1	Word count
2	TF
3	TF-IDF

sentences of English scientific papers, such as "in this paper." The emergence of collocations such as "the aim of" indicates that the abstract sentence is likely to describe the subject content of the paper. If the abstract sentence is expressed in the form of words and some stop words are filtered out, the text features obtained may not be fully representative of the category; in addition, the appearance of the symbol "%" is likely to indicate that this sentence is describing the result of English correspondence writing. In addition, using bigram as a feature doubles the amount of text information compared to using unigram as a feature, and retaining stop words also increases the amount of text information in a disguised manner, so the classification effect is improved [31].

5. Conclusion

The main work is to mine frequent patterns in all kinds of English correspondence writing abstracts. Firstly, this paper briefly introduces the frequent pattern mining task of abstract sentences and expounds its purpose, significance, characteristics, and the difference from ordinary frequent pattern mining tasks. Then, the paper briefly introduces the relevant knowledge of frequent pattern mining. When training support vector machine, selecting a larger penalty factor, that is, when paying more attention to noise points or outliers, we can obtain higher accuracy in the test set, but the negative impact is lower recall rate and F value, and the generalization is affected to a certain extent. The final accuracy reached more than 70%. Finally, FP growth algorithm is used to mine frequent patterns of summary sentence sets of various categories, and the mining results are studied and analyzed. In view of the shortcomings, the mining strategy is gradually adjusted to improve the quality of mining results. However, the result of mining is limited by the size of sentence set and mining algorithm, and there is still a certain gap with the expected goal. FP growth algorithm is used to mine frequent patterns in the collection of summary sentences of various categories. By using stop word filtering, bigram representation of sentences, and quality evaluation method combining support and stability, the mining effect is gradually improved and gradually becomes close to the expected goal. A large number of English correspondence writing corpora are obtained, the abstract sentences are divided into four categories: "research background," "subject content," "experimental method," and "results and conclusions," and some frequent patterns in each category are excavated, which supplements and improves the knowledge base of English assisted writing system in abstract writing of scientific papers.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by first-class undergraduate major construction project in Shaanxi Province: Business English Major in Xi'an Fanyi University. It was also supported by scientific research project at Xi'an Fanyi University with Shaanxi Danjian Experimental Equipment Co., Ltd.: "A Display Tool for English Vocabulary Teaching" Utility Model Patent Implementation Permit (21XYH232).

References

[1] J. Zhang, S. O. Williams, and H. Wang, "Intelligent computing system based on pattern recognition and data mining algorithms," *Sustainable Computing: Informatics and Systems*, vol. 20, no. DEC, pp. 192–202, 2018.

[2] H. Esmaeily, M. Tayefi, M. Ghayour-Mobarhan, and A. Amirabadizadeh, "Comparing three data mining algorithms for identifying the associated risk factors of type 2 diabetes," *Iranian Biomedical Journal*, vol. 22, no. 5, pp. 303–311, 2018.

[3] A. Goel and S. Srivastava, "Study of data mining algorithms in the context of performance enhancement of classification," *International Journal of Computer Application*, vol. 134, no. 9, pp. 1–5, 2016.

[4] T. Hong, W. Zhao, R. Liu, and M. Kadoch, "Space-air-ground IoT network and related key technologies," *IEEE Wireless Communications*, vol. 27, no. 2, pp. 96–104, 2020.

[5] A. Onan, "Sentiment Analysis on Product Reviews Based on Weighted Word Embeddings and Deep Neural Networks," *Concurrency and Computation: Practice and Experience*, vol. 1, 2020.

[6] V. Kirubha, S. M. Priya, and S. M. Priya, "Survey on data mining algorithms in disease prediction," *International Journal of Computer Trends and Technology*, vol. 38, no. 3, pp. 124–128, 2016.

[7] Q. Wang, J. Huang, Y. Feng, and J. Fei, "Efficient data mining algorithms for screening potential proteins of drug target," *Mathematical Problems in Engineering*, vol. 2017, no. -3-2, pp. 1–10, Article ID 9852063, 2017.

[8] S. Celik and O. Yilmaz, "Comparison of different data mining algorithms for prediction of body weight from several morphological measurements in dogs," *Journal of Animal and Plant Sciences*, vol. 27, no. 1, pp. 57–64, 2017.

[9] P. Rajesh, "A comparative study of data mining algorithms for decision tree approaches using weka tool," *Advances in Natural and Applied Sciences*, vol. 11, no. 9, pp. 230–241, 2017.

[10] J. Duan and R. Gao, "Research on English movie resource information mining based on dynamic data stream classification," *Security and Communication Networks*, vol. 2021, no. 4, pp. 1–10, 2021.

[11] K. T. Nwet and S. Darren, "Machine learning algorithms for Myanmar news classification," *International Journal on Natural Language Computing*, vol. 8, no. 4, pp. 17–24, 2019.

[12] R. Huang, A. Sato, T. Tamura, J. Ma, and N. Y. Yen, "Towards next-generation business intelligence: an integrated framework based on dme and kid fusion engine," *Multimedia Tools and Applications*, vol. 76, no. 9, pp. 11509–11530, 2017.

[13] H. Yu, "Online teaching quality evaluation based on emotion recognition and improved aprioritid algorithm," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 4, pp. 7037–7047, 2021.

[14] E. I. Molchanova, E. N. Korzhova, T. V. Stepanova, and V. V. Kuz'min, "Analysis of the samples with an unknown matrix using data mining algorithms," *Inorganic Materials*, vol. 53, no. 14, pp. 1454–1457, 2017.

[15] S. M. H. Hasheminejad and M. Khorrami, "Clustering of bank customers based on lifetime value using data mining methods," *Intelligent Decision Technologies*, vol. 14, no. 4, pp. 507–515, 2021.

[16] Y. Xin, "Analyzing the quality of business English teaching using multimedia data mining," *Mobile Information Systems*, vol. 2021, no. 12, pp. 1–8, Article ID 9912460, 2021.

[17] A. Onan, "Mining opinions from instructor evaluation reviews: a deep learning approach," *Computer Applications in Engineering Education*, vol. 28, no. 1, pp. 117–138, Article ID 9912460, 2020.

[18] L. Qiao, Y. Li, D. Chen, S. Serikawa, M. Guizani, and Z. Lv, "A survey on 5G/6G, AI, and Robotics," *Computers & Electrical Engineering*, vol. 95, no. 2021, Article ID 107372, 2021.

[19] Y. Li, Y. Zuo, H. Song, and Z. Lv, "Deep learning in security of internet of things," *IEEE Internet of Things Journal*, vol. 99, p. 1, 2021.

[20] M. M. Yatskou, V. V. Skakun, and V. V. Apanasovich, "Method for processing fluorescence decay kinetic curves using data mining algorithms," *Journal of Applied Spectroscopy*, vol. 87, no. 2, pp. 333–344, 2020.
[21] P. Pandey and I. Singh, "Improving accuracy using different data mining algorithms," *International Journal of Computer Application*, vol. 150, no. 10, pp. 10–13, 2016.
[22] Ö. Gülsüm Uzut and S. Buyrukoglu, "Veri̇ Madenci̇li̇ği̇ Algori̇tmalari Ile Gayri̇menkul Fiyatlarinin Tahmi̇ni̇," *Euroasia Journal of Mathematics, Engineering, Natural and Medical Sciences*, vol. 8, no. 9, pp. 77–84, 2020.
[23] Y. Liu and G. Fu, "Emotion recognition by deeply learned multi-channel textual and EEG features," *Future Generation Computer Systems*, vol. 119, pp. 1–6, 2021.
[24] N. Moqbel, "Analysis and implementation some of data mining algorithms by collecting algorithm based on simple association rules," *International Journal of Computer Application*, vol. 138, no. 4, pp. 20–26, 2016.
[25] V. Subeesh, E. Maheswari, G. R. Saraswathy, A. M. Swaroop, and S. S. Minnikanti, "A comparative study of data mining algorithms used for signal detection in fda aers database," *Journal of Young Pharmacists*, vol. 10, no. 4, pp. 444–449, 2018.
[26] R. Balasubramaniam, "A detailed analysis of different data mining algorithms with hypothyroid data set," *Innovative Food Science & Emerging Technologies*, vol. 5, no. 9, pp. 250–255, 2018.
[27] E. Balraj and D. Maalini, "A survey on predicting student dropout analysis using data mining algorithms," *International Journal of Pure and Applied Mathematics*, vol. 118, no. 8, pp. 621–626, 2018.
[28] S. Rosenthal, M. Veloso, A. K. Dey et al., "Is someone in this office available to help me?" *Journal of Intelligent and Robotic Systems*, vol. 66, no. 1-2, pp. 205–221, 2012.
[29] Z.-G. Liu, Y. Yang, and X.-H. Ji, "Flame detection algorithm based on a saliency detection technique and the uniform local binary pattern in the ycbcr color space," *Signal, Image and Video Processing*, vol. 10, no. 2, pp. 277–284, 2016.
[30] G. E. Sakr and I. H. Elhajj, "Vc-based confidence and credibility for support vector machines," *Soft Computing*, vol. 20, no. 1, pp. 133–147, 2016.
[31] M. Torres and G. Qiu, "Habitat image annotation with low-level features, medium-level knowledge and location information," *Multimedia Systems*, vol. 22, no. 6, pp. 767–782, 2016.

Hindawi
Scientific Programming
Volume 2022, Article ID 2249722, 10 pages
https://doi.org/10.1155/2022/2249722

Research Article

English Speech Recognition and Pronunciation Quality Evaluation Model Based on Neural Network

Li Wang

Department of Foreign Languages, Nanchong Vocational and Technical College, Nanchong 637131, Sichuan, China

Correspondence should be addressed to Li Wang; sallywhl@jou.edu.cn

Received 17 March 2022; Revised 3 May 2022; Accepted 14 May 2022; Published 30 June 2022

Academic Editor: Ahmed Farouk

An in-depth neural network-based approach is proposed to better develop an assessment model for English speech recognition and call quality assessment. By studying the structure of a deep nonlinear network, you can approximate complex functions, define distributed representations of input data, demonstrate a strong ability to learn important data set characteristics from some sample sets, and better simulate human brain analysis, and learning. The author uses in-depth learning technology to recognize English speech and has developed a speech recognition model with a deep belief network using the characteristics of the honey frequency centrum based on human hearing patterns. The test results show that examples include 210 machine and manual evaluations and 30 samples with first-grade differences. The overall compatibility level of the machine and human evaluation is 90.65%, and the adjacency consistency level is 90.65%. This is 100%, and the correlation coefficient is 0.798. We need to evaluate the quality of speech and pronunciation in English, which indicates a strong correlation between machine estimates and human estimates.

1. Introduction

With the development of pattern recognition technology, intelligent human-computer interaction modes and methods are gradually applied to various industries, especially the extended application of voice interaction. Speech recognition is rapidly integrating into many fields. It has improved the level and efficiency of intelligent interaction in many aspects, such as mobile phones, unmanned driving, and industrial robots, compared with text interaction, voice interaction is faster and more efficient; however, it is more complicated in terms of the stability of the realization function and the realization technology; therefore, speech recognition technology with high confidence is very important [1]. The current research on speech recognition mainly focuses on two aspects: speech signal feature extraction and speech feature recognition, the former focuses on filtering and signal analysis techniques, in order to extract the features of the native speech signal issued by people as accurately as possible, the latter focuses on training speech signal features and minimizing speech recognition errors as much as possible. The so-called speech neural network recognition technology, which supports artificial intelligence technology, is a widely used neural network information processing system [2]. Some experts in the field of speech neuroscience have used this new network information processing technology, called the independent processing unit of the neural network. The transfer of information and functional connections between different functional plates occurs as a result of the interaction of information processing systems of individual neurons [3]. Information is stored in the electronic core chip of the neuron system, simulating the information processing model of the human brain and realizing the conversion of the encoding of the abstract content of information to the concrete form of the transfer [4]. By encoding and translating nonlinear information, the performance efficiency of data transmission and processing can be improved as much as possible by mimicking neural network calls and adhering to basic operating principles. Building a smart neural information processing network has many advantages over traditional data transmission and processing modes. Based on the application

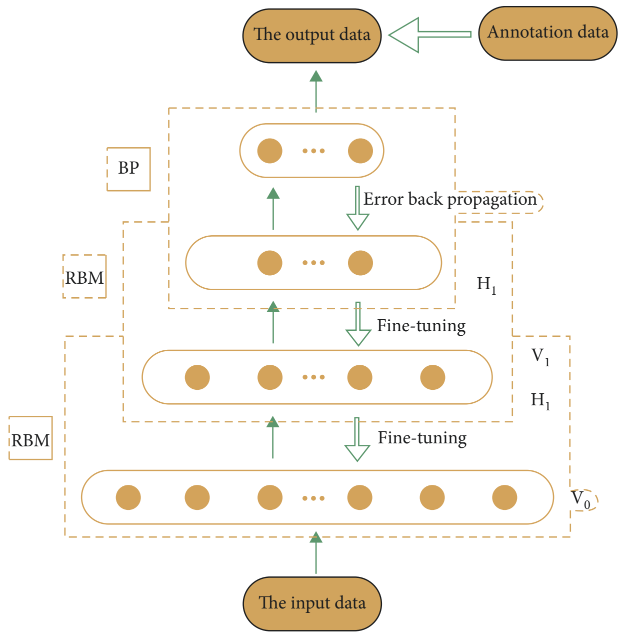


Figure 1: Deep belief network.

patterns of traditional neuron simulation information processing systems, a deep-faith network information transmission system for in-depth learning was developed (Figure 1) [5]. The use of English pronunciation quality and speech recognition methods will gradually lead to the development of English phonology, the structure of the learning system, and a multi-level development model. English teachers working in the field of educational research have made it clear that the main way to build this network based on in-depth learning based on neural structure models is based on self-directed learning, a form of learning, where education belongs to the category of uncontrolled learning.

2. Literature Review

Long proposed that by preprocessing the acoustic signal, in order to increase the accuracy and robustness of feature extraction, and optimize the combination of the acoustic feature Mel-frequency cepstral coefficients, the preprocessing method of this method for speech feature data is worth learning from [6]; By exploiting parallel model merging algorithms, in order to adjust the relevant parameters and weights in the model, compensated for speech distortion containing noise, which improves the robustness of speech recognition system in a noisy environment. However, the method in this paper only considers the influence of stationary noise, while in reality most of them are nonstationary noise [7]. Adjusting parameters in hidden Markov models and improving the Viterbi algorithm, models with relatively low confidence in the recognition process are trimmed, in order to achieve higher recognition accuracy and shorter matching time. However, this method has a large space complexity in the back-end decoding algorithm, which restricts the scalability of the overall speech recognition system [8]. The acoustic model of the convolutional neural network was established by Qin et al. for speech recognition. Compared with the deep neural network structure with the same number of layers, the performance is improved by more than 10% [9]. Wang and IBM's Watson research team optimized disruptive neural network parameters, such as the number of disruption layers, the number of latent layer nodes, and the choice of input functions, and used them extensively for continuous word recognition systems. Experimental results show that the CNN structure improves the performance of traditional GMM acoustic models by 13.30% [10]. Yun's parallel processing technology of compute unified device architecture (CUDA) through GPU realizes the complex layer structure and fast matrix operation of the neural network, it speeds up the parameter transfer process in neural networks. Experiments show that the software optimization (using the CUBLAS library) compared to NVDIA saves nearly 70% in time [11]. Yang et al. used cluster technology to build a large-scale distributed neural network, a model parallel training method is proposed, that is, the model is divided into blocks, they are handed over to the machines in the cluster for processing, and the resources of each machine are fully utilized, it is only necessary to synchronize the information of nodes on the edge of the dividing line to save the network overhead [12]. Bang In Hessian's ReLU activation function and dropout strategy are added to the free training method, that is to improve the performance of the neural network by preventing the joint action of local filters, and at the same time, the risk of falling into a local optimum is reduced [13]. Liu proposed a restricted Boltzmann machine with convolution as a pretraining mechanism for CNN models, experiments show that it shows better performance in large-vocabulary speech recognition tasks [14]. Ryu et al. demonstrated in detail the deep learning algorithm, the research situation in speech recognition, and the key problems to be solved, a research direction was proposed for the application of deep learning to speech recognition [15]. Arora et al. used recurrent neural networks for speech recognition; the recognition accuracy is high, but the recognition efficiency is low, which is not enough to meet the requirements of real-time recognition [16].

Based on current research, an in-depth study based on neural networks is proposed. By learning the structure of a deep nonlinear network, we use in-depth learning technology to recognize English speech and create a speech recognition model using parameters of the Mel-frequency cepstral characteristic based on the human auditory model and the deep belief network.

3. Neural Network Models

3.1. Overview of Neural Networks. Artificial neural networks (ANN), also known as neural networks (NN), is interconnected by a large number of processing units - neurons (neurons), simulating the way the human brain processes information, complex network systems for parallel processing, and nonlinear transformation of information [17]. Since the neural network is an abstraction, simplification, and simulation of the human brain, it has a large number of

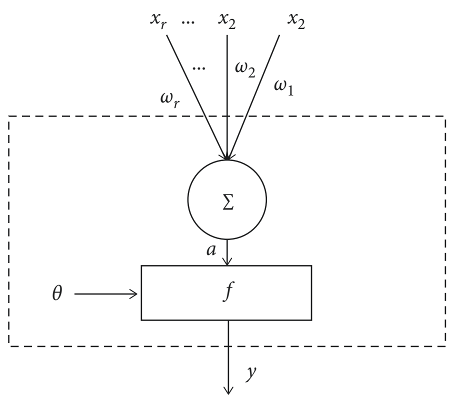


Figure 2: Neuron model.

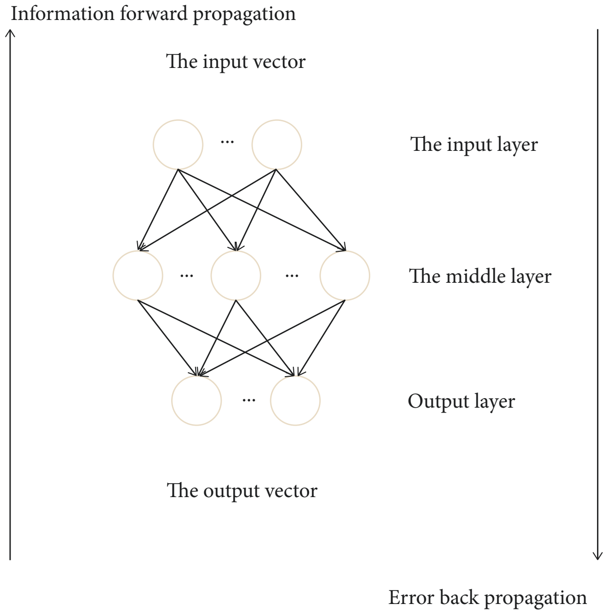


Figure 3: BP network model.

parallel distributed structures, nonlinear characteristics, and learning and induction capabilities, becoming prominent in areas such as signal processing and control, pattern recognition, modeling, and time series analysis [18].

The basic information processing unit of ANN is the neuron, also known as a node or a network. The neuron model is shown in Figure 2. Generally, it should have three elements.

(1) A set of connections, the weight on each connection represents the connection strength, can take positive or negative value, positive value means activation and negative values indicate inhibition.

(2) The additive is used to add a synaptic weight to the neuron corresponding to the input signal.

(3) Excitation function that limits the amplitude of neuron output. The excitation function limits the output signal to an acceptable range, making it a finite value, usually in a closed interval [0, 1] or [−1, 1]. In addition, an external bias (threshold) can be added to the neuron model, denoted by θ. The effect of restriction depends on whether it increases or decreases the network input to the excitation function, whether positive or negative. Therefore, artificial nerve cells can be expressed by

$$a = \sum_{i=1}^{r} \omega_i x_i,$$
$$y = f(a + \theta). \tag{1}$$

Among them, $x_1, x_2, \ldots, x_r$ represents the r inputs of a neuron; ω_i represents the connection strength (connection weight) of the ith input; θ is the bias (threshold) of the neuron; and y is the output of the neuron. It can be seen that the artificial neuron is a nonlinear structure with multiple inputs and single output [19].

3.2. BP Neural Network. As shown in Figure 3, the BP network is a neural network of three or more neurons. The BP network has two learning processes.

BP learning algorithm.

The learning process of the BP algorithm is shown in Figure 4.

3.3. Deep Learning Neural Networks. The essence of in-depth training is to improve the accuracy of predictions and classifications by creating multilayer machine learning models and large amounts of training data and ultimately to learn more important data functions. Therefore, the goal of "learning by feature" is a "deep model" approach. Unlike traditional shallow training, in in-depth learning features there are usually five, six, and ten hidden layers, which emphasize the depth of the design structure. The advantage of multilayers is that complex functions can be expressed with fewer parameters and features are highlighted. Significance and need for learning, i.e., the expression of a sample property in the original space, is transformed into a new property space through each layer of properties expressed by the nature of the distribution of the detected data and easily becomes a hypothesis and classification. Using big data to learn features can better represent important data information than artificially construct functions with rules [20].

3.3.1. Basic Concept and Training Process. The basic idea of in-depth training is to use supervised training to adjust teachers at each level to unsupervised training, and their learning outcomes are used as input from the previous level. The layers of single-layer neurons are made up of layers, and only one layer of the network is trained at a time. Use a cool sleep algorithm to adjust the parameters when training all layers. Change the weight between the layers except the top layer in two directions. In this way, all layers, except the top layer, remain a single-layer neural network, becoming a graphical model. Rising weight is "cognitive" and downward weight is "creating". Then use the sleep algorithm to adjust

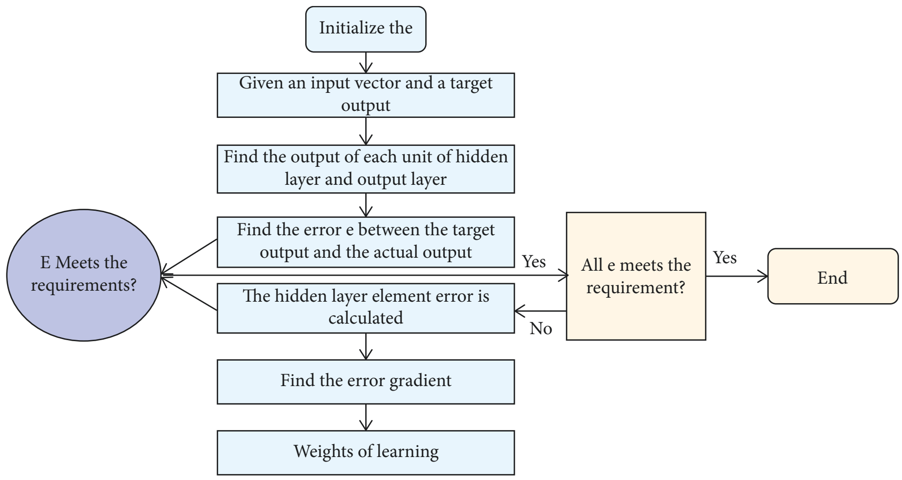


Figure 4: BP network learning flow chart.

the entire weight. Identify and create as much as possible, that is, the top-level representation created can restore the base node as accurately as possible.

The sleep-wake algorithm is divided into two parts: wake and sleep.

① Return Process: The cognitive process uses a gradient reduction method to create an abstract representation of each level (node state) with external characteristics and upward-pointing weights (cognitive weights) and to shift the weight from layer to layer. It changed my weight, so if the reality was different from what I imagined, it would be what I imagined [21].

② Sleep phase: High-level imagery (concepts learned while awake) and the process of creating low-level weights create a low-level state and change the weight from layer to layer. In other words, dreams are not a concept that fits in my head, and it is important to make changes in my cognition. This illusion is what I see.

The training process of deep learning is as follows:

① Learning without supervision from the bottom up (for example, using layers from bottom to top). Uncontrolled hierarchical training of the parameters of each layer using untested data (or using configured data): The biggest difference from traditional neural networks is that this step is tailored to the specifics of the learning process.

② Uncontrolled learning (e.g., labeled data training, top-down error distribution, and fine-tuning of design parameters): Uncontrolled training is based on the parameters of each layer obtained in the first stage and further adjusts multilayer design parameters. Unlike the initial startup of a random neural network, the initial configuration parameters of DL are obtained by studying the input data structure in the first stage, so it is not a random startup, and the initial value is close to global optimization. You can achieve better results. Thus, the effects of DL benefit from the effects of the early learning process.

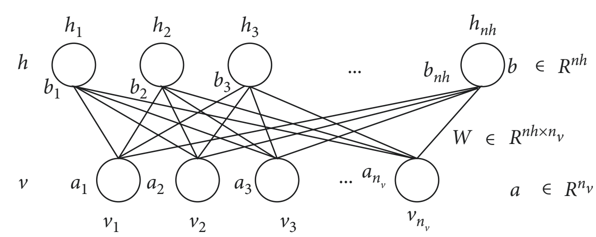


Figure 5: RBM model.

3.3.2. Restricted Boltzmann machine

① RBM overview

An RBM consists of a visible layer and a hidden layer, fully connected between layers and no connection within layers. In other words, there are only edges between the visible and hidden parts, and there is no edge connection between the visible and hidden parts [22].

Figure 5 is the structure of the RBM network, where n_v and n_h are the visible and hidden layers of the number of neurons in the text, v is the subscript, and the visible and hidden layers are h.

② RBM learning algorithm

The methods of interpreting RBM are the energy function and the probability distribution function. The combination of these two methods shows that the probability distribution is a function of the energy function.

$$E_\theta(v,h) = -\sum_i a_i v_i - \sum_j b_j h_j - \sum_{ij} v_i w_{ij} h_j \theta = \{W, a, b\}, \tag{2}$$

where $\theta = \{W, a, b\}$ is a parameter of the RBM model, a_i represents the bias of the visible layer node i, b_i represents the bias of the hidden layer node j, $w_{i,j}$ represents the connection weight between the visible layer node i and the hidden layer node j.

It can be seen from the energy function that the distribution of the joint probability can be determined from the Boltzmann distribution and the setting energy.

$$P_\theta(v, h) = \frac{1}{Z_\theta}\exp\left(-E_\theta(v, h)\right). \tag{3}$$

Among

$$Z_\theta = \sum_{v,h}\exp\left(-E_\theta(v, h)\right). \tag{4}$$

Z_θ is the normalization factor, also known as the partition function.

Because the hidden layer nodes are conditionally independent (that is, there is no connection between nodes), that is

$$P(h|v) = \prod_j P\left(h_j|v\right). \tag{5}$$

Further, factorizing the above formula factorizes, it can be obtained that on the basis of a given visual layer v, the probability that the jth node of the hidden layer is 1 or 0 is

$$P\left(h_j = 1|v\right) = \frac{1}{1 + \exp\left(-\sum_i W_{ij}v_i - b_j\right)}. \tag{6}$$

Similarly, given the hidden layer h, the probability that the ith node of the visible layer is 1 or 0 is

$$P(v|h) = \prod_i P\left(v_j|h\right), \tag{7}$$

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

Given training samples, training an RBM means learning to tune the parameters $\theta = \{W, a, b\}$. Even if this parameter is used to adjust a given training sample, the probability distribution expressed by the corresponding RBM is as close as possible to the training data.

Given a sample set that satisfies the independent and identical distribution: $S = \{v^{(1)}, v^{(2)}, \ldots, v^{(N)}\}$, the goal of training an RBM is to maximize the following log-likelihood function (maximum likelihood estimation: for a probability model, you need to choose a parameter that maximizes the probability of the current observed sample).

$$L_\theta = \prod_{i=1}^{N} P\left(v^i\right). \tag{9}$$

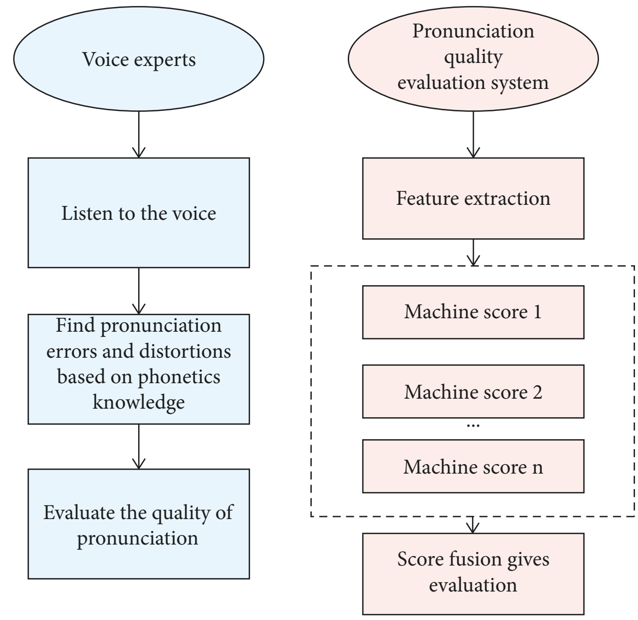


Figure 6: Comparison of subjective evaluation and objective evaluation of speech pronunciation quality.

Since the multiplication $\prod_{i=1}^{N} P(v^i)$ is more troublesome to deal with, according to the strict monotonicity of the function 1nx, maximizing L_θ is equivalent to maximizing InL_θ.

③ RBM evaluation method

The simplest assessment measure for learning RBM is the RBM log-probability of learning data. However, due to regulatory factors, the complexity of the calculations is very high and the advantages and disadvantages of RBM can only be assessed by approximation. The most commonly used approximation is the recovery error. The training sample is the initial state. The difference between the initial data and the initial data after the GBM transfer is made by RBM distribution. The recovery error is the probability of RBM. Training samples can be evaluated. It is not reliable. However, in general, the calculation is very simple and very low cost [23].

3.3.3. Pronunciation Quality Evaluation. The pronunciation quality evaluation of speech can be divided into subjective evaluation and objective evaluation, as shown in Figure 6. Subjective evaluation refers to the evaluation of the pronunciation quality of speech by language experts. The process can generally be divided into three steps: first is to listen to the test voice; then, according to the prior knowledge of language accumulated by oneself, the test voice is compared with the standard voice in memory, the differences between the two at all levels are discovered; finally, the differences of each level are integrated, and the overall evaluation of the test speech is given. Generally speaking, language experts evaluate the pronunciation of test speech, it can more realistically reflect the pronunciation quality of the

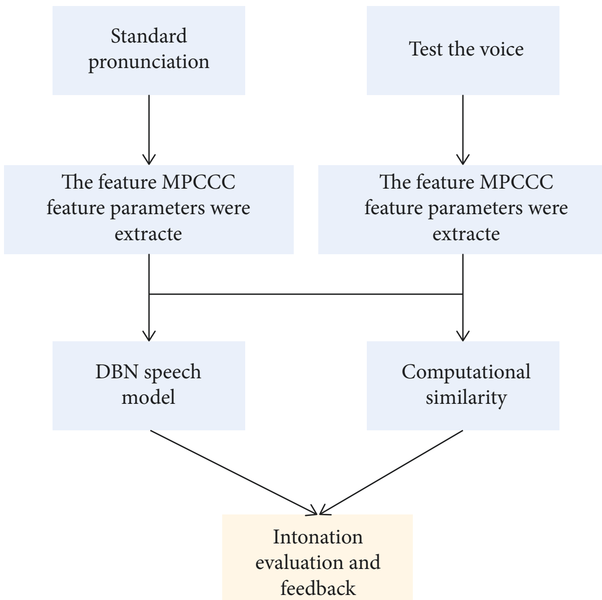


Figure 7: Pitch evaluation.

test voice and the tester's spoken English level. However, due to the differences in the knowledge structure and experience among language experts, different experts may have biases on the same test speech. In addition, since the evaluation of speech pronunciation quality is not only closely related to phonetics and linguistics but also related to physiology and psychology, even with the same test voice, the evaluation given by the same expert in different states may also be different. Therefore, the subjective evaluation of pronunciation quality ensures the authenticity of the evaluation results, but it also exposes its subjective shortcomings. Objective evaluation refers to the use of machines to automatically evaluate the pronunciation quality of speech. Computers are used to objectively evaluate learners' pronunciation quality, it can effectively overcome the shortcomings of subjective evaluation, reduce evaluation deviation, and improve evaluation efficiency. Objective evaluation has a unified evaluation standard, when faced with a large number of speech evaluation tasks, its advantages will be more prominent. The design of the objective evaluation system should simulate the evaluation process of English experts on test speech as much as possible.

① Pitch evaluation

The sound assessment mainly checks that the information in the pronunciation of the pronunciation is complete and accurate, that the pronunciation is clear and fluent, and that the pronunciation is inaccurate. The author uses the MFCC coefficient as a parameter to evaluate the sound level of the human hearing model, creates a speech recognition model through a network of deep speech recognition trusts, and filters out the completeness or accuracy of the content. As shown in Figure 7, the standard is used to calculate the characteristics of the input sentence and MFCC, to assess whether the pronunciation is clear and fluent, to make a comprehensive assessment, and to comment on the quality of the English pronunciation.

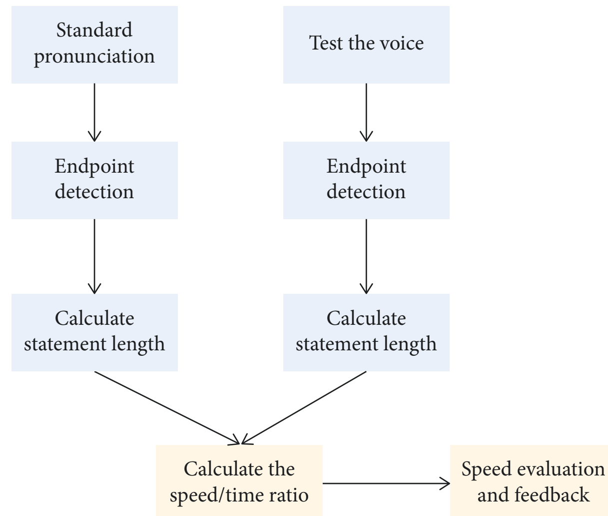


Figure 8: Speech speed evaluation.

② Speaking speed evaluation

There is a definite difference in sentence length between different people because the speed of speech is different between different speakers who pronounce the same sentence. In addition, the speaker's emotional state affects the speed of speech, such as anger and joy, for example, the speed of speech is slightly faster than moderate, while sadness is generally slower. As shown in the following formula:

$$\phi = \frac{Len_{Std}}{Len_{\mathrm{Test}}}. \tag{10}$$

Among them, Len_{Std} is the duration of the standard sentence and Len_{Test} is the duration of the test sentence.

Further, ϕ is compared with the set speech rate threshold, as shown in Figure 8.

4. Experimental Simulation and Result Analysis

4.1. Data Sources. The authors used a set of spoken Arabic numerical data from a UCI machine training warehouse developed by the Institute of Automatic Signaling at Baji Mokhtar University. The data set is an Arabic numeral call derived from the MFCC's 13th function parameter, containing 8,800 conversational data (10 calls in 10 Arabic numerals, each digit repeated 10 times) consisting of 44 women aged 16–40 years. The parameters that need to be set before decomposing the MFCC function parameters are 16 kHz sampling rate, 16 bit encoding, Hamming window is used to add the window function, and the prehighlighted filter function is 1–0.97 Z-1.

4.2. English Sentence Data Sources. We are college students, a total of 25 people, 14 boys and 11girls. Subjects were recorded using a soft recording editor with a sampling frequency of 16 kHz and 16 bit encoding. A total of 10 sentences were registered.

(1) We always post it.
(2) Store clothes in the refrigerator.
(4) HE WILL NOTIFY ON WEDNESDAY. I can tell her tonight.
(5) There is black paper on the edge of the paper.
(6) The leader will arrive in seven hours.
(7) What is that bag under the table?
(8) They had just moved to the second floor and are now descending again.
(9) I always come home to see Agnes.
(10) Take it and go with curly hair.

4.3. Experimental Results and Analysis. Here, the author's model is compared with the above model, and the results of the recognition level comparison are shown in Figure 9.

As can be seen from Figure 9, the recognition rate of the DBN model constructed by the author is 96.64%, which is better than the above models.

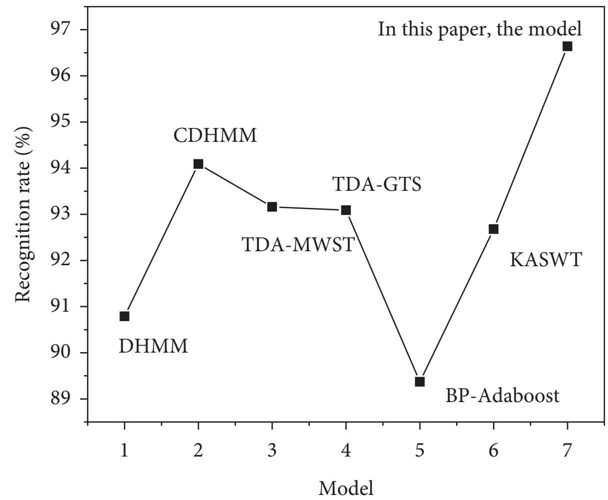


Figure 9: Comparison of recognition rates under different models.

4.4. Speech Evaluation Experiment. The purpose of the speech assessment test is to test the performance of the author's proposed English call quality assessment model and method, and to verify the relationship between machine assessment and manual assessment using examples of the same sentence in English. The specific process includes: first, checking the reliability of the human assessment, and also verifying the correlation between the machine assessment and the human assessment based on the reliability of the human assessment.

The specific method of calculation is as follows:

$$A_{\text{Consistent rate}} = \frac{\text{The sample number of machine evaluation was consistent with manual evaluation}}{\text{Total number of sample books}}. \tag{11}$$

The adjacent agreement rate is the ratio between machine evaluation and manual evaluation, the sum of the adjacent samples, and the total number of samples, among them, "adjacent" is defined as one level difference between machine evaluation and human evaluation. The specific calculation method is as follows:

$$A_{\text{Contiguous uniformity}} = \frac{\begin{pmatrix} \text{Number of samples consistent with machine evaluation and manual evaluation} \\ + \text{number of samples adjacent to machine evaluation and manual evaluation} \end{pmatrix}}{\text{The total number of samples}}. \tag{12}$$

The special method of calculation is as follows:

$$r = \frac{Q\sum a_i b_i - \sum a_i \sum b_i}{\sqrt{Q\sum a_i^2 - \left(\sum a_i\right)^2}\sqrt{Q\sum b_i^2 - \left(\sum b_i\right)^2}}. \tag{13}$$

① Manual evaluation

Depending on the different levels of English speech and the characteristics of the quality of pronunciation of college students, we have a comprehensive assessment of four different levels of assessment by the Committee of English Pronunciation Experts (layers, speed, rhythm, and melody), A, B, C, and D, respectively, and a detailed evaluation statement and related evaluation standards are listed in Table 1.

The manual assessment was conducted by two experienced college English teachers. They evaluated 10 commonly used English phrases written by students of 24 colleges of our school one by one, i.e., dialect, speed of speech, rhythm, melody 4 assessments, and comprehensive assessment indicators.

The author uses the Pearson correlation coefficient to verify the reliability of the manual assessment results, given that the subjectivity of teachers in the manual assessment process may affect the assessment results.

To make it easier to calculate, convert grades A, B, C, and *D* to 4, 3, 2, and 1, respectively. The scores of each of the four evaluation parameters, such as the Pearson's correlation test

Table 1: Manual evaluation grades and evaluation criteria.

Grade	Intonation	Speed of speech	Rhythm	Intonation	Overall
A	The content is complete and accurate, the voice is clear, the whole body is smooth, and there are no obvious pronunciation errors.	Moderate speech rate	Accurate accent pronunciation and strong sense of rhythm	Accurate and natural intonation	Excellent pronunciation in general
B	The content is relatively complete and accurate, the pronunciation is relatively clear and fluent, and there are no serious pronunciation errors.	Speak faster (slow)	Accent pronunciation is more accurate.	The tone is more accurate and natural	Pronunciation is generally good
C	The text is nearly complete with almost clear and fluent pronunciation, and contains word errors that interfere with comprehension.	Speaking too fast (slow)	Good sense of rhythm	The intonation is basically accurate, but not natural enough	General grasp of pronunciation
D	The content is incomplete and accurate, the pronunciation is not clear and fluent, and there are serious pronunciation errors that affect understanding.	Speaking too fast (slow)	Mispronunciation of accents, too many (less) accents, and poor sense of rhythm	The intonation is inaccurate and unnatural	Overall poor pronunciation

Table 2: Evaluation index experimental results - number of samples.

Index Number of samples	Consistent	One level difference	a difference of two	Difference of three
Intonation	258	36	2	0
Speed of speech	187	47	0	0
Rhythm	199	26	4	0
Intonation	187	39	2	0

Table 3: Evaluation experimental results.

Index Level of difference	Concordance rate (%)	Neighbor consistency rate (%)	Pearson
Intonation	87.54	99.68	0.874
Speed of speech	83.65	99	0.541
Rhythm	86.36	98.97	0.569
Intonation	79.83	96.74	0.657

(two-way test), tone, speed, rhythm, and melody, or the total score, are positively correlated for each group ($r > 0$, $p < 0.05$). This suggests that the assessment process for both teachers should be based on essentially the same assessment standards, effectively ensuring the reliability of the experimental information.

Further, the evaluation results of the two teachers are averaged (rounded up), different sentences of different students, each evaluation index and overall score are obtained as the final manual evaluation result [24].

According to the method described by the authors, 24 students, 10 sentences, a total of 240 sentences can be scored for the four evaluation indicators of pitch, speed, rhythm, and intonation, further comparison with manual evaluation, the experimental results are shown in Tables 2 and 3.

The regression analysis method uses mathematical statistics to establish statistical models, study the statistical relationship between the variables of objective things (the structural state and closeness of the relationship), through a large number of experiments and observation data on objective things, look for the statistical regularity hidden in those seemingly uncertain phenomena (that is, the expression of the regression relationship function between the dependent variable and the independent variable), make model predictions. The author uses the overall score of human evaluation as the dependent variable, taking intonation, speech rate, rhythm, and intonation scores as independent variables, English sentences that are completely consistent with human evaluation and machine evaluation are selected, the multiple linear regression analysis method is used, and the weight of each evaluation index is obtained by using the SPSS software, as shown in the following formula:

$$\begin{aligned}\text{Score} = {} & \text{AccuracyScore} \times 0.44 + \text{SpeedScore} \times 0.106 \\ & + \text{RhythmScore} \times 0.341 + \text{IntonationScore} \\ & \times 0.312 - 0.397.\end{aligned} \tag{14}$$

The author also conducted a comprehensive assessment of 24 students with a total of 10 sentences and 240 sentences using formula (14). Figure 10 and Table 4 show the test results. Examples include 210 machine and manual evaluations, 30 samples with first grade differences. The overall compatibility level of the machine and human evaluation is 90.65%, the adjacency consistency level is 90.65%. This is 100%, and the correlation coefficient is 0.798. The quality of speech and pronunciation in English is evaluated.

Some experimental data are shown in Table 5.

Although the results of this experiment are very good, the author reiterates that this may be due to the following factors: (1) the author has a small amount of

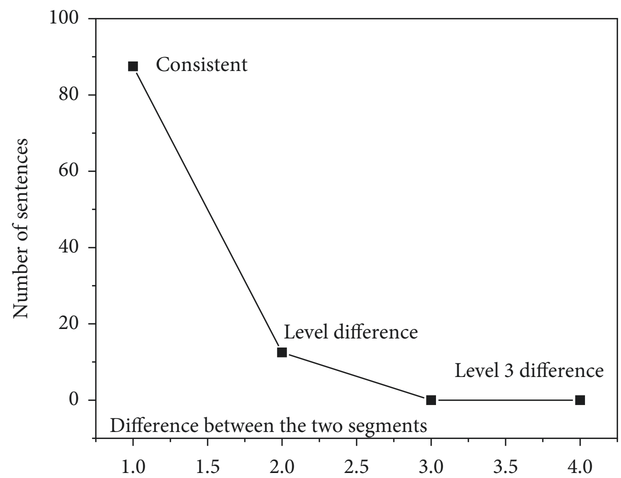


FIGURE 10: Overall evaluation difference between machine and human.

TABLE 4: Overall evaluation experimental results.

Index level of difference	Concordance rate (%)	Neighbor consistency rate (%)	Pearson
Intonation	90.65	100	0.798

TABLE 5: Partial experimental data.

Sentence index		Intonation	Speed of speech	Rhythm	Intonation	Overall
1	Machine rating	A	A	B	A	A
	Human rating	A	A	B	B	A
2	Machine rating	A	B	A	B	A
	Human rating	A	A	B	A	A
3	Machine rating	A	A	B	B	A
	Human rating	A	B	B	C	A
11	Machine rating	A	A	A	B	A
	Human rating	A	A	B	B	A
12	Machine rating	A	B	B	B	A
	Human rating	A	B	B	C	A

data and adjusted the model by linear regression analysis. (2) Two English teachers use the average score as the final score for the manual assessment, and the rounded score is higher. (3) The author uses the four-level scoring method for the assessment. In equation (14), the melody weighs the most, followed by rhythm, melody, and speed. After obtaining the results of the abovementioned experiments, the author contacted the English phonologists of our school and confirmed the reliability of the model for evaluating the quality of speech proposed by the author in many parameters. According to experts, in assessing the quality of English pronunciation, the melody is accurate, the pronunciation is smooth, there are no obvious errors in pronunciation, the rhythm and melody mainly reflect the speaker's emotional tone, improve the tone of voice, improve pronunciation, and tone. It is the most important indicator that requires you to improve and report the tone of the call, optimize the tone of the call, express the tone of the call correctly, pronounce the tone of the call correctly, and avoid making mistakes in the call.

5. Conclusion

With the help of deep learning technology research, neural networks can be rejuvenated with a new round of vitality, and speech recognition technology has also been developed with each passing day. Deep neural networks represent complex functions with few parameters based on the structure of multilayer nonlinear neural networks. The step-by-step conversion of uncontrolled traits can better detect the nature of data distribution and demonstrate excellent learning ability, which is more helpful in improving the accuracy of classifications or hypotheses. This is confirmed by the Arabic numerical data set at the UCI of the machine learning library, and the recognition results are better than the improved latent Markov model, the BP neural network model, and the tree proximity model. In addition, this article uses a deep-faith network model to assess the quality of English speech. A deep-faith network-based speech recognition model is used to assess intonation.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] K. I. Lee, Han, and L. Kun, "Speech recognition and lip shape feature extraction for English vowel pronunciation of the hearing - impaired based on SVM technique," *Journal of Rehabilitation Welfare Engineering & Assistive Technology*, vol. 11, no. 3, pp. 247–252, 2017.

[2] Z. Lv, Y. Li, H. Feng, and H. Lv, "Deep Learning for Security in Digital Twins of Cooperative Intelligent Transportation Systems," *IEEE Transactions on Intelligent Transportation Systems*, vol. 12, 2021.

[3] G. Zhang, "Quality evaluation of English pronunciation based on artificial emotion recognition and Gaussian mixture model," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 2, pp. 1–11, 2020.

[4] G. Wang and J. Zhou, "Dynamic robot path planning system using neural network," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 2, pp. 3055–3063, 2021.

[5] J. Cai and Y. Liu, "Research on English pronunciation training based on intelligent speech recognition," *International Journal of Speech Technology*, vol. 21, no. 3, pp. 633–640, 2018.

[6] Y. H. Long and H. Ye, "Filled pause refinement based on the pronunciation probability for lecture speech," *PLoS One*, vol. 10, no. 4, e0123466 pages, 2015.

[7] Y. Hai, "Computer-aided teaching mode of oral English intelligent learning based on speech recognition and network assistance," *Journal of Intelligent and Fuzzy Systems*, vol. 39, no. 4, pp. 5749–5760, 2020.

[8] H. B. Park, D. H. Kim, and J. Joung, "An automatic pronunciation evaluation system using non-native teacher's speech model," *The Journal of The Institute of Internet Broadcasting and Communication*, vol. 16, no. 2, pp. 131–136, 2016.

[9] L. Qin, "On spoken English phoneme evaluation method based on sphinx-4 computer system," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 12, no. 12, p. 57, 2017.

[10] Y. Wang and P. Zhao, "A probe into spoken English recognition in English education based on computer-aided comprehensive analysis," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 15, no. 03, p. 223, 2020.

[11] Z. Yun, "Research on spoken English speech recognition technology in computer network environment," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 16, pp. 445–449, 2017.

[12] B. Yang, "An evaluation of Korean students' pronunciation of an English passage by a speech recognition application and two human raters," *Phonetics and Speech Sciences*, vol. 12, no. 4, pp. 19–25, 2020.

[13] J. U. Bang, S. H. Kim, and O. W. Kwon, "Performance of speech recognition unit considering morphological pronunciation variation," *Phonetics and Speech Sciences*, vol. 10, no. 4, pp. 111–119, 2018.

[14] M. Liu, X. Chen, M. Li et al., "Improving English pronunciation via automatic speech recognition technology," *International Journal of Innovation and Learning*, vol. 25, no. 2, p. 126, 2019.

[15] H. Ryu, M. Na, and M. Chung, "Pronunciation variation patterns of loanwords produced by Korean and graphene-to-phoneme conversion using syllable-based segmentation and phonological knowledge," *Phonetics and Speech Sciences*, vol. 7, no. 3, pp. 139–149, 2015.

[16] V. Arora, A. Lahiri, H. Reetz, and Henning, "Phonological feature-based speech recognition system for pronunciation training in non-native language learning," *Journal of the Acoustical Society of America*, vol. 143, no. 1, pp. 98–108, 2018.

[17] Z. Lv, S. Zhang, and W. Xiu, "Solving the security problem of intelligent transportation system with deep learning," *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 7, pp. 4281–4290, 2021.

[18] Y. He, P. Baumann, H. Fang et al., "Using pronunciation-based morphological subword units to improve oov handling in keyword search," *IEEE/ACM Transactions on Audio, Speech, and Language Processing*, vol. 24, no. 1, pp. 79–92, 2016.

[19] S. Kim, "A knowledge-based pronunciation generation system for French," *Phonetics and Speech Sciences*, vol. 10, no. 1, pp. 49–55, 2018.

[20] X. Chen, "Simulation of English speech emotion recognition based on transfer learning and CNN neural network," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 2, pp. 2349–2360, 2021.

[21] Y. Hu and X. Li, "An evaluation model of comprehensive human resources quality of financial enterprises based on deep neural network," *Ingénierie des Systèmes d'Information*, vol. 25, no. 5, pp. 629–636, 2020.

[22] S. H. Jung, J. C. Kim, and C. B. Sim, "A novel data prediction model using data weights and neural network based on r for meaning analysis between data," *Journal of Korea Multimedia Society*, vol. 18, no. 4, pp. 524–532, 2015.

[23] B. Rehmam, Z. Halim, G. Abbas, and T. Muhammad, "Artificial neural network-based speech recognition using dwt analysis applied on isolated words from oriental languages," *Malaysian Journal of Computer Science*, vol. 28, no. 3, pp. 242–262, 2015.

[24] T. T. Shi, X. B. Zhang, L. P. Guo, Z. X. Jing, and L. Q. Huang, "Research on remote sensing recognition of wild planted lonicera japonica based on deep convolutional neural network," *Zhongguo Zhong yao za zhi = Zhongguo zhongyao zazhi = China journal of Chinese materia medica*, vol. 45, no. 23, pp. 5658–5662, 2020.

Hindawi
Scientific Programming
Volume 2022, Article ID 4710163, 10 pages
https://doi.org/10.1155/2022/4710163

Research Article

Influence Model of Analyzing the Effect of Mental Health Level Based on Big Data Mining System

Xiaolong Wang

Faculty of Teacher Education, Pingdingshan University, South Weilai Road, Xinhua District, Pingdingshan 467000, Henan, China

Correspondence should be addressed to Xiaolong Wang; wangxl@pdsu.edu.cn

Received 21 February 2022; Revised 21 April 2022; Accepted 3 May 2022; Published 28 June 2022

Academic Editor: Ahmed Farouk

In order to explore the effect of big data mining system on analyzing mental health level, this paper proposes to influence model of analyzing the effect of mental health level based on big data mining system. Through continuous testing and analysis, the main symptom affecting students' mental health is obsessive-compulsive disorder. Therefore, taking obsessive-compulsive disorder as the classification target to view the model, in this application, the factor of compulsion in students' psychology occupies a relatively high proportion. Anxiety, interpersonal relationship, and paranoia have a great impact on goal attribute obsessive-compulsive disorder. The results showed that if the degree of anxiety = medium, there was a tendency of obsessive-compulsive disorder regardless of the degree of interpersonal relationship. If anxiety level = none, when paranoia level = [mild, moderate], obsessive-compulsive symptoms level = mild, and when paranoia level = none, it is related to interpersonal relationship and hostility. If the degree of paranoia = "severe" or "extremely severe", the degree of obsessive-compulsive symptoms = none. If the degree of anxiety = light, there is a tendency of obsessive-compulsive disorder regardless of the degree of interpersonal relationship. If the degree of anxiety = severe, the degree of obsessive-compulsive symptoms = moderate. If the degree of depression = medium, the degree of anxiety = medium. If the degree of depression = none, when the degree of terror = medium, the degree of anxiety = light, and when the degree of terror = [none, light, heavy], there is almost no anxiety. If the degree of depression = mild and the degree of obsessive-compulsive symptoms = none, there is no anxiety tendency. If the degree of depression = severe, the degree of anxiety = severe. If the degree of depression = medium, the degree of interpersonal relationship = medium. If the degree of depression = none, when the degree of terror = light and there is psychosis, the degree of interpersonal relationship = light. If the degree of depression = mild and there is obsessive-compulsive disorder, there are problems in interpersonal relationship. The data analysis of mental health problems has been greatly improved, verifying the reliability of the application of data mining systems in mental health evaluation systems.

1. Introduction

Accompanied by many psychological problems, especially contemporary students [1, 2], when freshmen enter the university campus, they will face a completely different living environment from the past [3]. It is difficult for many students to adapt to this new environment. Moreover, great changes have taken place in the interpersonal relationship around me [4]. I need to make new friends, leave my parents for the first time, and deal with everything by myself. Freshmen will have many negative psychological emotions, such as depression, anxiety, loneliness, etc., resulting in no interest in learning, unwillingness to communicate with others, etc. [5]. At present, universities have to conduct psychological investigation on students when freshmen enter the university, which has also accumulated a large amount of psychological data. However, how to use these psychological measurement data to get more meaningful results, so as to better carry out psychological education? Data mining technology includes many algorithms: cluster analysis (or unsupervised learning), association rule mining, prediction, time series mining, and deviation analysis. We will select appropriate algorithms according to the characteristics of psychological data to achieve the expected data mining objectives, as shown in Figure 1, data analysis, and mining technology [6]. With the large-scale enrollment expansion of universities, the psychological problems of students are more prominent. Psychological education has been paid attention to, and the research on psychological problems is imminent. Among the psychological problems of students, anxiety and depression have become important risk factors affecting students' physical and mental health. Only by their healthy growth and talent can we ensure that the cause of socialism with Chinese characteristics has successors and prosperity.

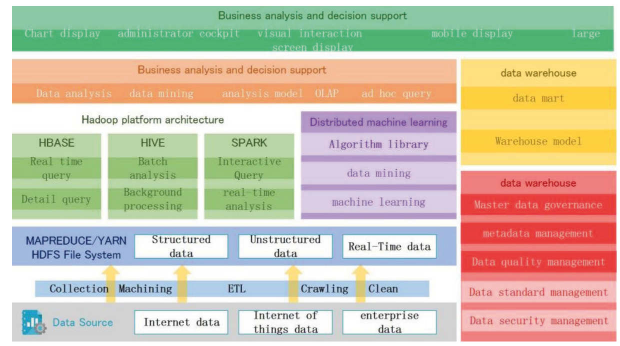


Figure 1: Data analysis and mining.

2. Literature Review

To solve this research problem, Tang et al. proposed tan algorithm (seminaive Bayesian algorithm). Tan relaxed the assumption of conditional independence between attributes and made the results of naive Bayesian algorithm into a tree structure, allowing each node to rely on at most one node other than the parent node [7]. Sp-tan (seminaive Bayesian algorithm) proposed by Li et al. is another tan algorithm. Sp-tan adopts greedy heuristic search algorithm. When selecting each edge, it will select the edge that will improve the accuracy of the whole classifier the most [8]. Tabbakha and Razavi combine inert learning with tan, which also weakens the hypothesis of conditional independence [9]. Jie et al. made a corresponding comparison between LBR (rule extraction algorithm) and tan and proposed lazy tan (seminaive Bayesian algorithm) in combination with their characteristics. The quality of a classifier cannot be fully evaluated by the accuracy of classification [10]. Liu et al. used AUC as the classification degree to add parent nodes [11]. Usui et al. combined boosting with tan and proposed a higher performance classification algorithm [12]. Alharbi and Shahrjerdi proposed another two-layer improved algorithm, which divides the attribute set into strong attribute set and weak attribute set. Any two attributes in the strong attribute set have dependencies, and the weak attribute sets are conditionally independent. The result of Bayesian network is a probability graph model, which also has a good structure and does not require conditional independence between attributes [13]. Kumar et al. applied Bayesian network to the analysis of primary liver cirrhosis and tested its hypothesis with a confidence of 95% [14]. Sharma et al. used Bayesian belief criterion to establish Bayesian network model in incomplete data. Someone proposed smart BN, which can be effectively used to predict human actions in video and can dynamically change the number of nodes and the relationship between nodes [15]. Lukyanov et al. assume that all points of a given cluster obey the same probability distribution, and the objects in the data set are determined according to the maximum probability value in the distribution. Hierarchical clustering, also known as agglomerative clustering, is also a very organized clustering technology. Hierarchical clustering is a method based on greedy algorithm. Each time, it calculates the similarity of data points, then selects the closest elements to form a class, and then inserts them into the original data set. The end condition of iteration is that there is only one point in the data set [16].

Through continuous test and analysis, it is found that the main symptom affecting students' mental health is obsessive-compulsive disorder. Viewing the model with obsessive-compulsive disorder as the classification target, we can understand that anxiety disorder and interpersonal relationship also play a great role. Set the target attributes as anxiety and interpersonal relationship and the output variables as the remaining 9 factor variables to mine the main causes of obsessive-compulsive disorder, so as to provide reference for staff guiding mental health.

3. Method

3.1. Main Process of Data Mining. After years of exploration and research, people have summarized the basic process of data mining technology [17, 18]. It includes cleaning, extracting, and transforming the required data from the initial data that has not been cleaned up, generating a data set, establishing a classification or clustering model on this, and finally extracting and analyzing the information [19] (the specific process is shown in Figure 2).

3.2. Decision Tree. Decision tree is a very classic classification algorithm, which has good classification effect, and its result model has good interpretation function. Decision tree is a tree data structure composed of decision nodes and decision leaves. A leaf node can determine the category of an instance, and the function of the node is to determine how to select the next node in the test case by comparing the attribute values. For discrete attribute a, there are h possible values from $A = d_1, \ldots, A = d_n$. For continuous attributes, each node has a country value. You can judge which branch should be selected by comparing with the threshold. In fact, the classification process of the decision tree is a process of moving the instance from the tree root to the leaf node. The class marks owned by all leaf nodes of the instance are the class marks owned by the instance. At present, the commonly used decision tree algorithms include ID3, C4.5, cart, etc. (as shown in Table 1). The construction algorithm of decision tree is similar. It is a construction method based on greedy thought. The division of nodes is obtained by calculating the information moisture, but the algorithm adopts different information moisture calculation methods [20].

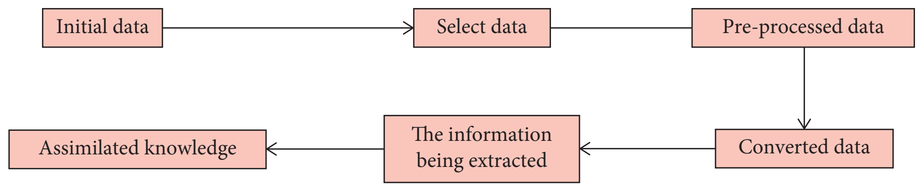


Figure 2: Big data mining process.

Table 1: Common decision tree algorithms.

Decision tree algorithm	Algorithm description
ID3 algorithm	The core of ID3 algorithm is to use the information gain method as the selection criteria of attributes at each level of the decision tree to help determine the appropriate attributes to be used when generating each node.
C4. 5 algorithm	The selection of node attributes is determined by information gain rate, which is a derivation and improvement of ID3 algorithm. ID3 decision tree algorithm is usually suitable for discrete description attributes, while C45 decision tree algorithm can deal with continuous attributes and discrete description attributes.
Cart algorithm	It is a very useful nonparametric classification and regression method. Usually, the construction and generation of binary tree have three processes: Construction tree, pruning tree, and evaluation tree. When the end point is a classification variable, the tree is a classification tree. When the end point is a persistent variable, the tree is a regression tree.

3.3. Principle of Decision Tree. The construction of decision tree is recursively realized by top-down greedy algorithm. In each internal node, select the test attribute with the best classification effect to classify the training sample set, and recursively call the process to construct the following sub-branches until all attributes are used or all training samples belong to the same category. If the data instance and the node type in the decision tree are the same, it will be classified into the same class. If the two are different, the instance is placed as a new node in the corresponding decision tree. Repeatedly, the decision tree containing only one root node can be extended to a complete decision tree [21], as shown in Figure 3.

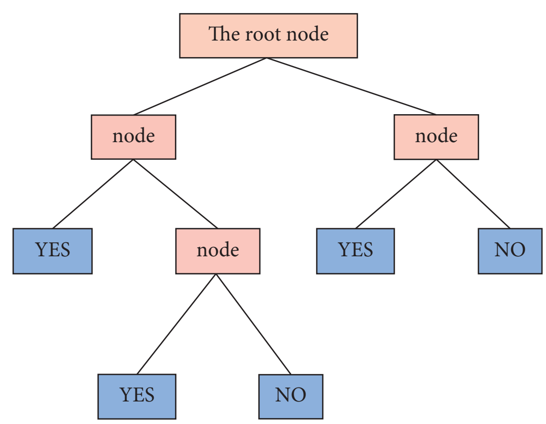


Figure 3: Decision tree.

3.4. Data Acquisition. The data used in this study comes from the SCL-90 psychological data of first-year students in a university. There are 1643 people in this test, 989 girls and 654 boys [22].

The data mining process of students' mental health evaluation is shown in Figure 4.

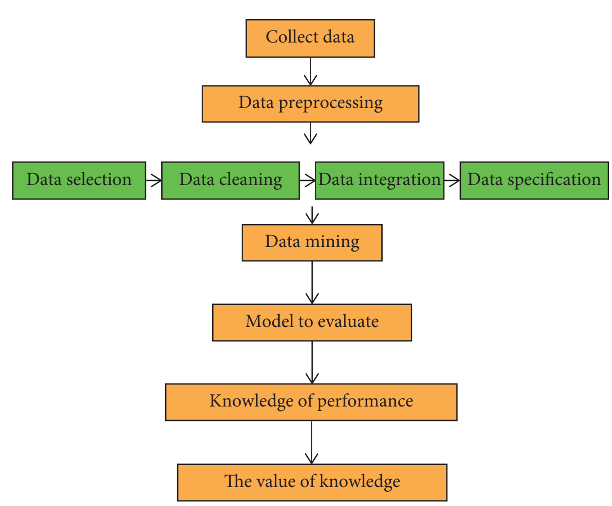


Figure 4: Data mining flowchart of student mental health evaluation.

3.5. Data Preprocessing. Data preprocessing is an important link in the process of data mining. Data mining usually deals with data containing a lot of noise, fuzzy data, redundant data, or incomplete data. In the mental health evaluation data of students, incomplete data and invalid data are caused by students' carelessness or other reasons, which will lead to a lot of inaccurate noise data. Due to the existence of these worthless data, it will eventually affect the accuracy of mining analysis results. Through data preprocessing, the level of mining can be greatly improved and the time spent in analysis can be reduced [23–25].

3.5.1. Data Selection. Data selection is a common data processing method for data analysis and mining in the early stage. It is the first step of data preprocessing. Due to the large scale of the original data set, mining and analyzing all data sets cost a lot of operation resources and operation cycle, so it is necessary to select data from the data set to reduce the impact on the results [26]. According to the mining project objectives, collecting and finding the information records in the data set can not only simplify the data content, but also find the internal relations between attributes and the laws hidden behind the data. Delete the useless information of the student basic information table, including student ID, ID number, name, date of birth, native place, telephone number, and other attributes. This information will only affect the efficiency of mining calculation. For the attribute of students' nationality, because the students in school are mainly Han and there are few other nationalities, the deletion of nationalities has no impact on the mining results.

Delete the useless information in the "student mental health evaluation form," including the student number, gender, department, major, and other attributes of students, with the selection score of 90 questions in the psychological evaluation symptom checklist SCL-90, and retain 10 psychological dimension factors as the analysis content of data mining [27].

Finally, the data fields associated with the mining task are determined by deleting the useless attribute information in the above two tables. The data set required for the student basic information table is composed of gender (XB), household registration (HK), only child (DSZN), and family status (JTZZ). The data required by the student mental health evaluation form are composed of obsessive-compulsive symptoms (QPZZ), depression (YY), somatization (QTH), hostility (DD), anxiety (JL), interpersonal sensitivity (RJGX), psychosis (JSBX), phobia (KB), paranoia (PZ), and others (QT).

3.5.2. Data Cleaning. The main purpose of this operation is to eliminate redundancy, errors, and noise in data. Data cleaning is mainly to filter and remove duplicate data, supplement and improve incomplete data, and correct or delete wrong data. Duplicate data is mainly information with the same attribute value, incomplete data is mainly missing due information, and wrong data is mainly information written directly to the database without judgment.

3.5.3. Data Integration. Data integration is the process of integrating records from multiple related data sets into a new one to the mining target content. The data used in the paper mainly comes from the student basic information table and SCL-90 mental health evaluation table. The two tables are connected through the associated field XH (student number), and a new student mental health evaluation table is generated from the data set determined in the "data selection" process, as shown in Tables 2 and 3.

3.5.4. Data Specification. Data specification is a crucial link in data mining processing [28–30]. In data processing, we must first convert the data into a data form in line with data mining. The conversion principle usually uses continuous data discretization and discrete data classification. In this paper, the data standard operation is carried out for the information of "student SCL-90 mental health evaluation form." The main processes are as follows.

Data discretization: the continuous data discretization of mental health test scale is helpful to data mining operation. According to each item in the symptom checklist SCL-90, grade 1 to 5 scores were taken, and 10 factors reflected psychological symptoms. If any of these factors scores more than 2 points, the screening can be regarded as positive. Therefore, the 10 factor scores of psychological symptoms are divided into two intervals: symptomatic and asymptomatic, of which more than 2 points are symptomatic and less than 2 points are asymptomatic.

Data categorization: there are many attribute values of student household registration and family economic situation. Classification conversion is required before data mining. Finally, the household registration is divided into rural (HK1) and urban (HK2), and the family economic situation is divided into difficult families (JT1) and non-difficult families (JT2).

xb1 and XB2 are used to represent men and women in gender; BX1 represents the department of nursing, bx2 represents the department of pharmacy, BX3 represents the department of medical technology, bx4 represents the department of clinical medicine, and bx5 represents the Ministry of Public Affairs; DS1 and DS2 are used to indicate whether they are only children.

All attributes in the student mental health evaluation form have passed. The codes after the above principles and specifications are shown in Tables 4 and 5.

The data table of each attribute in the student mental health evaluation table after data standardization is shown in Tables 6 and 7.

3.6. Constructing Decision Tree

3.6.1. Basic Strategy of Decision Tree Induction. Firstly, the splitting criterion of the algorithm is used to find an attribute as the splitting attribute of the training sample set. Then recursively call the above method for the subset on each branch to establish the branch on the node. With the growth of the tree, the training sample set is recursively divided into smaller and smaller subsets until all subsets contain only samples of the same category; that is, they reach the leaf node. Finally, a decision tree classification model similar to flowchart is generated.

3.6.2. Attribute Selection Metrics. Let the data be divided into D as a training sample set containing class marks, and the class label attribute has m different values, then it is defined as m different classes $C_i\,(i = 1, 2, \ldots, m)$, $C_{i,D}$ is the sample set of class C_i in D, $|D|$ is the number of samples in D, and $|C_{i,D}|$ is the number of samples in $C_{i,D}$.

Table 2: Partial data content after data integration 1.

Gender	Registered residence	Only child	Family status	Faculty	Somatization	Obsessive-compulsive symptoms	Depressed	Anxious	Psychotic	Other
Female	Town	Yes	Nonpoor	Nursing department	1.32	1.50	1.32	1.41	1.11	1.28
Female	Town	Yes	Nonpoor	Nursing department	1.16	2.10	1.93	1.61	1.50	1.72
Female	Countryside	No	Poor	Nursing department	1.91	2.30	2.16	2.21	2.00	1.87
Female	Countryside	No	Nonpoor	Nursing department	1.91	2.10	2.01	2.11	1.90	1.56
Female	Countryside	No	Nonpoor	Nursing department	1.32	2.10	1.16	1.31	1.20	1.44
Female	Town	Yes	Nonpoor	Nursing department	1.51	2.30	2.78	2.41	2.40	1.87
Female	Countryside	No	Nonpoor	Nursing department	1.07	1.60	1.29	1.21	1.10	1.02
Female	Countryside	No	Nonpoor	Department of pharmacy	2.32	2.40	2.24	1.71	1.30	1.73

Table 3: Partial data content after data integration 2.

Gender	Registered residence	Only child	Family status	Faculty	Somatization	Obsessive-compulsive symptoms	Depressed	Anxious	Psychotic	Other
Female	Countryside	No	Nonpoor	Department of medical technology	1.51	1.70	1.32	1.20	1.40	1.28
Female	Countryside	No	Nonpoor	Department of medical technology	1.16	1.20	1.32	1.20	1.20	1.28
Male	Town	Yes	Nonpoor	Department of clinical medicine	2.07	2.70	1.93	2.50	2.70	2.15
Female	Countryside	No	Poor	Department of clinical medicine	2.57	2.90	2.47	2.30	2.50	2.44
Female	Town	Yes	Nonpoor	Department of clinical medicine	1.01	1.30	1.01	1.10	1.10	1.15
Female	Countryside	No	Poor	Department of clinical medicine	1.18	1.90	1.55	1.7	1.5	1.15
Male	Countryside	Yes	Nonpoor	Department of clinical medicine	1.00	1.00	1.00	1.30	1.20	1.20
...	...	...	...	...	...	...	...	...	...	...

3.6.3. Information Gain. Let node n store all samples of data division D. The expected information required for sample classification in D is given by the following formula:

$$\text{Info}(D) = -\sum_{i=1}^{m} P_i \log_2 (P_i), \tag{1}$$

where p_i is the probability that any sample in D belongs to C_i, which is calculated by $|C_{i,D}|/|D|$. In fact, the above formula is only the proportion of the number of samples of each class in the total number of samples. Info(D) is also called the entropy of D. Entropy is a statistic used to measure the degree of chaos of a system.

Suppose that the samples in D are divided according to attribute a, and attribute a has V different values $\{a_1, a_2, \ldots, a_v\}$. If the value of attribute a is a discrete value, attribute a can divide d into v subset $\{D_1, D_2, \ldots, D_v\}$, where the value of the sample in D_j $(j = 1, 2, 3 \ldots v)$ on attribute A is a_j. These subsets correspond to each branch growing from node N. The expected information required for the sample classification of D based on attribute a can be obtained from the following formula:

$$\text{Info}_A(D) = -\sum_{i=1}^{v} \frac{|D_j|}{|D|} \times \text{Info}(D_j), \tag{2}$$

where $|D_j|/|D|$ is the weight of the subset whose value is a_j on attribute A. Info$_A(D)$ is the expected information required to classify D samples based on attribute A.

Knowing the value of attribute a leads to the reduction of entropy, which can be obtained from the following formula:

Table 4: Standard Table 1 of "students' mental health evaluation table."

Attribute	Explain	Attribute value	Code
XB	Gender	Male Female	XB1 XB2
BX	Department	Nursing department Department of pharmacy Department of medical technology Department of clinical medicine Public Ministry	BX1 BX2 BX3 BX4 BX5
HK	Registered residence	Countryside Town	HK1 HK2
DSZN	Only child	Yes No	DS1 DS2
JTZZ	Family status	Difficult family Nonneedy households	JT1 JT2
QTH	Somatization	Symptomatic Asymptomatic	QT1 QT2
QPZZ	Obsessive-compulsive symptoms	Symptomatic Asymptomatic	QP1 QP2

Table 5: Standard Table 2 of "students' mental health evaluation table."

Attribute	Explain	Attribute value	Code
RJGX	Interpersonal sensitivity	Symptomatic Asymptomatic	RJ1 RJ2
YY	Depressed	Symptomatic Asymptomatic	YY1 YY2
JL	Anxious	Symptomatic Asymptomatic	JLI JL2
DD	Hostile	Symptomatic Asymptomatic	DD1 DD2
KB	Terror	Symptomatic Asymptomatic	KB1 KB2
PZ	Paranoid	Symptomatic Asymptomatic	PZ1 PZ2
JSBX	Psychotic	Symptomatic Asymptomatic	JS1 JS2
QT	Other	Symptomatic Asymptomatic	QT1 QT2

Table 6: Mental health assessment of students (data 1).

XB	HK	DSZN	JTZK	BX	QTH	QPZZ	RJGX	YY	JL	DD	KB	PZ	JSBX	QT
XB2	HK2	DS1	JT2	BX1	QTH2	QP2	RJ2	YY2	JL2	DD2	KB2	PZ2	JS2	QT2
XB2	HK2	DS1	JT2	BX1	QTH2	QP1	RJ2	YY2	JL2	DD2	KB2	PZ2	JS2	QT2
XB2	HK1	DS2	JT1	BX1	QTH2	QP1	RJ1	YY1	JL1	DD1	KB2	PZ1	JS2	QT2
XB2	HK1	DS2	JT2	BX1	QTH2	QP1	RJ1	YY1	JL1	DD1	KB2	PZ2	JS2	QT2
XB2	HK1	DS2	JT2	BX1	QTH2	QP1	RJ2	YY2	JL2	DD2	KB2	PZ2	JS2	QT2
XB2	HK2	DS1	JT2	BX1	QTH2	QP1	RJ1	YY1	JL1	DD1	KB1	PZ1	JS1	QT2
XB2	HK1	DS2	JT2	BX1	QTH2	QP2	RJ2	YY2	JL2	DD2	KB2	PZ2	JS2	QT2

$$\text{Gain}(A) = \text{Info}(D) - \text{Info}_A(D). \tag{3}$$

3.6.4. Gain Rate. Based on the splitting of attribute XH (student number), because everyone's student number is different, there will be as many divisions as the number of student number attribute values, and these divisions are pure, and each division has only one data record. According to formula (2), the expected information required for the division of D samples according to XH (student number) can be obtained:

Table 7: Mental health assessment of students (data 2).

XB	HK	DSZN	JTZK	BX	QTH	QPZZ	RJGX	YY	JL	DD	KB	PZ	JSBX	QT
XB2	HK1	DS2	JT2	BX2	QTH1	QP1	RJ2	YY1	JL2	DD2	KB1	PZ2	JS2	QT2
XB2	HK1	DS2	JT2	BX2	QTH2	QP2	RJ2	YY2	JL2	DD2	KB2	PZ2	JS2	QT2
XB2	HK1	DS2	JT2	BX3	QTH2	QP2	RJ2	YY2	JL2	DD2	KB2	PZ2	JS2	QT2
XB2	HK2	DS1	JT2	BX3	QTH1	QP1	RJ1	YY2	JL1	DD1	KB2	PZ1	JS1	QT1
XB2	HK1	DS2	JT1	BX4	QTH1	QP1	RJ1	YY1	JL1	DD1	KB1	PZ1	JS1	QT1
XB2	HK2	DS1	JT2	BX5	QTH2	QP2	RJ2	YY2	JL2	DD2	KB2	PZ2	JS2	QT2
XB2	HK1	DS2	JT1	BX6	QTH2	QP2	RJ2	YY2	JL2	DD2	KB2	PZ2	JS2	QT2

$$\text{Info}_{\text{XH}}(D) = 0. \tag{4}$$

According to formula (3), the information gain of this attribute is the largest and will be preferentially regarded as the splitting attribute. However, for classification, it is meaningless to divide based on student number.

The basic principle of C4.5 is the same as that of ID3. The difference is that C4.5 uses the gain rate instead of the information gain as the attribute selection measure (splitting rule) to make up for the disadvantage that ID3 prefers attributes with more selection values when using the information gain to select attributes. The information gain rate is defined as follows:

$$\text{GainRatio}(A) = \frac{\text{Gain}(A)}{\text{SplitInfo}(A)}. \tag{5}$$

Split information is used in the above formula to normalize the information gain. Split information is similar to info (D), which is defined as

$$\text{SplitInfo}_A(D) = -\sum_{j=1}^{v} \frac{|D_j|}{|D|} \times \log 2\left(\frac{|D_j|}{|D|}\right) \times \log 2\left(\frac{|D_j|}{|D|}\right), \tag{6}$$

$\text{SplitInfo}_A(D)$ represents the information generated by dividing the training sample set D into v plans corresponding to V outputs of attribute A test.

4. Results and Analysis

4.1. Construct the Decision Tree of Students' Psychological Problems. Steps 1 and 2 are performed recursively on each of the split sub-data sets.

The class label attribute Mg (interpersonal sensitivity) has two different values: 1 (symptomatic) and 0 (asymptomatic). Therefore, the training sample set has two different categories. We first calculate the expected information of training sample set D classification as follows:

$$\begin{aligned} &\text{Info}(D) = -\frac{270}{960} \times \log 2\frac{270}{960} - \frac{690}{960} \times \log 2\frac{690}{960}, \\ &\text{Info}(D) = 0.85714844. \end{aligned} \tag{7}$$

Next, the expected information of each split attribute needs to be calculated. Taking XB (gender) as an example, attribute XB has two different values: xb0 (male) and xb1 (female). Therefore, according to the value of attribute XB, samples can be divided into two categories: xb0 and XB1. There are 370 samples in XB0, of which 40 samples have a value of 1330 on attribute mg and 0 on attribute mg. There are 590 samples in xb1, of which 230 samples have a value of 1360 on attribute mg and 0 on attribute MG. According to formula (2), classify the samples in D as

$$\text{Info}_{\text{XB}}(D) = 0.78334879. \tag{8}$$

Therefore, according to formula (3), the information gain of attribute XB (gender) can be obtained as

$$\begin{aligned} &\text{Gain}(XB) = \text{Info}(D) - \text{Info}_{\text{XB}}(D), \\ &\text{Gain}(XB) = 0.07379965. \end{aligned} \tag{9}$$

Then, according to formula (6), the splitting information of attribute XB (gender) can be obtained as follows:

$$\begin{aligned} &\text{SplitInfo}_{\text{XB}}(D) = -\frac{370}{960} \times \log 2\frac{370}{960} - \frac{590}{960} \times \log 2\frac{590}{960}, \\ &\text{SplitInfo}_{\text{XB}}(D) = 0.96177798. \end{aligned} \tag{10}$$

Finally, according to formula (5), gain rate of attribute is as follows:

$$\begin{aligned} &\text{GainRatio}(\text{XB}) = \frac{\text{Gain}(\text{XB})}{\text{SplitInfo}_{\text{XB}}(D)}, \\ &\text{GainRatio}(\text{XB}) = 0.07673252. \end{aligned} \tag{11}$$

Using the same method, the information gain rates of attributes ZY (Major), SY (place of origin), DS (only child or not), DQ (single parent family or not), and JJ (family economic status) are calculated as follows:

$$\begin{aligned} \text{GainRatio}(\text{ZY}) &= 0.02068808, \\ \text{GainRatio}(\text{SY}) &= 0.03070646, \\ \text{GainRatio}(\text{DS}) &= 0.18323913, \\ \text{GainRatio}(\text{DQ}) &= 0.12276085, \\ \text{GainRatio}(\text{JJ}) &= 0.11974200. \end{aligned} \tag{12}$$

The sample is divided into two subsets according to whether it is only child or not. Repeat the above steps to classify the sub-data set of each branch, and then export the branch again. With the increase and extension of branches, the sample data set is recursively divided into smaller sub-data sets.

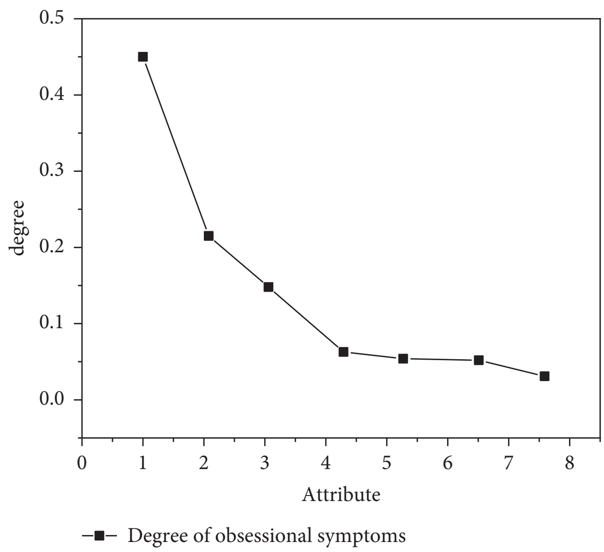


Figure 5: Results of obsessive-compulsive symptom degree model.

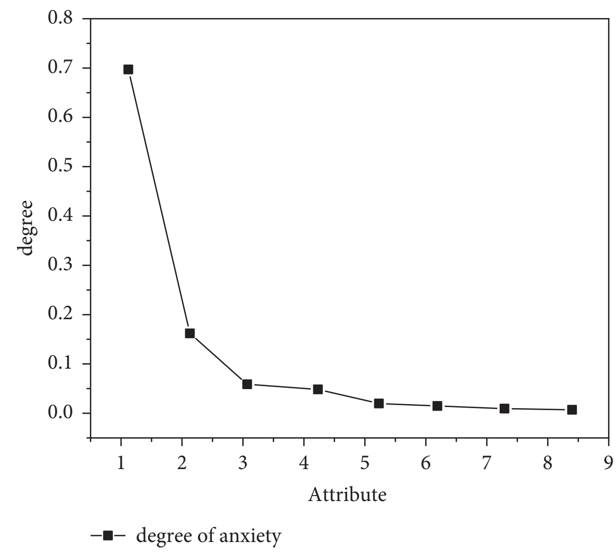


Figure 6: Anxiety model results.

Through continuous testing and analysis, the main symptom affecting students' mental health is obsessive-compulsive disorder. Therefore, when viewing the model with obsessive-compulsive disorder as the classification target, the results shown in Figure 5 can be obtained, according to C4.5 algorithm principle. It can be seen from Figure 2 that anxiety disorder and interpersonal relationship also play a great role.

Set the target attribute as anxiety level and interpersonal relationship level, respectively, set the output variable as the remaining 9 factor variables, and execute the data flow. The results are shown in Figures 6 and 7, respectively.

Dig out the main causes of OCD, as shown in Figure 8.

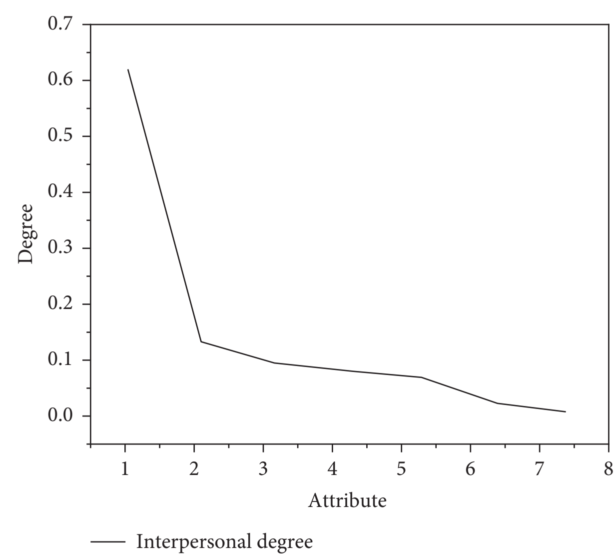


Figure 7: Results of interpersonal relationship degree model.

4.2. Analysis. From various angles, on the whole, the psychological quality of students is healthy. In this application, the factor of compulsion in students' psychology occupies a relatively high proportion. Anxiety, interpersonal relationship, and paranoia have a great impact on goal attribute obsessive-compulsive disorder.

It can be seen from Figure 2 that if the anxiety level = medium, there is a tendency of obsessive-compulsive disorder regardless of the degree of interpersonal relationship. If anxiety level = none, when paranoia level = [mild, moderate], obsessive-compulsive symptom level = light; when paranoia level = none, it is related to interpersonal relationship and hostility; if paranoia level = "heavy" and "extremely heavy", obsessive-compulsive symptom level = none. If the degree of anxiety = light, there is a tendency of obsessive-compulsive disorder regardless of the degree of interpersonal relationship. If the degree of anxiety = severe, the degree of obsessive-compulsive symptoms = moderate.

As can be seen from Figure 3, if the degree of depression = medium, the degree of anxiety = medium. If the degree of depression = none, when the degree of terror = medium, the degree of anxiety = light, and when the degree of terror = [none, light, heavy], there is almost no anxiety. If the degree of depression = mild and the degree of obsessive-compulsive symptoms = none, there is no anxiety tendency. If the degree of depression = severe, the degree of anxiety = severe.

As can be seen from Figure 4, if the degree of depression = medium, the degree of interpersonal relationship = medium. If the degree of depression = none, when the degree of terror = light and there is psychosis, the degree of interpersonal relationship = light. If the degree of depression = mild and there is obsessive-compulsive disorder, there are problems in interpersonal relationship.

As can be seen from Figure 5, in the known mining results, it is found that the causes of students' psychological obsessive-compulsive disorder are mainly distributed in family atmosphere, family structure, and origin. Children from healthy families are full of hope for life and have great confidence in their emotional life. Due to the lack of parental

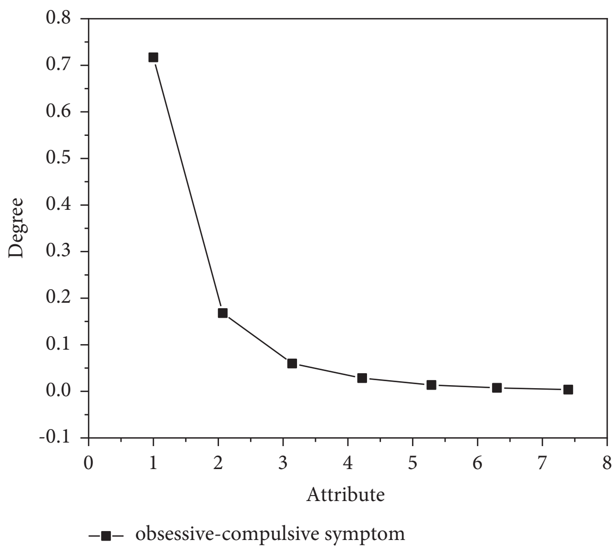


Figure 8: Mining results of forced symptom decision tree.

care, lack of sense of security, nerve sensitivity, and emotional vulnerability, students who have both parents died are always timid in doing things, and their psychological problems are very significant. Unsound families with single parents or divorced parents will always do harm to their children's mental health in varying degrees and levels.

5. Conclusion

This paper proposes to influence model of analyzing the effect of mental health level based on big data mining system. Through continuous test and analysis, it is found that the main symptom affecting students' mental health is obsessive-compulsive disorder. Viewing the model with obsessive-compulsive disorder as the classification target, we can understand that anxiety disorder and interpersonal relationship also play a great role. Set the target attributes as anxiety and interpersonal relationship and the output variables as the remaining 9 factor variables to mine the main causes of obsessive-compulsive disorder, so as to provide reference for staff guiding mental health. Future association rule algorithms can be used to analyze students' attribute data, with more intensive research.

Data Availability

The data that support the findings of this study are available from the author upon reasonable request.

Conflicts of Interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

[1] A. J. Mian and K. Fazlullah, "Application of big data, blockchain, and internet of things for education informatization," in *Proceedings of the First EAI International Conference, BigIoT-EDU 2021, Virtual Event*, August 2021.

[2] Y. Jian, Y. Cheng, D. Lin et al., "Analyzing the effect of the incidence angle on chlorophyll fluorescence intensity based on laser-induced fluorescence lidar," *Optics Express*, vol. 27, no. 9, pp. 12541–12550, 2019.

[3] Y. A. Eremin and A. G. Sveshnikov, "Method for analyzing the influence of the quantum nonlocal effect on the characteristics of a plasmonic nanolaser," *Doklady Mathematics*, vol. 101, no. 1, pp. 20–24, 2020.

[4] R. Shirey and H. Wu, "Su-f-t-194: analyzing the effect of range shifter air gap on tps dose modeling accuracy in superficial pbs proton therapy," *Medical Physics*, vol. 43, no. 6, Article ID 3506, 2016.

[5] K. T. Hwang, K. D. Han, S. Oh et al., "Influence of metabolic syndrome on risk of breast cancer: a study analyzing nationwide data from Korean national health insurance service," *Cancer Epidemiology Biomarkers & Prevention*, vol. 29, no. 10, 2047 pages, Article ID 2038, 2020.

[6] C. Chen, Y. Zhu, X. Zeng, G. Huang, and Y. Li, "Analyzing the carbon mitigation potential of tradable green certificates based on a tgc-ffsro model: a case study in the Beijing-Tianjin-Hebei region, China," *Science of the Total Environment*, vol. 630, pp. 469–486, 2018.

[7] T. Q. Tang, Q. Yu, H. J. Huang, and W. X. Wu, "Analyzing the travel time of car-following model on an open road," *Modern Physics Letters B*, vol. 29, no. 12, p. 19, 2015.

[8] S. Li, H. Liao, H. Yuan, Q. Ai, and K. Chen, "A mppt strategy with variable weather parameters through analyzing the effect of the dc/dc converter to the mpp of pv system," *Solar Energy*, vol. 144, pp. 175–184, 2017.

[9] M. Tabbakhha and A. M. F. Razavi, "Analyzing the effect of workmanship quality on performance of unreinforced masonry walls through numerical methods," *Computers & Structures*, vol. 167, pp. 1–14, 2016.

[10] Z. Jie, W. Xuan, L. Zhang, H. Cheng, and Z. Yang, "System dynamics modeling of the influence of the tn/tp concentrations in socioeconomic water on ndvi in shallow lakes," *Ecological Engineering*, vol. 76, no. 5210, pp. 27–35, 2015.

[11] Z. Liu, J. Zhang, Y. Zhang et al., "Effects and interaction of meteorological factors on influenza: based on the surveillance data in Shaoyang, China," *Environmental Research*, vol. 172, pp. 326–332, 2019.

[12] K. Usui, T. Inoue, C. Kurokawa, S. Sugimoto, K. Sasai, and K. Ogawa, "Analyzing the effect of scattered photons on cone beam computed tomography-based adaptive radiation therapy," *International Journal of Radiation Oncology, Biology, Physics*, vol. 96, no. 2, p. E635, 2016.

[13] A. Alharbi and D. Shahrjerdi, "Analyzing the effect of high-k dielectric-mediated doping on contact resistance in top-gated monolayer mos transistors," *IEEE Transactions on Electron Devices*, vol. 65, no. 10, pp. 1–9, 2018.

[14] S. Kumar, M. S. Hur, and M. Chung, "Analyzing the effect of slotted foil on radiation pulse profile in a mode locked afterburner x-ray free electron laser," *Journal of Applied Physics*, vol. 121, no. 24, Article ID 243101, 2017.

[15] P. Sharma, S. Kumar, A. Garg, and C. Ghosh, "Analyzing the effect of atmospheric trace elements on selected plant species," *Environmental Earth Sciences*, vol. 74, no. 12, pp. 7793–7800, 2015.

[16] V. K. Lukyanov, E. V. Zemlyanaya, K. V. Lukyanov, and I. A. M. A. Magead, "Application of a folding-model optical potential to analyzing inelastic pion-nucleus scattering and the in-medium effect on a pion-nucleon amplitude," *Physics of Atomic Nuclei*, vol. 79, no. 6, pp. 978–986, 2016.

[17] A. P. Liu, X. X. Yao, X. Wang, D. X. Yang, and X. M. Zhang, “Damped harmonic oscillator model for analyzing the dynamic characteristics of stm system,” *International Journal of Modern Physics B*, vol. 29, no. 25, Article ID 1542008, 2015.
[18] J. Y. Hong, H. Ko, L. Mesicek, and M. B. Song, “Cultural intelligence as education contents: exploring the pedagogical aspects of effective functioning in higher education,” *Concurrency and Computation Practice and Experience*, vol. 33, 2019.
[19] T. Fujita, “Analyzing the influence of blood loss on outcomes of cancer surgery,” *Annals of Surgery*, vol. 261, no. 3, e70 pages, 2015.
[20] C. Picard, S. Soubeyrand, E. Jacquot, and G. Thébaud, “Analyzing the influence of landscape aggregation on disease spread to improve management strategies,” *Phytopathology*, vol. 109, no. 7, pp. 1198–1207, 2019.
[21] C. Marschik, L. B. Bernhard, and J. Miethlinger, “Analyzing the influence of surface renewal on diffusive mass transport in vented single-screw extruders,” *International Polymer Processing*, vol. 32, no. 3, pp. 387–393, 2017.
[22] T. Baldini, K. Caperton, M. Hawkins, and E. Mccarty, “Effect of a novel sterilization method on biomechanical properties of soft tissue allografts,” *Knee Surgery, Sports Traumatology, Arthroscopy*, vol. 24, no. 12, pp. 3971–3975, 2016.
[23] W. Shi, J. Wang, J. Zheng, J. Jiang, V. Viswanathan, and J.-G. Zhang, “Influence of memory effect on the state-of-charge estimation of large-format li-ion batteries based on lifepo4 cathode,” *Journal of Power Sources*, vol. 312, pp. 55–59, 2016.
[24] M. Elhoseny, G. R. Gonzalez, O. M. A. Elnasr, S. A. Shawkat, N. Arunkumar, and A. Farouk, “Secure medical data transmission model for IoT-based healthcare systems,” *IEEE Access*, vol. 6, pp. 20596–20608, 2018.
[25] A. F. Metwaly, M. Z. Rashad, F. A. Omara, and A. A. Megahed, “Architecture of multicast centralized key management scheme using quantum key distribution and classical symmetric encryption,” *The European Physical Journal - Special Topics*, vol. 223, no. 8, pp. 1711–1728, 2014.
[26] Z. Lv, H. Ko, and K. S. Amit, “Introduction to the special issue on recent trends in medical data security for e-health applications,” *ACM Transactions on Multimedia Computing, Communications, and Applications*, vol. 17, pp. 1–3, 2021.
[27] O. V. Zhukova, S. D. Zaitsev, S. A. Ryabov, E. V. Arkhipova, T. F. Kovaleva, and I. V. Mukhina, “Effect of (co)polymers based on methacrylic acid on the state of cells of the immune system,” *Russian Chemical Bulletin*, vol. 69, no. 8, pp. 1579–1584, 2020.
[28] G. Chen, Y. Lu, B. Li, K. Tan, and T. Moscibroda, “Mp-rdma: enabling rdma with multi-path transport in datacenters,” *IEEE/ACM Transactions on Networking*, no. 99, pp. 1–16, 2019.
[29] G. Chen, Y. Lu, Y. Meng et al., “Fuso: fast multi-path loss recovery for data center networks,” *IEEE/ACM Transactions on Networking*, vol. 26, pp. 1–14, 2018.
[30] Y. Zeng, G. Chen, K. Li, Y. Zhou, X. Zhou, and K. Li, “M-skyline: taking sunk cost and alternative recommendation in consideration for skyline query on uncertain data,” *Knowledge-Based Systems*, vol. 163, pp. 204–213, 2019.

Hindawi
Scientific Programming
Volume 2022, Article ID 9003869, 7 pages
https://doi.org/10.1155/2022/9003869

Research Article

Research on Structuring a "Student-Centered" Training Model of Innovative and Entrepreneurial Graduates in Colleges and Universities

Caiyan Chen

College of Education, Xi'an Fanyi University, Xi'an 710105, Shaanxi, China

Correspondence should be addressed to Caiyan Chen; chencaiyan@xafy.edu.cn

Received 9 April 2022; Revised 21 May 2022; Accepted 31 May 2022; Published 24 June 2022

Academic Editor: Ahmed Farouk

"Student-centered" innovation and entrepreneurship education is a new perspective and new model of higher education concepts in the new century. At present, the talent training model of innovation and entrepreneurship education in Chinese universities has undesirable problems such as the lack of integration of content, the convergence of educational methods, the oversimplistic training method, and the quality of teachers to be improved, which directly affects the effect of innovation and entrepreneurship education. Constructing a student-centered innovation and entrepreneurship education model that effectively combines student development, student learning, and learning effects is a powerful manifestation to emphasize the dominant position of students in the school education system. Establishing a student-centered education concept, a teaching system, and a team of teachers with innovative and entrepreneurial qualities is an important guarantee for building a "student-centered" innovation and entrepreneurship education model. It is also the true embodiment of student-centered, student-based characteristics and the connotation of innovation and entrepreneurship education.

1. Questions Raised

In October 1998, the World Declaration of "Higher Education in the 21st Century: Prospects and Actions" published by the UNESCO World Higher Education Conference in Paris put forward the "student-centered" educational philosophy. And it is noted that "In today's fast-changing world, higher education obviously needs a new student-centered perspective and new model." It is required that "decision makers in the state and higher education institutions should focus on students and their needs and should regard them as the main and responsible participants in the reform of higher education [1]. With the development of new technology, modern technology has brought a huge impact on the education field. Subversive changes have taken place in student learning methods, education and teaching methods, and school education forms. It is not only an inevitable choice of the times to establish a student-centered innovation and entrepreneurial talent training model in colleges and universities, it is also an important way to accelerate the modernization of education. The government, education departments, and related scholars have attached great importance to the implementation of "double innovation" education. Innovation and entrepreneurship education has become an important part of the reform of education and teaching in Chinese universities.

After several years of development, innovation and entrepreneurship education in Chinese universities has achieved certain results in both practical exploration and theoretical research. However, the learning method of students is relatively single, and the traditional pedagogy has not led to a fundamental change. The writer has focused on innovation and entrepreneurship education in Chinese universities and consulting a lot of literature [2]. Although there are many references and successful cases involving innovation and entrepreneurship education in Chinese universities or student-centered, there are few "student-centered" innovation and entrepreneurship education literature. Based on this, this article analyzes and deconstructs the "student-centered" university innovation model, attempts to explore the "student-centered" university innovation and entrepreneurship model, and builds a student-centered "double innovation" education model, with a view to providing new ideas and references for advancing "double innovation" education.

2. Concept Definition

2.1. Student-Centered. The "student-centered" educational concept was first proposed by American progressive philosopher and educator Dewey in the early 20th century. In the 1950s, psychologist Carl Rogers developed it into a learning theory. The theory emphasizes that students are the main body of learning, and all educational activities should be based on the development of students. In the second half of the 20th century, due to the development of information technology and the rise of constructivist theories, "student-centered" was once again emphasized, becoming the trend of international higher education development and the direction of reform. In 1998, the World Higher Education Conference pointed out that higher education in the 21st century requires "a new student-centered perspective and a new model," requiring decision makers in various countries and institutions of higher learning to focus on students and their needs.

"Student-centered" is both educational theory and educational practice mode. It includes comprehensive teaching goals, active student roles, generative teaching process, scientific management, and evaluation [3]. It emphasizes that students are the main body of learning, and each student is the discoverer and constructor of knowledge. Students should actively participate in the teaching process, control their own learning, and develop their own learning path. This student-centered subjectivity is reflected not only in the diversities of student identities, but also in the differences between individuals, and at the same time it has its autonomy, independence, creativity, and comprehensiveness. Under the prevalence of educational democratic thoughts such as obvious differentiation of social strata, equality of all, and seeking common ground while reserving differences, the concept of "student-centered" has been put forward in accordance with the requirements of the times from theoretical development to social practice.

2.2. Innovation and Entrepreneurship Education. Innovation and entrepreneurship education belong to two different concepts. The root cause of the concept of innovative education is the dispute between "cognitive learning theory" and "behavioral learning theory." The "behavior learning theory" believes that "innovative education" is to use the positive influence of the external environment and its own genetics; it plays the leading role of education, fully mobilizes the subjective initiative of students' understanding and practice, and forms innovative personality and innovative ability [4]. "Cognitive learning theory" believes that, through the cultivation of students' innovative spirit and ability, they can be self-motivating and have a high degree of frustration tolerance [5]. Although the two have different understandings of students' cognition, innovative approaches, and methods, the goals and value orientations of innovative education are the same. The fundamental goal is to cultivate innovative talents with innovative spirit and innovative ability. A series of training processes such as awareness, innovative spirit, innovative thinking, and innovative ability are realized [6].

Compared with innovation education, the concept of entrepreneurship education has a higher degree of consensus. Entrepreneurship education in a broad sense refers to education that focuses on stimulating students' entrepreneurial awareness, cultivating and developing students' entrepreneurial qualities and abilities, and cultivating possible future entrepreneurs as the highest goal. Entrepreneurship education in a narrow sense refers to entrepreneurship training, with the sole goal of cultivating self-employed freelancers. Entrepreneurship education is to cultivate future business managers and entrepreneurs with innovative spirit and entrepreneurial ability.

At the same time, innovation and entrepreneurship education are mutually independent and interdependent. The innovation and entrepreneurship education are simply merged either from the subject of the concept or from the scope of influence, so there is a suspicion of concept replacement, which will give people some misunderstandings in understanding and practice. To clarify the concepts and relationships between the two will help promote the specific implementation of entrepreneurship and innovation education. On the one hand, innovation education has a certain degree of creativity. Creativity and entrepreneurship education is to create wealth for society and individuals in social production and practice activities of talents with these two innovative characteristics. At the same time, entrepreneurship education will also provide innovative results in the course of practice, so as to evaluate and modify innovative education. Innovation and entrepreneurship can be simply understood as the relationship between "theory" and "practice." Innovation is for the whole, and entrepreneurship is for the individual. On the other hand, compared with innovation education, entrepreneurship education is a deeper and higher-level education, a deep-level and fundamental education, rather than a branch and superficial basic education. Innovation education is the foundation of entrepreneurship education, entrepreneurship education is the "pushing hand" of innovation education, and entrepreneurship is the practice and test of innovation effects. Therefore, both innovation and entrepreneurship education are essentially interdependent systems, which cannot be dismembered or reversed.

2.3. The Structure of Student-Centered Innovation and Entrepreneurial Talent Training Model. "Student-centered" innovation and entrepreneurship education emphasizes that students are the main body of learning. All innovation and entrepreneurship education activities are centered on the learning and development of students, fostering innovative awareness, entrepreneurial thinking, and perseverance and entrepreneurial spirit. Specifically, it includes the internal needs of three aspects: student development, student learning, and learning effect.

First of all, increase students' innovation and entrepreneurship capabilities. The purpose of education is to make people develop in all-around way. Education promotes human development through the guidance of human growth. In the "student-centered" innovation and entrepreneurial talent training system, on the one hand, it is necessary to clarify the service orientation centered on the development of students' innovative ability. All-round and multichannel education concepts centered on serving the development of students' innovative ability will be penetrated into departments, management departments, and innovation and entrepreneurship education. The education of innovation and entrepreneurship runs through the entire process of talent training. Specialized institutions or innovation and entrepreneurship service centers should be established to serve the development of students' innovative capabilities. The evaluation channels of innovation and entrepreneurship education should be broadened. The evaluation feedback and demand information of innovation and entrepreneurship education, talent innovation ability, and teaching service should be grasped timely. An analytical report on the quality of innovation and entrepreneurship education should be formed to provide an important reference for school decision-making. On the other hand, it must not violate the laws of human development. Human development is continuous, phased, and irreversible. As a university education, we must first understand the content of people's development at the university stage, as well as the current state of development of college students. It is necessary not only to focus on the development of students' professional knowledge, but also to cultivate students' creative ability and sense of innovation. They can demonstrate their individuality and improve their abilities so as to promote the sustainable and healthy development of college students.

Secondly, meet the needs of students' innovation and entrepreneurship learning.

"Student-centered mode" requires teachers to help students to "learn," and it is clear that students "learning" is the purpose of college education. At present, innovation and entrepreneurship education generally attaches great importance to "general education" and neglects professional education based on the individual needs of students. Taking student learning as the goal is based on the different characteristics of students in different periods and their different needs for innovation and entrepreneurship education. It is embodied in three aspects: management, curriculum, and teaching. First, strengthen the awareness of management and service. From the point of view that managers should establish a mindset based on the interests of students, it will provide convenience for students' innovation and entrepreneurship learning and practice in an all-round way, for example, the introduction of innovative and entrepreneurial teachers and the creation of an innovative and entrepreneurial atmosphere, innovative and entrepreneurial resource development, etc., to create opportunities and conditions for students' innovation and entrepreneurship as much as possible. Secondly, build a curriculum service system that integrates innovation and entrepreneurship and professional courses based on students' individual development. On the one hand, in addition to completing the compulsory courses based on general public basis, students should supplement them by taking corresponding innovation and entrepreneurship courses based on their own personalities and career development needs. On the other hand, it is necessary to make a reasonable allocation of innovation and entrepreneurship courses and professional courses, theory and practice, and compulsory and elective courses. Third, we must strengthen teachers' sense of service to students. Teachers should establish the core idea that all teaching activities are to promote the development of students' innovative ability and provide students with diversified services and support. At the same time, teachers should fully understand students, actively interact with students, create a democratic innovation atmosphere, and find teaching entry points that stimulate students' enthusiasm for innovation and entrepreneurship. For teachers themselves, it is necessary to actively improve their own innovative theoretical literacy and innovative practical ability, and only with excellent quality can they provide students with more professional and comprehensive guidance.

Finally, promote student innovation and entrepreneurship evaluation.

"Learning effect as the center" can not only provide two-way feedback for learning and teaching, but also help students and teachers make synchronous adjustments to improve learning efficiency and effectiveness [7]. The focus of teaching evaluation should be the ultimate "learning effect" of students, which in turn directly reflects the effect of teachers' "teaching." It is necessary to establish a comprehensive, multiform, and multievaluation strategy. Change the previous single evaluation status that the industry enterprise evaluation lacked or became a mere formality. For the teaching module of innovation and entrepreneurship theory, we can evaluate the impact of students on students' specific performance and different developments in the learning process and can also conduct formative evaluations on students' innovative consciousness and innovative thinking during the entire teaching process. It can also conduct a summative evaluation of students' performance in exams or innovative project design at the end of the course. Help students find their own strengths and weaknesses in innovation and entrepreneurship learning, combine the teacher's evaluation of students with students' self-evaluation, and let students find their own direction in the evaluation. At the same time, teachers should adjust teaching content and change teaching strategies in a timely manner based on student evaluations. Regarding the innovation and entrepreneurship practice sector, industry enterprises must make a comprehensive evaluation of the curriculum construction of the education system, the degree of integration between professional education and innovation and entrepreneurship education, and the provision of innovation and entrepreneurship teachers. School leaders or administrators adjust teaching strategies for innovation and entrepreneurship education in a timely manner based on the evaluation results. Based on the evaluation results, “learning effect as the center” not only provides effective teaching and learning results basis for students and teachers, but also provides decision-making reference for managers. It allows students, teachers, and administrators to understand the teaching dynamics in an all-round and multichannel way, helps each to understand their own strengths and existing problems, and guides them to continuously improve teaching and improve teaching effects. Figure 1 shows the structure of the “student-centered” innovation and entrepreneurship education talent training model.

3. Influencing Factors of the Student-Centered University Innovation and Entrepreneurship Talent Training Model

With today’s highly developed information technology, the channels, methods, and means for students to acquire knowledge are diversified, and the knowledge structure is diversified. The traditional teacher centered teaching model can no longer meet the inherent needs of students in pursuit of knowledge. Especially for innovation and entrepreneurship education, it is necessary to arouse students’ desire for knowledge, innovation consciousness, and entrepreneurial passion. We clearly see that although the “student-centered” talent training model has developed and achieved certain results in colleges and universities, there are still some restrictive factors.

3.1. The Impact of Information Technology. The rapid development of grid information technology has accelerated the historical process of higher education modernization. Networked multimedia teaching allows students to study without being restricted by time, space, and conditions and provides students with the possibility of free choice. Using the network platform, students can choose independently in terms of learning content, learning progress, learning methods, and teaching teachers. Students can participate in the teaching process and communicate with teachers without being restricted by time and place, discuss important issues with teachers, and enjoy rich teaching resources. Therefore, the mission of educational informatization is not to arm traditional teaching with information technology and strengthen and consolidate traditional teaching models, but to transcend the traditional classroom teaching model characterized by teachers’ teaching and indoctrination, promote fundamental changes in learning methods, and realize the transition from traditional classrooms to efficient schools. Student-centered innovation and entrepreneurship education not only means that students have equal rights to receive education, but also implies that students can equally control various learning resources. This kind of learning right is embodied in “learning” rather than “teaching.” The purpose of teachers’ teaching is mainly to give students necessary and active guidance, rather than simply repetitive knowledge instillation in the past.

3.2. The Influence of the Class Teaching System. The Industrial Revolution not only brought profound changes to the organization, ideology, lifestyle, and social structure of today’s society. Moreover, it has a far-reaching impact on educational concepts and teaching methods, especially in the way of talent training, which has opened up industrialized mass production methods, which has accelerated the formation of the class teaching system. Since entering the 21st century, with the expansion of Chinese colleges and universities, the number of students has been increasing year by year. In addition to the consideration of economic costs, the innovation and entrepreneurship courses in universities are all taught in large classes. The teaching class ranges from dozens of students to hundreds of students. In this way, only the traditional teacher centered “Yiyantang” teaching model can be developed in the classroom teaching process. Open teaching scenarios such as student-centered free discussions and personal presentations are simply difficult to achieve, which is not conducive to the cultivation of students’ innovative thinking and entrepreneurial passion.

3.3. The Influence of Teaching Methods. The influence of teaching methods is mainly reflected in the following four aspects: First of all, the classroom teaching method is single. At present, the innovation and entrepreneurship education in colleges and universities is mainly a single classroom teaching method with large class teaching and teacher “teaching” as the mainstay. Although most schools integrate into classroom teaching in different ways such as group discussion, inquiry sharing, and project-based teaching in the process of innovation and entrepreneurship teaching, they are also mechanically passively copied under the guidance of teachers. It does not highlight the subjectivity of students and does not determine the teaching method based on the characteristics of the students. Secondly, the teaching mode is single. At present, the curriculum of innovation and entrepreneurship education in colleges and universities lacks integration among many disciplines and is too repetitive. There is an obvious issue of pursuing “big and complete” or conforming to the crowd. Although some colleges and universities have carried out some targeted curriculum development attempts based on their own characteristics, there have been some phenomena such as fewer hours of social practice courses, insufficient value of the curriculum as a whole, and low academic research levels. These are still in the exploration or initial stage, with lack of effective guidance, and the results are not obvious. Thirdly, the evaluation method is single. The current teaching effect evaluation mainly adopts traditional methods such as questionnaires and examinations, lacks comprehensive, full-process, and individualized evaluation, and lacks teaching process monitoring and later social follow-up. Finally, the learning method is traditional (teachers, classrooms, and textbooks are the center). The current higher education in innovation and entrepreneurship is only a superficial

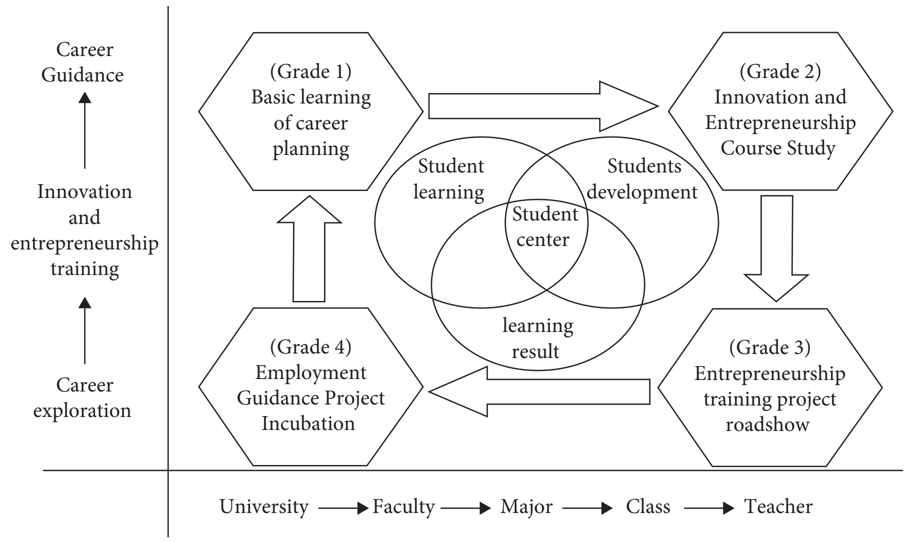


Figure 1: Student-centered innovation and entrepreneurship education framework.

theoretical explanation, and a lot of energy and time are spent on solving the level of students' understanding of the theoretical knowledge of innovation and entrepreneurship. It fails to guide students to have a deep learning.

4. The Construction of the Student-Centered Innovation and Entrepreneurship Education Talent Training Model

4.1. Constructing a Student-Centered Concept of Innovation, Entrepreneurship, and Education. "Student-centered" does not refer to the difference between the roles, identities, and status of teachers and students, but refers to the transformation of teaching concepts, management concepts, service concepts, teaching methods, and evaluation methods. The purpose and task of teaching are not "teaching" but "learning" [8].

First, the student-centered concept of innovation and entrepreneurship education should be changed. Nowadays, the administrators or teachers at colleges and universities have been cultivated under the mode of "teaching" as the center in the past. Regardless of ideology and teaching behavior habits, the concept of "teaching" is the dominant position. As an activity, school education is to provide students with learning services. Students receive learning services through their own understanding and digestion and condense on themselves, so as to realize the needs of students, their families, and society. Therefore, both managers and teachers have changed the deep-rooted traditional thinking of teaching as the mainstay and turned to the modern education concept with learning as the mainstay. School leaders and grassroots administrators must go deep into the students, go deep into the classroom, understand the students' learning situation, solve the problems that exist in the students' learning, create an environment and cultural atmosphere conducive to students' learning, and create a broad space for students' growth. It is necessary to explore organizational and management forms that are conducive to student learning, such as the college system and tutorial system. Therefore, the systems, methods, and work attitudes of other aspects of schoolwork must be based on the benefit and service of students' learning.

Second, the student-centered innovation and entrepreneurship education system should be improved. Policy has a guiding function. The national policy and the school system should start from "student-centered." On the one hand, it is necessary to review and adjust at the national level and further weaken the evaluation of a school with academicians, doctoral degrees, scientific research funding, awards, and excellent papers as the main indicators. The proportion of evaluation indicators can reflect the learning status and learning effect of students. On the other hand, the school level should also be reviewed. For example, the reward system, examination system, school status management, degree system, etc. should be adjusted based on the student-centered approach to better promote student learning and growth.

Third, implement a paradigm shift in education and teaching. Under the "student-centered" education paradigm, teachers need to design a student-based classroom teaching model based on the actual situation of students and set learning goals and design activities that students actively participate in. In the classroom teaching process, the organic unity of teaching and learning is realized, and the goal of "teaching" is determined by "learning," and the goal of "learning" in "teaching" is implemented, and effective teaching is implemented. At the same time, teachers need to clarify the principle of effective learning: Teachers are the coordinators of teaching activities. In the teaching process, students not only learn from teachers, but also learn from each other. This educational model is flat, circular, and at the same level [9]. In the learning process, only when students feel interested or motivated, they will actively participate in learning and will concentrate their energy and efficiency into it and can actively manage their own learning in the learning process, instead of relying more passively on teachers.

4.2. Constructing a Student-Centered Innovation and Entrepreneurship Faculty Team. Since China's innovation and entrepreneurship education started late, there has not been a professional team of innovation and entrepreneurship teachers. Most of the innovation and entrepreneurship teachers in universities are from school administrators and teachers engaged in employment guidance. Neither do these teachers have excellent theoretical teaching literacy, nor do they have entrepreneurial experience, professional teaching ability, and the ability to observe and evaluate. It is difficult for them to improve their professionalism through short-term innovation and entrepreneurship training, and it is even more difficult for them to effectively guide students' innovative practice.

In the process of direct contact with students, in the "student-centered" school training model, teachers, as an important part of teaching activities, need to change their roles and recognize themselves as "learners" who are in the same position as students. Practice has proved that teachers can play a leading role in at least three aspects: One is to choose educational materials. In the information age, there is a vast ocean of educational materials. Teachers choose educational materials by compiling teaching materials, lectures, asking questions, and discussing, so as to guide students in learning. The second is to activate knowledge. Knowledge is dead, but teachers activate knowledge through teaching and arouse students' interest in learning. Interest is the best teacher. Once students experience the joy of learning, they will have the endogenous motivation to continue learning. The third is to promote thinking. Through a variety of methods, mobilize students' initiative and enthusiasm in learning, and carry out in-depth thinking, so as to internalize external knowledge into their own knowledge structure, enhance ability, and improve quality.

4.3. Constructing an Innovation and Entrepreneurship Experience Center Integrating Industry, Academia, and Research. Colleges and universities should strive to create an experience center (maker center, incubator, practice base) integrating "production, study, and research" as a practical carrier of innovative education. It is necessary to fully realize the importance of the active participation of teachers and business partners to student education. "Innovation" is not only the task of research institutions. In order to enable students receiving entrepreneurship education to fully experience the social environment and atmosphere of entrepreneurship, the innovation center can also be an R&D center for social services directly or an internal R&D center of an enterprise. It is best not to set up the center in the school. The innovative practical activities of the third and fourth grade students are mainly completed in the center. This requires colleges and universities to have a strategic vision, actively seek strategic cooperation with enterprises, and strengthen the organic combination of scientific research and teaching. An innovation center centered on the three themes of education, R&D, and the innovation environment (market) connects internal and external participants. At this time, the center resembles a constantly changing innovative education agent.

5. Conclusion

"Student-centered" is an inevitable requirement for the connotative development of higher education in the new era and a revolution in teaching paradigm. With the rapid development of modern information technology and the urgent need for innovative talents in the country, we should make full use of "Internet + education" and "smart + education" to master the dominance and discourse power of university teaching and deepen the integration of online and offline teaching. Make full use of virtual reality and artificial intelligence technology, innovate educational forms, enrich teaching resources, guide students with more cutting-edge knowledge, and stimulate students' innovative spirit and entrepreneurial enthusiasm [10]. Constructing a "student-centered" university innovation and entrepreneurship education talent training model is a transformation of the teaching paradigm of innovation and entrepreneurship education and a shift of focus in the process of university teaching. Student-centered and student-oriented innovation and entrepreneurship education is the connotation of innovation and entrepreneurship, and it is the source of power for China's innovation and entrepreneurship education to radiate infinite vitality and vitality in an increasingly broad prospect.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by Xi'an Fanyi University 2020 Scientific Research Team: "One Belt One Road' Chinese International Education Research Team" (XFU20-KYTDD01) and Xi'an FanYi University 2020 Scientific Research Team: "Research on Innovation and Entrepreneurship Ecology and Youth Career Development" (XFU20KYTDC01).

References

[1] K. Cai, "Based on the all-round development of students-an important educational concept and educational reform," *Higher Education Research*, vol. 5, pp. 11–15, 2000.

[2] N. Sun and Y. Zhang, "The operation mechanism of the construction of teachers' team of innovation and entrepreneurship education in applied undergraduate colleges," in *Proceedings of the International Conference on Application of Intelligent Systems in Multi-modal Information Analytics*Springer, Cham, Switzerland, February 2019.

[3] Y. Hong, ““Student-centered” Undergraduate Teaching Quality “Four-dimensional” Evaluation,” *University Education Science*, vol. 2, pp. 14-15+122, 2019.
[4] L. Zhang, “Innovation·Education Innovation·Innovative education,” *Journal of East China Normal University*, vol. 4, pp. 26–32+38, 1999.
[5] Y. You, “The basic characteristics of innovative education,” *Chinese Journal of Education*, vol. 3, pp. 25–27, 2000.
[6] Y. Lu and S. Zhang, “Analysis of the relationship between entrepreneurship education and innovation education for college students,” *Jiangsu Higher Education*, vol. 6, pp. 106–108, 2011.
[7] J. Xu, H. Zhao, X. Liu, M. Wang, Q. Fan, and M. Zhang, “A “student-centered” university innovation and entrepreneurship education quality evaluation index system,” *Heilongjiang Animal Husbandry and Veterinary Medicine*, vol. 9, pp. 230–232, 2018.
[8] X. Liu, “On “student-centered”,” *Higher Education Research*, vol. 33, no. 8, pp. 1–6, 2012.
[9] Y. Zhang and L. Zhang, “Research on the “learner-centered” university talent training model,” *Heilongjiang Higher Education Research*, vol. 8, pp. 83–86, 2018.
[10] G. Chen and X. Yang, “The real dilemma and transcendence of “student-centered” in university teaching,” *Journal of National Academy of Educational Administration*, vol. 12, pp. 72–77, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 9991794, 13 pages
https://doi.org/10.1155/2022/9991794

Research Article

Spring Festival Holiday Tourism Data Mining Based on the Deep Learning Model

Ruijun Wang

School of Business Administration, Shandong Management University, Jinan 250357, Shandong, China

Correspondence should be addressed to Ruijun Wang; yushu2021@126.com

Received 26 March 2022; Revised 11 May 2022; Accepted 21 May 2022; Published 18 June 2022

Academic Editor: Ahmed Farouk

With the advent of the era of big data, people have entered a situation of information overload, how do users filter out the information they need from a large amount of information. When users browse the website, they will record their search or click behavior, and the recommendation system will mine the data based on these data, and recommend the information they need for each user. With the birth of the recommender system, it has indeed changed the way people obtain information. Instead of relying solely on search engines to obtain information, it can obtain the information they want without people's "consciousness." This shift has made it easier for people to access information. This paper conducts research on travel recommendation during the Spring Festival holiday. The paper introduces deep learning model and data mining technology, proposes that the recommendation system has three important modules, and obtains the corresponding flowchart. The recommendation system was optimized, and a comparison chart of coverage before and after optimization was obtained. Before optimization, the coverage rate of cities and scenic spots was 45.52% and 21.25%, respectively, and reached 55.65% and 49.81% after optimization.

1. Introduction

Nowadays, people have entered an era of big data explosion. The Internet has long been inseparable from lives and has become a part of lives. People can watch movies and TV series on websites such as Youku, listen to songs on music platforms such as QQ Music and NetEase Cloud Music, and shop on shopping platforms such as Taobao and JD.com. How people filter out the information that is beneficial to themselves from a lot of information, it really costs people a lot of energy and time. How will the filtered information be presented in front of people's eyes, and whether this part of the screening work can be converted into computer processing by people themselves.

The birth of the Internet has indeed brought convenience to people's lives, making people's lives more and more colorful. But with the advent of the era of big data, the Internet has also brought unavoidable problems to people-information overload, making people dazzled and unable to choose. In most cases, people are not clear about their goals. For example, the user wants to travel to a certain place, but the attractions of this place may not be known to him, but the truth is what he wants to visit. At this time, the search engine cannot be displayed, and the results obtained through the search engine are not personalized and are immutable and single. As long as the same keywords are entered, the results presented are the same. With the birth of the recommendation system, these problems are solved, and compared with the search engine, it has more personalized functions.

The innovation of this paper is that the deep learning model is introduced, an improved deep learning framework is constructed, and a schematic diagram of the algorithm flow of the framework is obtained. Data mining technology is introduced, and the remaining parameters are not further compressed by any subsequent steps, and the test accuracy and the results on the dataset are obtained. The tourism recommendation system proposed in the article is optimized, and the comparison data before and after optimization are obtained.

2. Related Work

Regarding deep learning, relevant scientists have done the following research. Litjens et al. outline key medical imaging research concepts and has collected more than 300 papers on the topic, most of which were published last year. He evaluates in-depth research practices in image classification, object analysis, segmentation, recording, and other activities and provides a brief overview of research in each application area, discussing open challenges and directions for future research [1]. Kermany et al. have developed a deep learning framework based on diagnostic tools for screening patients with simple treatments for blinding retinal diseases. The framework uses transfer learning, which uses a small subset of data from traditional methods to train a neural system, using this method to check database visual consistency. The latter tool can help expedite the diagnosis and diagnosis of treatable diseases, leading to earlier treatment and better clinical outcomes [2]. He et al. use a denoising-based predictive communication channel that can learn from the channel structure and evaluate the network against a large amount of training data. He also provides an analytical framework for assessing asymptomatic functioning of the network. According to He et al.'s analysis and simulation results, deep learning is a powerful tool for channel estimation in millimeter wave communications [3]. Weinan and Yu proposed a deep learning-based method for numerically solving variational problems, especially those arising from partial differential equations. The method is naturally nonlinear, naturally adaptive, and has the potential to work in fairly high dimensions. The framework is very simple and well suited for the stochastic gradient descent method used in deep learning. Weinan and Yu illustrate the method on several problems, including some eigenvalue problems [4]. Tom et al. carefully examine key models and techniques used in many NLP projects and describe their development. They also summarize, compare, and create different categories and provide a complete understanding of the past, present, and future of deep learning NLP research [5]. Zhu et al. analyze the challenges of using deep learning for remote sensing data analysis, review recent advances, and provide resources that hopefully make deep learning in remote sensing seem ridiculously easy. Zhu et al. encourage remote sensing scientists to bring their expertise to deep learning as an implicit universal model to address unprecedented, large-scale, and impactful challenges such as climate change and urbanization [6]. Xu proposed a learning-based DOA estimation method for multiple broadband far-field sources. The processing mainly includes two steps. First, a beam-spatial preprocessing structure with frequency-invariant properties is applied to the array output to perform focusing over a wide bandwidth. In the second step, the classification is implemented using a hierarchical deep neural network. Unlike neural networks trained on huge datasets containing combinations of different angles, deep neural networks can achieve multisource DOA estimation with small datasets, since the classifier can be trained in different small subregions. Simulation results show that the method performs well in generalization and defect adaptation [5]. These methods provide some references for research, but due to the short time and small sample size of the relevant research, this research has not been recognized by the public.

3. Spring Festival Holiday Tourism Data Mining Method

3.1. Deep Learning. Deep learning is the study of the principles and layers of presentation of data samples, and the information gathered during these learning processes is useful for interpreting data such as text, images, and sounds [7]. Its main purpose is to observe and learn from machines, as well as recognize people and data such as words, images, and sounds. Deep learning is a complex mechanical algorithm that analyzes speech and artwork without similar techniques [8].

Simply put, deep learning is a technique that enables computer systems to improve from empirical data [9]. Neural networks, inspired by biomimicry research, simulate how neurons in the brain work, with axons responsible for receiving signals. It is from hundreds of billions of these neurons that make up human brain through complex connections [10]. A perceptron is a linear artificial neuron with a binary classification function:

$$\text{output} = \left\{ \begin{array}{l} 0,\ \text{if} \sum_{v} \lambda_v m_v \leq \text{thread} \\ 1,\ \text{if} \sum_{v} \lambda_v m_v > \text{thread} \end{array} \right\}, \tag{1}$$

where $\sum_v \lambda_v m_v$—the sum of the assigned weights.

Computer vision: the Multimedia Lab of the Chinese University of Hong Kong is the first Chinese team to apply deep learning for computer vision research. In the world-class artificial intelligence competition LFW (Large-scale Face Recognition Competition), the laboratory has won the championship, making the recognition ability of artificial intelligence surpass that of real people for the first time in this field.

For speech recognition, Microsoft researchers cooperated to first introduce RBM and DBN into the training of speech recognition acoustic models and achieved great success in large-vocabulary speech recognition systems, reducing the error rate of speech recognition by 30%. However, there is no effective parallel and fast algorithm for DNN, and many research institutions are using large-scale data corpus to improve the training efficiency of DNN acoustic model through GPU platform.

Artificial neural network is now very popular and widely used. As the basis of deep learning, its characteristics include the following: (1) strong learning ability. The biggest feature of the neural network is that it has a strong ability to extract features. Similar to the brain, it can deal with the transformation of various inputs. When the input changes, it can adjust the features extracted by itself in time and has strong adaptability. (2) Parallelism. The human brain can process multiple things at the same time, which reflects the parallelism of the human brain. The neural network can process information independently by simulating the human brain, which reflects the same similar parallelism. (3) Nonlinear. Neural network is an important nonlinear system research tool. It can effectively discover the nonlinear relationship model between input and output, and from the outside, the neural network is similar to a black box tool, which hides other parts of the neural network structure except the input and output. (4) Robustness. Since there are many neurons in the neural network, each neuron will share the contribution value, so the influence of each neuron on the overall result is relatively weak. When some data are polluted, they have little effect on the results of the entire network, especially in distributed computing, which can reflect this robustness [11]. Figure 1 shows the network classification performance statistics.

Common deep learning models include:

(1) Autoencoder. It consists of input layer, hidden layer, and output layer. It models a network with a three-layer neural network structure: the same number of neurons in the input and output layers. Autoencoders are a bit predictive software, image-guided, text-guided. The hidden layers that describe users and objects are learned by recreating relevant information about users and objects, and then these expressions are used to predict user behavior settings.

(2) Restricted Boltzmann Machines. The Boltzmann machine is composed of visible units and hidden units, and the corresponding variables are called visible variables and hidden layer variables, and they are all binary variables with a value of 0-1. When a neuron is inhibited, its state is 0, and when it is activated, its state changes from 0 to 1.

(3) The deep belief network is related to the restricted Boltzmann machine, which is composed of multiple restricted Boltzmann machines. It learns layer by layer starting from the underlying RBM.

(4) Convolutional Neural Networks. Convolutional Neural Networks are multilayer perceptual network models that can be used to process network data such as image data [12, 13]. The main difference between it and a typical multilayer perceptron is that a convolutional neural network can reduce the number of neurons in a sample by combining layer actions. Not only that, the weights of the convolutional neural network can be shared, so that the parameters can be greatly reduced, so that the complexity of the network is reduced, and the generalization ability of the network is improved at the same time. And it also has translation invariance; in addition, the most important thing is that it can directly operate on the picture, and it mainly consists of five parts [14].

The energy model establishes a functional relationship between the energy of a certain state of the system and its probability of occurrence through the energy function and realizes a measure of the probability

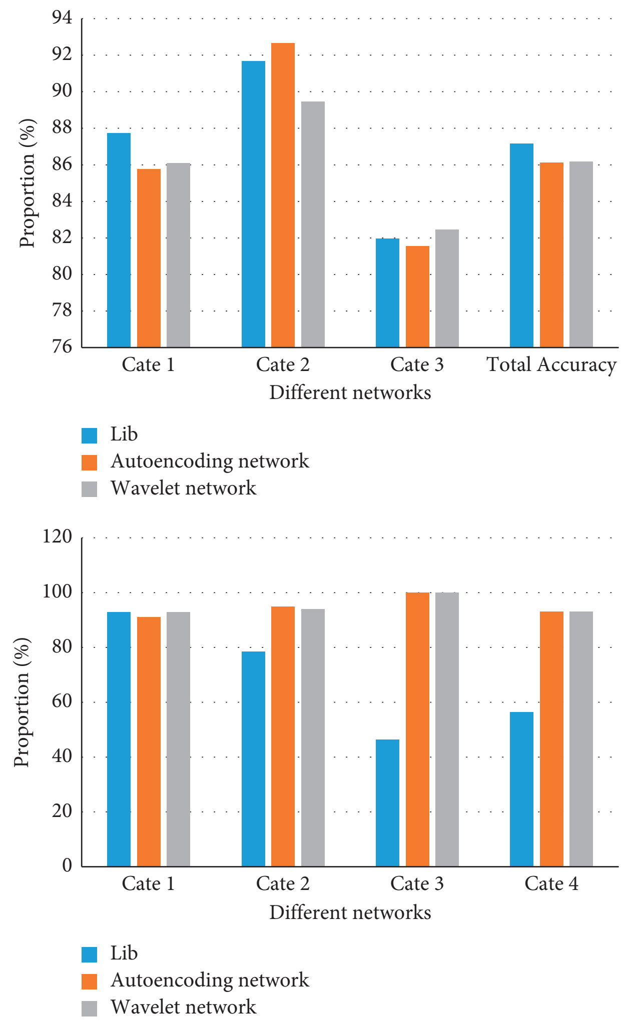


Figure 1: Network classification performance statistics.

distribution of a random network. Its energy function is usually recorded as

$$l(m) = \frac{e^{-R(m)}}{C}, C = \sum_m e^{-R(m)}, \qquad (2)$$

where $R(m)$—energy function.

When introducing hidden units:

$$l(m) = \sum_h l(m,h) = \sum_h \frac{e^{-R(m,h)}}{C}. \qquad (3)$$

The joint distribution probability function is as follows:

$$l\left(m, g^1, \ldots, g^p\right) = \left(\prod_{d=0.}^{p-2} l\left(g^d | g^{d+1}\right)\right) l\left(g^{p-1}, g^p\right), \qquad (4)$$

where

m—output layer.

$l(g^{1-1}, g^1)$—joint probability of taking values.

$l(g^{k-1}|g^k)$—probability under the condition of taking the value.

Its mathematical expression can be written as follows:

$$l(U = u|m, Q, c) = \text{soft}\max(Qm + c) = \frac{e^{Q_u m + v_u}}{\sum_v e^{W_v m + c_v}}, \quad (5)$$

where

Q—weight matrix.

c—bias vector.

The loss function is a common objective function for optimizing parameters in a learning model. In the multiclass classification scenario, the negative log-likelihood function is usually used as the loss function, and the formula is as follows:

$$\begin{aligned} P(\theta = \{Q, c\}, S) &= \sum_{u=0}^{|S|} \log\left(l\left(N = n^{(u)}|m^{(u)}, Q, c\right)\right), \\ p(\theta = \{Q, c\}, S) &= -P(\theta = \{Q, c\}, S), \end{aligned} \quad (6)$$

where

P—loss function.

l—negative log-likelihood function.

For the probability of each sentence, it is expressed by the joint probability of each word that composes the sentence, namely:

$$l(\delta) = l\left(\delta_1^T\right) = l(\delta_1, \delta_2, \ldots, \delta_T), \quad (7)$$

where

$l(\delta)$—the probability of a sentence.

δ-T sentence composed of words.

According to the relevant formula, the above formula can be decomposed into:

$$l\left(\delta_1^T\right) = l(\delta_1) * l(\delta_2|\delta_1) * l\left(\delta_3|\delta^2{}_1\right) \ldots l\left(\delta_r|\delta^{T-1}{}_1\right). \quad (8)$$

The specific calculation method of the feature extraction method is as follows:

$$\begin{aligned} DS(r) &= \frac{b_r}{B}, \\ IDS(r) &= \frac{|D|}{j\colon r \in d}, \\ DS - IDS &= DS(r) \times IDS(r), \end{aligned} \quad (9)$$

where:

b_r—the number of feature words in the current text.

B—the number of all feature words in the current text.

$j\colon r \in d$—the number of feature words that the text contains.

$|D|$—the number of all texts in the corpus.

The likelihood estimate is calculated as follows:

$$l(s|b_i) = l\left(\left(r_1, r_2, \ldots r_i, \ldots r_n\right)|b_j\right) = \prod_{i=1}^{n} l(r_i|b), \quad (10)$$

where:

r_i—features in text features.

$l(r_i|b)$—probability of appearing in the text.

$$l\left(b_j|s\right) = \frac{l\left(s|b_j\right)l\left(b_j\right)}{\sum_{i=1}^{m} l(b_i)l\left(s|b_j\right)}, \quad (11)$$

where

s—target text.

The posterior probability is as follows:

$$l\left(b_j|s\right) = l\left(s|b_j\right)l\left(b_j\right) = l\left(b_j\right)\prod_{i=1}^{n} l\left(r_i|b_j\right), \quad (12)$$

where

s—calculated text.

r_i—text-based features.

Convex optimization can be expressed as

$$o.p.n_v\left[\frac{\delta}{\|\delta\|} * m_u\right] + \frac{b}{\|\delta\|} \geq \mu, i = 1 \ldots N, \quad (13)$$

where

μ—geometry from dataset to hyperplane.

N—the number of samples in the sample set.

δ—weight.

The optimal solution to the original problem is obtained by solving the dual problem:

$$P(a, s, \lambda) = \frac{1}{2}\|\delta\|^2 = \sum_{u=1}^{N} \lambda_u n_i(\delta m_i + s) + \sum_{u=1}^{N} \lambda_u. \quad (14)$$

The internal structure of a neuron is as follows:

$$n = f(\delta_1 m_1 + \delta_2 m_2 + \ldots \delta_i m_i \ldots + \delta_n m_n), \quad (15)$$

where

m_n—input to the neuron.

δ_n—weight of connected edges.

b—bias.

f—activation function.

$$q_k = f_1\left(\sum_{u=0}^{n} b_{ku} m_u\right) k = 1, 2, \ldots l, \quad (16)$$

where

n—the number of neurons in the input layer.

l—the number of neurons in the hidden layer.

m—the number of neurons in the output layer.

b_{ku}—weights between the input layer and the hidden layer.

f_1—the activation function of the hidden layer.

$$n_v = f_2\left(\sum_{u=0}^{l} b_{vk} q_k\right) v = 1, 2, \ldots m, \quad (17)$$

where

f_2—activation function of the output layer.

n_v—the output of the network.

$$T = \frac{1}{2B}\sum_{u=1}^{B}\sum_{v=1}^{m}\left(r_v^u - n_v^u\right)^2 = \frac{1}{2B}\sum_{u=1}^{B} T_u, \quad (18)$$

where

B—the number of data.

u—the number of samples.

n_v^u—corresponding network output.

r_v^u—corresponding target output.

T—average error.

Different from traditional shallow learning, the difference of deep learning is as follows:

(1) The depth of the model structure is emphasized, usually with 5, 6, or even 10 layers of hidden layer nodes.

(2) The importance of feature learning is clarified. That is to say, through layer-by-layer feature transformation, the feature representation of the sample in the original space is transformed into a new feature space, thereby making classification or prediction easier. Compared with the method of constructing features by artificial rules, using big data to learn features can better describe the rich intrinsic information of data.

By designing and establishing an appropriate amount of neuron computing nodes and multilayer operation hierarchy, selecting appropriate input layer and output layer, through network learning and tuning, the functional relationship from input to output is established. Although the functional relationship between input and output cannot be found 100%, it can approximate the actual relationship as much as possible. Using a successfully trained network model, automation requirements for complex transaction processing can be achieved.

As a new method of machine learning in the development of artificial intelligence technology, deep learning is very important [15]. Based on the power of parallel computing and big data cloud algorithms, we will build a learning network that is closer to the human brain, allowing computers to find ways to solve "abstract ideas" and make computers more intelligent [16]. A deep online learning algorithm is an uncontrollable learning feature. It builds on the analytic hierarchy attributes, by combining and analyzing the attributes behind the buildings and replacing the original top-level attributes with more abstract attributes to create top-level abstract attributes that show work characteristics. Deep networks try to imitate the thinking process in the human brain to interpret information, create deep neural networks with analytical and learning properties, and imitate the way of thinking in the human brain to interpret and analyze data to find scattered information [4].

The unsupervised learning that rises from the bottom is to start from the bottom and train to the top layer by layer. Using uncalibrated data (or with calibrated data) to train the parameters of each layer, layer by layer, this step can be regarded as an unsupervised training process, which is also the biggest difference from the traditional neural network, which can be regarded as a feature learning process. Specifically, the first layer is trained with uncalibrated data, and the parameters of the first layer are learned during training. This layer can be regarded as the hidden layer of a three-layer neural network that minimizes the difference between the output and the input. Due to the limitation of model capacity and sparsity constraints, the resulting model can learn the structure of the data itself, thereby obtaining features that are more expressive than the input. After learning the *n-l* layer, the output of the *n-l* layer is used as the input of the *n*th layer, and the *n*th layer is trained, thereby obtaining the parameters of each layer.

Top-down supervised learning is to train with labeled data, and the error is transmitted top-down to fine-tune the network. Based on the parameters of each layer obtained in the first step, the parameters of each multilayer model are further optimized. This step is a supervised training process. The first step is similar to the random initialization initial value process of neural network. Since the first step is not randomly initialized, but obtained by learning the structure of the input data, this initial value is closer to the global optimum so that better results can be achieved. So the good effect of deep learning is largely due to the process of feature learning in the first step.

3.2. Data Mining.

Data mining, also known as knowledge discovery in databases, is a hot topic in the field of artificial intelligence and big data and has attracted much attention. Data mining is to analyze and calculate a large amount of data in the database and then reveal hidden, previously unknown data, and this process is of extraordinary significance. Data mining itself is carried out without a clear target, so the results after mining data are also uncertain, which can indicate the future development direction and have a profound impact on the trend of e-commerce.

Commonly used methods of data mining include the following:

Classification: the classification method is mainly to search and classify the general characteristics of one or more data groups in the database according to a specific classification model. Its main purpose is to map the information in the database into specific categories. It can be used to classify customers and predict customer characteristics and characteristics, customer satisfaction, and customer development. For example, a car dealership can rank customers based on their car-related preferences. Then marketers can mail advertisement brochures of different types of new cars to users according to this preference, so through this method, business opportunities can be greatly increased [17].

Regression analysis: regression analysis methods usually describe the value attribute of a specific attribute in a database over time, map the actual value of the generated data column to a function of the predictor variable, and look for dependencies between variables or attributes.

The cluster analysis method is to divide the dataset into different categories according to the difference and probability, and its main purpose is to minimize the similarity and similarity of the data belonging to different categories, as wide as possible.

Association rules: the association rules method is an association that describes the relationship between data

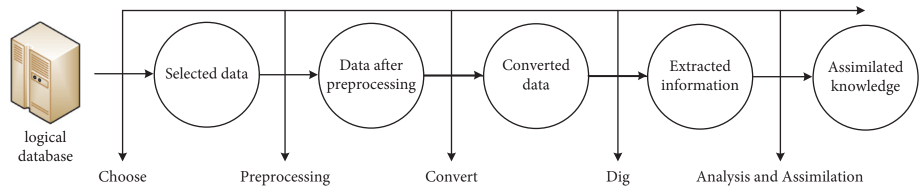


Figure 2: The basic process of data mining.

elements in a database. In other words, depending on the occurrence of certain parts of an event, other elements of the same event can be searched for, such as hidden links in the data or links between them.

Feature: feature analysis method is to extract the feature formula of these data from a set of data. These feature expressions represent the general characteristics of the dataset. For example, by extracting the main characteristics of customer churn, marketers can obtain the main reasons and characteristics that lead to customer churn and then avoid a large number of customer churn according to these reasons and characteristics.

Variation and bias analysis: bias includes a large amount of latent and interesting knowledge, such as abnormal instances in classification, abnormal patterns, and observational bias in expectations. Often unexpected rules can hide huge benefits. Once these abnormal rules have found their potential value, the benefits are immeasurable.

Data mining is a step in finding information. Data mining refers to processing algorithms to find hidden information in a large amount of data. With the massive generation of data, big data technology is becoming more and more popular, and big data platform technology is also making continuous progress. Although the data processing at the big data level is not much different from the previous data processing in terms of extraction and algorithm due to the difference in the width and size of big data, the implementation of big data mining will also be somewhat different. The common solution is to redesign the data mining algorithm under the big data platform and realize the expansion of the processing data volume through the dynamic expansion of the cluster [18]. The basic process of data mining is shown in Figure 2.

Data mining, also known as database recovery, is the use of sample computations to extract unknown and potentially valuable data from noisy, inconsistent, large amounts of data, and random data. Data mining can process many types of data, which can be divided into three types: unorganized data (such as video, text, etc.), organized data (such as data stored in communication databases), and unstructured data (such as biotechnological data, data, etc.). Decision makers can find hidden links in data by processing data and identifying ignored factors and data. Query optimization, decision support, information query, process control, etc. all need to use the discovered knowledge. It is a great help in predicting and decision-making behavior. Nowadays, data mining technology is more and more mature and reliable, and it can be applied in more and more scenarios, such as some of the fields listed below:

The field of marketing, in the field of marketing, usually analyzes the actual needs of customers, and according to the customer's consumption habits and consumption characteristics, a simple and direct management is carried out for different customers, hoping to achieve the purpose of smooth product sales and improving the success rate of personal sales. The scope of sales has also developed from the early supermarket shopping to other businesses such as banking and insurance.

In the field of scientific research, in the field of science, scientific research needs to make a lot of experimental tests, and it is necessary to perform complex analysis of experimental data, summarize the reasons for failure, and make adequate preparations for the next experiments. However, the data generated by the experiment are usually huge, so data mining technology is also widely used in the field of scientific research.

Cluster analysis is one of the important research directions in the field of data mining. Fuzzy clustering algorithm is a mathematical method based on fuzzy mathematics, first, a brief introduction to fuzzy mathematics. The revolutionary discipline of mathematics deviates from the absolute black-and-white relationship of classical science. Fuzzy mathematics can accurately analyze and filter complex data with uncertainty. The fuzzy clustering algorithm first describes the properties of the searched objects through a fuzzy table and displays the clusters according to the appropriate membership level. The purpose of clustering is to group small disparate data into one category, and the differences between categories should be clear [19].

Generally speaking, traditional techniques and improved techniques are two distinct branches of data mining theoretical techniques. In addition, data mining objects are mostly variable, with large numbers of samples used to simplify and alter multivariate analysis contained in higher statistics. Factor analysis, discriminant analysis for classification, and group analysis for partitioning groups are especially commonly used in data mining processes.

Artificial neural networks, also known as Neural Networks or known as Connectionist Models, are abstractions and modeling of the basic features of the human brain or natural Neural Networks. Artificial neural network is a physiological research result based on the brain. Its purpose is to simulate some mechanisms of the brain and realize some of its functions.

Decision Tree is a decision analysis method based on various conditional probabilities. By building a decision tree to obtain the probability that the expected value of the net present value is equal to or greater than zero, the project risk

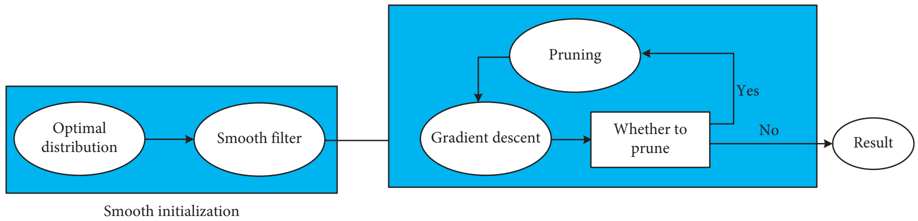


Figure 3: Improved deep learning framework algorithm flow.

is assessed and its feasibility is determined. This is a graphical method using probabilistic analysis. In machine learning, a decision tree is a predictive model. It represents the mapping relationship between object properties and object values.

4. The Spring Festival Holiday Tourism Data Mining Experiment

The improved deep learning framework proposed in this paper includes the following elements: (1) using good starting variables and smoothing layers in compressed form to improve network performance. (2) Normal network training and powerful editing methods eliminate unnecessary and useless process variables, simplify network organization, and improve the computational efficiency of the network. The algorithm flow of this framework is shown in Figure 3. First, the optimal distribution is selected to initialize the network parameters, and the initial parameters are smoothed. During the training of the network, after each period of gradient descent training, dynamic pruning is performed on the current network. After several times of dynamic pruning, a new network with significantly simplified structure and basically unchanged accuracy is obtained [20].

The main steps are as follows:

(1) Determining the business object. Although the results of data mining have unpredictable characteristics, the problems that need to be mined are very clear, and the results of blind data mining will not be successful.

(2) Data preparation. The selection of data collects all external and internal data information related to the business object, and then selects the appropriate data. In data preprocessing, in order to ensure the quality of data mining results, it is necessary to analyze the quality of the data itself and then prepare for the next process. And according to the purpose of excavation, the type of excavation to be performed is determined. Data conversion, converting data into an analysis model built for mining algorithms, and establishing an appropriate analysis model are the key factors for the success of data mining.

(3) Data mining. Except for the selection of appropriate mining algorithms, everything else can be done automatically.

(4) Result analysis. The results of data mining need to be interpreted and evaluated. The analysis method used is generally determined by data mining operations, and visualization techniques are currently used.

The dataset is trained and classified, all parameters in the network are initialized by relevant methods, and the network is recorded as the original network. The test accuracy is shown in Table 1.

The first fully connected layer in the introduced shallow neural network is replaced with a convolutional pooling layer with the same number of channels, and other parameter settings remain unchanged. For ease of identification, this network is named convolutional pooling network. Likewise, the performance of convolutional pooling networks between nonsmooth initialization and smooth initialization is compared, and for different kinds of layers in the network. A typical fully connected layer is shown in Figure 4.

Different smoothing filters make the parameters have different distributions, and the different parameter distributions are reflected in the different precision performances of the neural network. A comparison of different smoothing filters is shown in Table 2.

After deleting unimportant parameters in the neural network, it is sometimes necessary to continue deleting unnecessary neurons (nodes). After parameter pruning, some hidden layer neurons will have no input connection at all or no output connection. This makes these neurons out of the decision-making process of the network, so they need to be deleted to further simplify the structure of the network [21]. Stranded neurons are shown in Figure 5.

Since we use a convolutional pooling layer in the flattening layer, we can prune more parameters in this layer. This shows that using the initialization and pruning method proposed in this paper, the deleted parameters do not make a relatively large contribution to the decision-making process of the network. And the subsequent training process is only a fine-tuning of the network accuracy, rather than relearning the connectivity between the remaining neurons. The pruning results on the dataset are shown in Table 3.

The focus of this paper is on how to prune redundant parameters in the normal training process without affecting the network performance as much as possible, without further compressing the remaining parameters with any subsequent steps. Table 4 shows the test accuracy and the results on the dataset.

Table 1: Test accuracy of two hidden layer convolutional neural networks.

Initialization method		Nonsmooth initialization	
Training layer	Convolutional layer	All pass layer	All layers
Original network	95.54%	95.21%	98.74%
Convolutional pooling network	94.78%	94.91%	98.78%
		Smooth initialization	
Training layer	Convolutional layer	All pass layer	All layers
Original network	88.71%	92.34%	98.24%
Convolutional pooling network	92.74%	93.73%	98.54

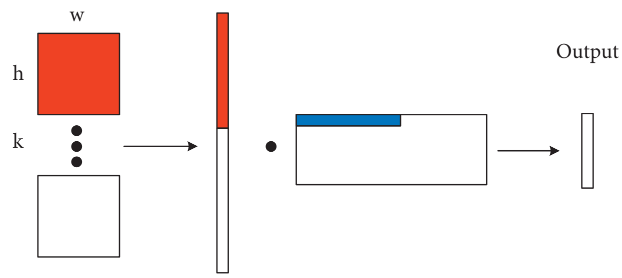


Figure 4: A typical fully connected layer.

Table 2: Comparison of different smoothing filters.

		Not smooth	3×3 Gaussian	5×5 Gaussian	3×3 Median	5×5 Median
Test accuracy		95.48%	95.62%	65.41%	95.58%	95.62%
Pruning	Conv1	25 (39%)	30 (45%)	32 (49%)	30 (42%)	28 (44%)
	Conv2	4.5 K	4.5 K	5.1 K	4.5 K	4.4 K
	Conv3	8.7 K	7.8 K	9.4 K	6.8 K	7.2 K
	Precision	95.44%	95.45%	95.32%	95.47%	95.52%

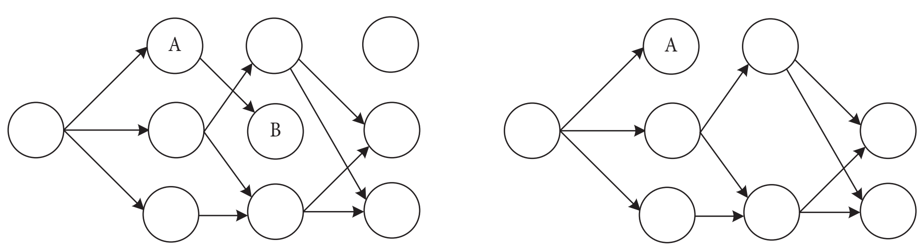


Figure 5: Stranded neurons.

Table 3: Pruning results on the dataset.

	Convolutional layer 1	Convolutional layer 2	Flattening layer	Output layer	Total
Total number of parameters	0.5 K	25 K	350 K	5 K	421 K
Threshold	0.02	0.05	0.015	—	—
Pruning ratio 1	34%	87%	91%	82%	93%
Pruning ratio 1	30%	74%	95%	—	94%

The number of data in the training set for the experiment is 7494, and the number of data in the test set is 3498. The classification result statistics are shown in Figure 6.

Using the constructed deep learning model to mine user preferences, travel popularity, and other data, a vacation travel recommendation system is constructed. The vacation travel recommendation system has three important modules: user modeling module, recommendation object modeling module, and recommendation algorithm module. The recommender system model process is shown in Figure 7.

Using a free crawler software to obtain national tourism information from certain tourism official websites. It includes the name, rating, recommendation index, and user comments of a scenic spot. The user's comments mainly obtain the time of the user's comment, and the user's

Table 4: Test accuracy and results on the dataset.

Training/pruning method	Test accuracy (%)	Parameter compression ratio
Original network	93.55	1X
GD	92.71	2X
DGC	93.65	3X
Before dynamic pruning	94.12	1X
Dynamic pruning (36%)	93.54	4X
Dynamic pruning (41%)	93.85	7X

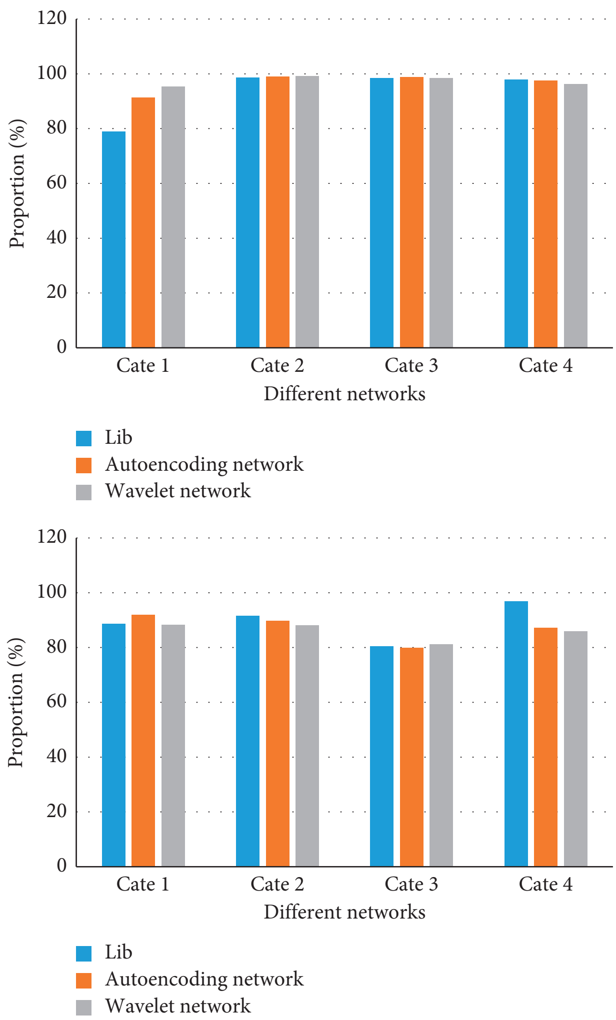


Figure 6: Classification result statistics.

comment is used to judge whether the user is a local order or a remote order [22]. Using WEKA to mine the data, the results are shown in Figure 8.

From the analysis, the following conclusions can be drawn: among the tourist attractions in city A, the tourist attractions with local characteristics are more inclined to visit by nonlocal tourists, and the locals of popular attractions are more inclined to visit. Therefore, it can be inferred that tourists from different places prefer different tourist attractions, local tourists prefer popular scenic spots, and nonlocal tourists prefer local special scenic spots. In summer, tourists are more inclined to go to scenic spots with water sports, while in winter, tourists are more inclined to go to scenic spots with hot springs such as health spas and tourist resorts. Therefore, it can be inferred that the number of orders for tourist attractions will be different in different seasons, especially some attractions with water activities, which are more seriously affected by seasons. It was also found through analysis that couple travelers prefer scenic spots with the sea, and parent-child travelers prefer scenic spots such as safari parks. Therefore, it can be inferred that different types of travelers have different favorite tourist attractions [23].

Due to the variability of Spring Festival travel information, many external factors need to be considered. The so-called external factors refer to factors such as seasons, weather, user preferences, and historical behaviors of users, due to many factors. Therefore, when generating a recommendation candidate set, only relying on a certain strategy cannot solve the user problem very well. Therefore, it is necessary to build a set of combined strategies and carry out at the same time to ensure the rationality of the recommended candidate set for users. After the recommendation candidate set is generated, it is necessary to sort the generated recommendation candidate set according to a certain sorting strategy. The purpose of sorting is that those information will be recommended to users first, and those information will be filtered out because they are unreasonable. Therefore, there are three steps when constructing a recommendation candidate set. The first step is called a recall strategy. This step is to generate a recommendation candidate set according to the user's behavior information. The second step, called a filtering strategy, filters the initially generated candidate set. The third step is called the sorting strategy, which sorts the generated candidate set to generate the final recommendation set. As shown in Figure 9, the recall strategy for generating the recommended candidate set is shown.

The recall strategy for generating the recommended candidate set consists of four recommendation strategies. The first strategy is a strong correlation strategy for user historical behavior, which is mainly for users to browse and collect unpurchased travel products to generate a recommended set. The second strategy is a collaborative filtering strategy based on sights browsing behavior and user real-time search behavior. The third one is a recommendation strategy based on geographic location, and the last one is a substitute strategy, which is a popular city recommendation strategy when users cannot apply the above three strategies.

The system proposed in this paper is optimized, as shown in Figure 10. The left picture is a schematic diagram of coverage before and after optimization, and the right picture is the score of the results of the four recall strategies.

For users, the strong correlation strategy of historical behavior and the collaborative filtering strategy are personalized recommendations for users, and this recommendation is also the best way to express the user's interest. The location-based recommendation and popular city recommendation are an auxiliary recommendation because the historical behavior strong correlation strategy and the collaborative filtering strategy are based on the

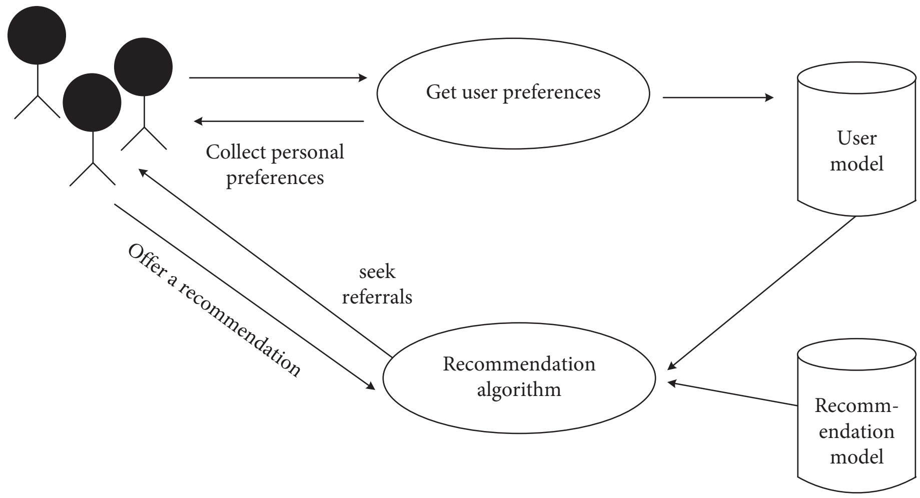
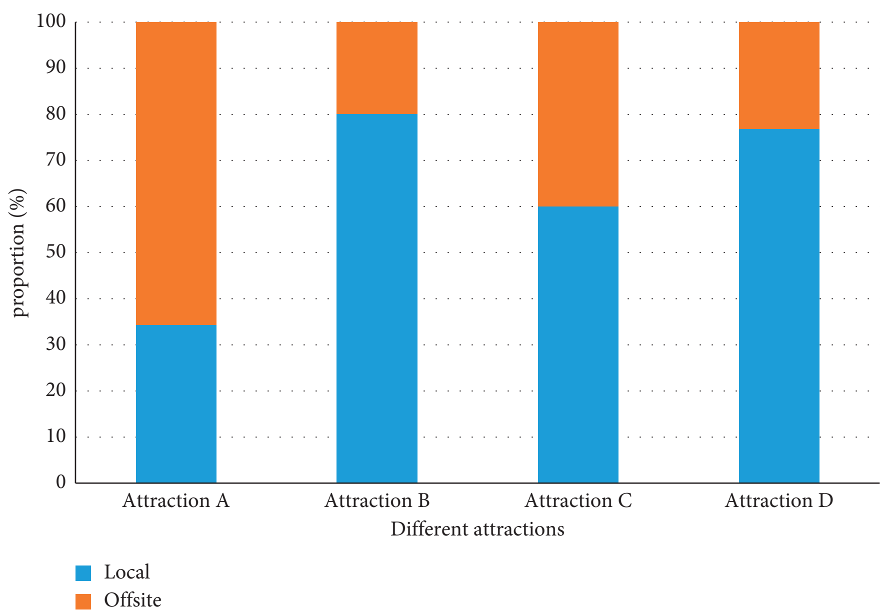


Figure 7: A general model for recommender systems.



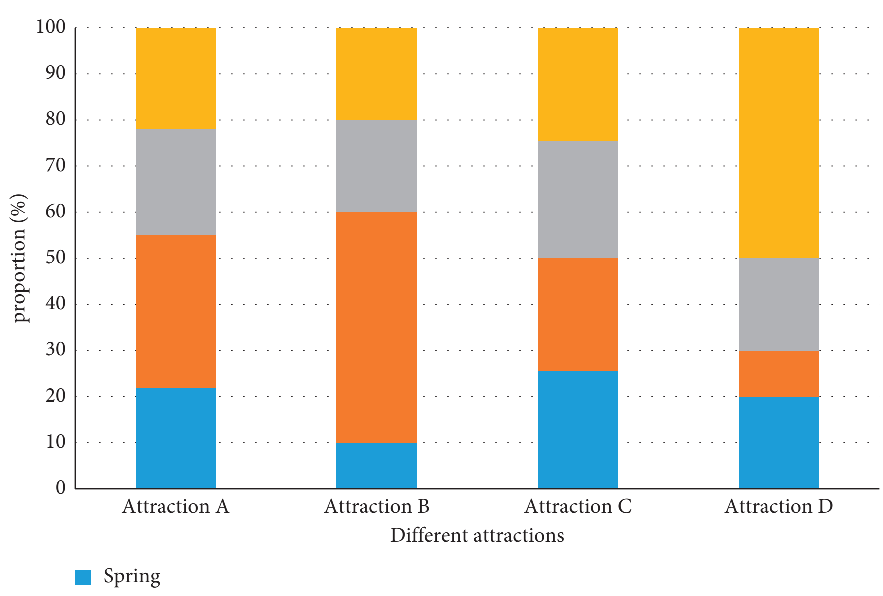


Figure 8: Order sources for different attractions and data graphs for different seasons.

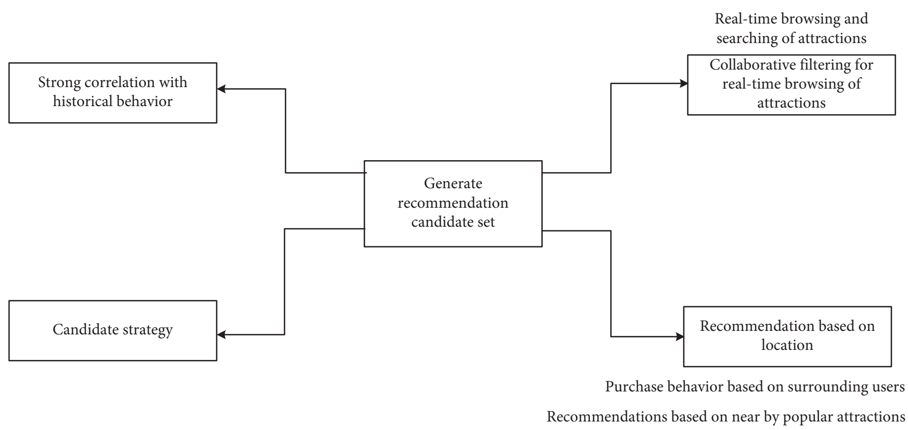


Figure 9: Generate recommendation candidate set recall strategy.

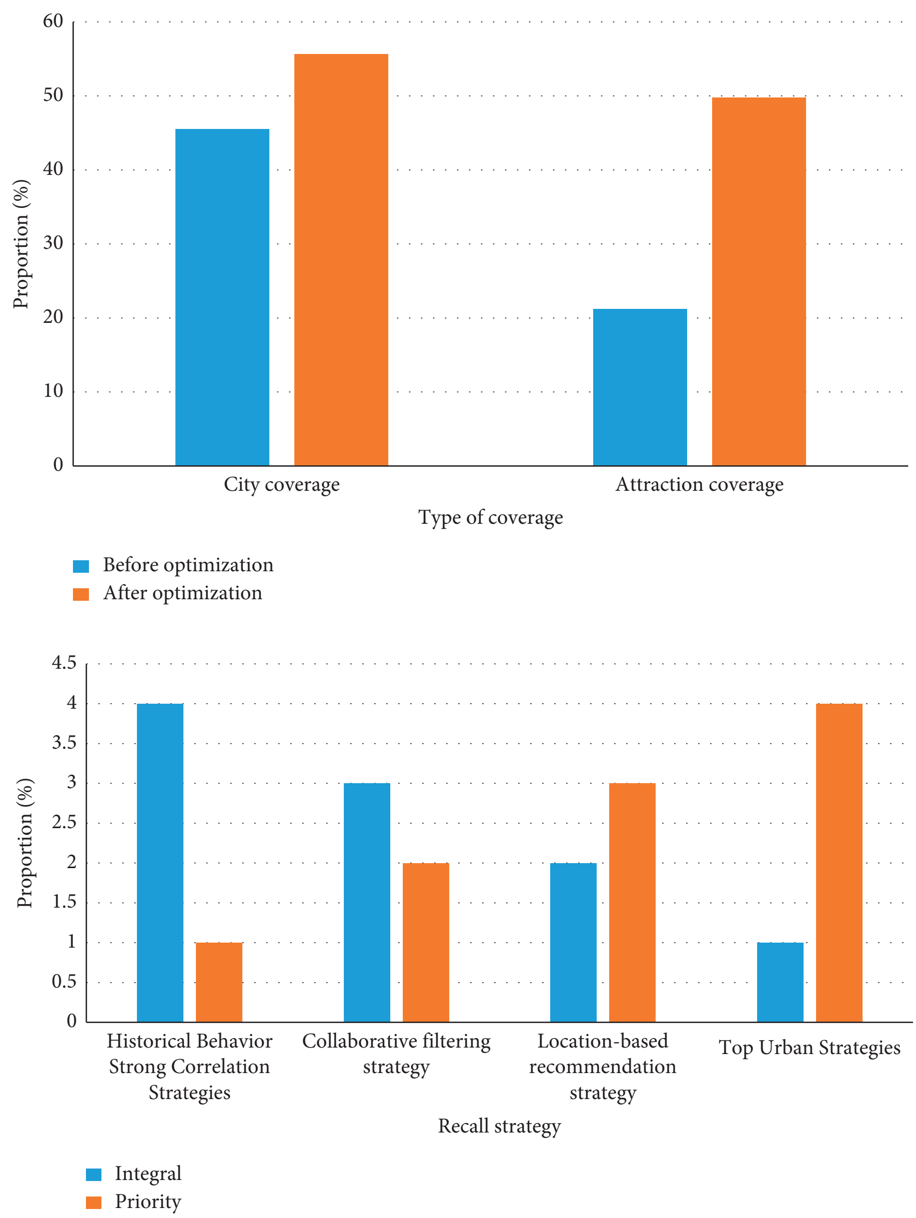


Figure 10: Schematic diagram of coverage before and after optimization.

user's behavior. If the user does not have any historical behavior, then this situation must rely on the recommendation based on location and the recommendation of popular cities, which are aimed at a popular recommendation method and can only indicate the interest of most people. Therefore, the results of the four recall strategies can be given a point, and the result set obtained by the strong correlation strategy of historical behavior is given 4 points. The result set obtained by the collaborative filtering strategy is given 3 points, the result set obtained by the geographic location-based recommendation strategy is given 2 points, and the result set of the last popular city strategy is given 1 point [24].

5. Discussion

The travel recommendation system needs to record the user's historical behavior. It includes the tourist attractions that users purchased, browsed, and collected, comments and ratings on purchased attractions, comments on some guides, and interactions with authors who wrote guides, and filter, analyze, and mine the information to form the user's preference model. Then, in the recommendation engine, the user's preference model is used as input to obtain the recommended item set. Finally, the recommended item set is displayed to the user, and the user's feedback results are recorded, whether they are satisfied with the recommended results, and what needs to be improved. The system analyzes and optimizes according to the feedback results and adjusts a new user preference model. Therefore, the functions of a complete travel recommendation system can be divided into the following modules: user behavior collection, collection information preprocessing, collection information mining, establishment of user preference model, item recommendation, UI display, and user feedback analysis.

The tourism information recommendation system based on data mining is to build a user-oriented personalized tourism information recommendation platform based on the existing tourism information system, combining data mining knowledge and recommendation system algorithm. First, through a large amount of tourism information, the key factors affecting the choice of tourist attractions by tourists are excavated. Through the analysis of the key factors, the difficulties in realizing the tourism recommendation system are obtained. Then, aiming at the difficulties, a combined recommendation strategy is proposed, and the collaborative filtering algorithm is optimized, which can solve the coverage problem to a certain extent. Finally, some functions of the tourism information recommendation system are realized.

In different recommendation systems, the best recommendation algorithm should be selected according to specific scenarios. After decades of development, personalized recommendation algorithms have produced a variety of recommendation algorithms. These algorithms have their own unique application scenarios, advantages and disadvantages. The three most common recommendation algorithms are described below.

For content-based recommendation, the algorithm first needs to extract the feature points of the items, then calculate the similarity between the items, and then give the final recommendation through calculation. The advantage is that the recommended results are intuitive, easy to explain to users, and do not require a certain domain of knowledge. The disadvantage is that it is very time-consuming to extract features and calculate similarity, and usually requires a lot of offline calculations, but the recommended results are not ideal.

For collaborative filtering recommendation, this algorithm is the current mainstream recommendation technology, and it does not need to extract the features of the items nor the association rules of the items, but only needs to calculate the similarity between users or items. The collaborative filtering algorithm is suitable for personalized recommendation and can handle complex unstructured objects, but it also has inevitable shortcomings, such as poor recommendation quality at the beginning of the system and new user problems.

6. Conclusion

The tourism information recommendation system based on data mining is to build a user-oriented personalized tourism information recommendation platform based on the existing tourism information system, combining data mining knowledge and recommendation system algorithm. First, through a large amount of tourism information, the key factors affecting the choice of tourist attractions by tourists are excavated. Through the analysis of the key factors, the difficulties in realizing the tourism recommendation system are obtained. The paper proposes that different parameter distributions are reflected in different precision performances of neural networks and obtains a comparison of different smoothing filters. In this paper, a preliminary prediction research is carried out. Given the limited data sources and academic level, the research will inevitably have omissions. In the current situation analysis stage, the analysis is not thorough enough, only showing the changes of relevant indicators, and lack of internal judgment analysis; in the theoretical research stage, the grasp of the theory is not deep enough. The improved algorithm in this paper only solves the coverage problem to a certain extent, but the cold start problem of the recommendation system is still not well solved. When the user's historical record does not exist, it is converted to recommend popular attractions in the target city to the user. Although the recommendation can be achieved, it cannot solve the problem of user personalization.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this article.

References

[1] G. Litjens, T. Kooi, B. E. Bejnordi, A. A. A. Setio, and C. I. Sánchez, "A survey on deep learning in medical image analysis," *Medical Image Analysis*, vol. 42, no. 9, pp. 60–88, 2017.

[2] D. S. Kermany, M. Goldbaum, W. Cai, and C. C. S. Valentim, "Identifying medical diagnoses and treatable diseases by image-based deep learning," *Cell*, vol. 172, no. 5, pp. 1122–1131, 2018.

[3] H. He, C.-K. Wen, S. Jin, and G. Y. Li, "Deep learning-based channel estimation for beamspace mmWave massive MIMO systems," *IEEE Wireless Communications Letters*, vol. 7, no. 5, pp. 852–855, 2018.

[4] W. E and B. Yu, "The Deep Ritz method: a deep learning-based numerical algorithm for solving variational problems," *Communications in Mathematics and Statistics*, vol. 6, no. 1, pp. 1–12, 2018.

[5] T. Young, D. Hazarika, S. Poria, and E. Cambria, "Recent trends in deep learning based natural language processing [review article]," *IEEE Computational Intelligence Magazine*, vol. 13, no. 3, pp. 55–75, 2018.

[6] X. X. Zhu, D. Tuia, L. Mou, and G.-S. L. F. F. Xia, "Deep learning in remote sensing: a comprehensive review and list of resources," *IEEE Geoscience and Remote Sensing Magazine*, vol. 5, no. 4, pp. 8–36, 2017.

[7] S. Xie, Z. Yu, and Z. Lv, "Multi-disease prediction based on deep learning: a survey," *Computer Modeling in Engineering and Sciences*, vol. 128, no. 2, pp. 489–522, 2021.

[8] J. Lee, "Integration of digital twin and deep learning in cyber-physical systems: towards," *Smart Manufacturing*, vol. 38, no. 8, pp. 901–910, 2020.

[9] Y. Li, Y. Zuo, H. Song, and Z. Lv, "Deep Learning in Security of Internet of Things," *IEEE Internet of Things Journal,* 1 page, 2021.

[10] X. Sun, P. Wu, and S. C. Hoi, "Face detection using deep learning: an improved faster RCNN approach," *Neurocomputing*, vol. 299, pp. 42–50, 2018.

[11] H. Li, K. Ota, and M. Dong, "Learning IoT in edge: deep learning for the Internet of things with edge computing," *IEEE Network*, vol. 32, no. 1, pp. 96–101, 2018.

[12] a admin, I. e el-henawy, K. Ahmed, fnm au, I. e. el-henawy, and K. Ahmed, "An improved equilibrium optimizer algorithm for tackling global optimization problems," *Fusion: Practice and Applications*, vol. 3, no. 1, pp. 01–28, 2021.

[13] a. admin, A. M. Abdulazeez, fnm au, and A. M. Abdulazeez, "Electrocardiogram classification based on deep convolutional neural networks: a review," *Fusion: Practice and Applications*, vol. 3, no. 1, pp. 43–53, 2021.

[14] J. Han, D. Zhang, G. Cheng, and N. D. Liu, "Advanced deep-learning techniques for salient and category-specific object detection: a survey," *IEEE Signal Processing Magazine*, vol. 35, no. 1, pp. 84–100, 2018.

[15] M. Elsharkawy, N. Ahmed, and A. Masri, "A novel image encryption with deep learning model for secure content based image retrieval," *Journal of Cybersecurity and Information Management*, vol. 0, no. 2, pp. 54–64, 2019.

[16] M. Hammoudeh, S. M. Aljaberi, fnm au, and S. M. Aljaberi, "Modeling of deep learning based intrusion detection system in Internet of things environment," *Journal of Cybersecurity and Information Management*, vol. 8, no. 1, pp. 17–25, 2021.

[17] A. S. Heinsfeld, A. R. Franco, A. Buchweitz, and F. Meneguzzi, "Identification of autism spectrum disorder using deep learning and the ABIDE dataset," *NeuroImage: Clinic*, vol. 17, no. C, pp. 16–23, 2018.

[18] N. Sünderhauf, O. Brock, W. Scheirer, and R. D. J. B. P. W. M. P. Hadsell, "The limits and potentials of deep learning for robotics," *The International Journal of Robotics Research*, vol. 37, no. 4-5, pp. 405–420, 2018.

[19] Q.-s. Zhang and S.-c. Zhu, "Visual interpretability for deep learning: a survey," *Frontiers of Information Technology & Electronic Engineering*, vol. 19, no. 1, pp. 27–39, 2018.

[20] S. S. Han, M. S. Kim, W. Lim, and G. H. I. S. E. Park, "Classification of the clinical images for benign and malignant cutaneous tumors using a deep learning algorithm," *Journal of Investigative Dermatology*, vol. 138, no. 7, pp. 1529–1538, 2018.

[21] M. Araya-Polo, J. Jennings, A. Adler, and T. Dahlke, "Deep-learning tomography," *The Leading Edge*, vol. 37, no. 1, pp. 58–66, 2018.

[22] K. Grm, V. Štruc, A. Artiges, M. Caron, H. K. Ekenel, and H. K. Ekenel, "Strengths and weaknesses of deep learning models for face recognition against image degradations," *IET Biometrics*, vol. 7, no. 1, pp. 81–89, 2018.

[23] R. Kemker, C. Salvaggio, and C. Kanan, "Algorithms for semantic segmentation of multispectral remote sensing imagery using deep learning," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 145, pp. 60–77, 2018.

[24] R. Ranjan, S. Sankaranarayanan, A. Bansal, and N. Bodla, "Deep learning for understanding faces: machines may Be just as good, or better, than humans," *IEEE Signal Processing Magazine*, vol. 35, no. 1, pp. 66–83, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 2730532, 12 pages
https://doi.org/10.1155/2022/2730532

Research Article

Study on the Development Model of the Combination of "Third-Tier" Industrial Heritage and Rural Tourism under the Concept of Urban Image

Lu Yang

Academy of Fine Arts, Hubei Normal University, Huangshi 435002, Hubei, China

Correspondence should be addressed to Lu Yang; yanglu@hbnu.edu.cn

Received 30 March 2022; Revised 4 May 2022; Accepted 14 May 2022; Published 16 June 2022

Academic Editor: Ahmed Farouk

In order to pay attention to the protection of the third tier industrial heritage, this paper puts forward the protection measures of combining the third tier industrial heritage with tourism based on the concept of urban image. The tourism value of the tertiary industrial heritage is evaluated by using the comprehensive evaluation method. Through the analysis of the tourism value evaluation system combining the three-level industrial heritage and rural tourism in a certain city, the following conclusions are drawn. In the comprehensive evaluation layer, the value of the third tier industrial heritage accounts for the largest weight of 0.5581, indicating that the third tier industrial heritage resources occupy an important position in the third tier industrial heritage tourism value system. Tourism development conditions also account for a large proportion, which explains that while adhering to the principle of third tier industrial heritage protection, we should pay attention to the consideration of tourism development conditions. It once again emphasizes the importance of the third tier industrial heritage for the development of industrial heritage tourism and the significance of the protection of the third tier industrial heritage for tourism development. In the three-level evaluation layer of industrial heritage and rural tourism, the historical and cultural value and social and cultural value have the largest weight. They are the leading factor of the combined value of tertiary industrial heritage and rural tourism. Historical and cultural value is one of the important meanings of three-level industrial heritage protection and also the essence of the combined development of third-level industrial heritage tourism and rural tourism. Social value determines the recognition of tourists and people to participate in the development of tourism. In the evaluation layer of tourism development conditions, the development potential is particularly prominent. The development potential is the characteristic of the third tier industrial heritage tourism of a city. The development of the third tier industrial heritage tourism of a city must be combined with the local characteristics to highlight the differences.

1. Introduction

Rural planning plays a positive role in promoting China's ruralization and accelerating rural functional construction and leads the scientific development of cities through reasonable rural planning guidance. To strengthen rural planning and construction, we need to do a good job in rural image analysis and make targeted rural image analysis according to the development characteristics and economic conditions of different cities, so as to provide a solid foundation guarantee for rural planning. China has a vast territory and different regions have different landscape cultures. In recent years, the development of rural tourism has become one of the important ways to strengthen economic construction and attract foreign investment in rural planning. The main research object of rural intention is rural residents, and the main service object of rural landscape construction and environmental construction is also rural residents. With the rapid development of economy, the existing cultural life can no longer meet the needs of the masses. Strengthening the rural internal landscape and environmental design can effectively improve the attraction of the city to foreign tourists and drive the regional economic development [1, 2]. Therefore, based on the research of rural intention, this paper uses the rural image to analyze the internal landscape and cultural characteristics of the city, create more attractive rural viewing points, show the unique cultural charm of the city in many aspects, and improve the scientificity and practicability of rural tourism planning by organizing activities, so as to create environmental atmosphere and strengthening cultural publicity. In the traditional sense, the production, production, and management of tourism products and services involve a considerable range and should consume considerable time cost and human resources in real life. There is no doubt that it increases the investment cost of rural tourism industry development to a large extent. In the process of development and operation of rural tourism industry, if information technology can be properly integrated, it can steadily increase the work efficiency of related links of rural tourism industry and improve the management level of tourism products and services [3, 4]. The utilization of electronic information system can quickly process all kinds of data and information and reduce the relevant statistical and accounting pressure of agricultural tourism products and services. Using the powerful auxiliary function of information technology can handle all kinds of information and data in a very short time and can ensure the accuracy of important information and data. It can scientifically formulate the enterprise development strategy for the rural tourism enterprises, supplemented by reliable basis, so that they can avoid various risks in the operation and development. At the same time, because a lot of tourism enterprises take a variety of information technology, on the network to promote related tourist attractions, products, and services, to a greater extent, cut the cost of the traditional rural tourism management capital, enhance the effectiveness of tourism industry service information and data, and continue to retain and expand more source market in the industry.

"Industrial heritage" refers to the remains of industrial civilization, which have historical, scientific, social, architectural, or scientific values. These relics include buildings, machinery, workshops, factories, mines, and mining areas for beneficiation and smelting, warehouses, places for energy production, transmission and utilization, transportation and infrastructure, and places for social activities related to industry, such as residential, religious, and educational facilities. In recent decades, it is common to study the relationship between industrial heritage protection and urban development, whether from theoretical research or practical case operation, but so far, there are few studies on the relationship between third tier industrial heritage protection and small city development planning. In view of this, this paper takes the third tier industrial heritage of a city as the research object and uses SWOT analysis to comprehensively evaluate it, so as to make the industrial heritage play its due role in the current small city planning and construction through research. The SWOT analysis framework is shown in Figure 1.

2. Literature Review

This research problem has been verified by some scholars. Petrova and others concluded that industrial heritage, as a tourism resource, has a certain impact on urban image and development [5]. Daoud and others studied the personalized heritage of mining towns by taking the landscape of Springhill and Herbert River as an example [6]. Zhang and others studied the potential of abandoned industrial parks into social life [7]. By analyzing the protection and reuse of industrial heritage, Cheng and others studied its role in the accumulation of urban memory and cultural rejuvenation [8]. Wan and others took the industry in Yangshupu area as an example, evaluated the value of its industrial heritage buildings, put forward graded and classified protection measures, and deeply discussed the planning strategies for the overall protection and comprehensive rejuvenation of the industrial heritage area [9]. Coratza and others proposed that industrial heritage, as the witness, protection, and reuse of urban historical context, should be combined with the strategy of urban context inheritance [10]. Marcak and others put forward five typical reuse modes of industrial heritage from the relationship between urban characteristics and industrial heritage [11]. Li and others advocate that the protection and utilization of industrial heritage can only be combined with the overall development of the city to highlight its real value and achieve the purpose of coordinating protection and utilization [12]. At the nonmaterial level, Pickell and others all unanimously emphasized the participation of tourists in the protection of traditional villages, which also expressed that the trend of traditional village tourism development is the harmony between people and traditional villages. Industrial heritage is divided to broad industrial heritage and narrow industrial heritage. The broad industrial heritage includes handicraft, processing, mining, and other ancient sites before the industrial revolution, such as prehistoric scale stone sites and large-scale water conservancy projects, like Dujiangyan irrigation system; narrow industrial heritage started in the 18th century, using steel, coal, and oil as the production of new energy, after the industrial revolution. Broad industrial heritage includes industrial production and industrial-production-related construction, transportation, education, service, and other related industries. It also includes the related achievements of new energy, new technology, and new materials that have brought major changes to the society and also includes the social places engaged in industrial activities, such as employees' family areas, and religious places. In the narrow sense, industrial heritage mainly refers to the industrial remains of production, processing, storage, and transportation including steel, coal industry, and many other industrial categories and all kinds of industrial buildings and ancillary buildings. From the perspective of the research object form, the industrial heritage has two forms: material and intangible heritage. Material heritage includes construction, processing, and production machinery and products; intangible heritage mainly refers to the production, processing, enterprise culture, spirit, and technology. On the other hand, this paper expounds the

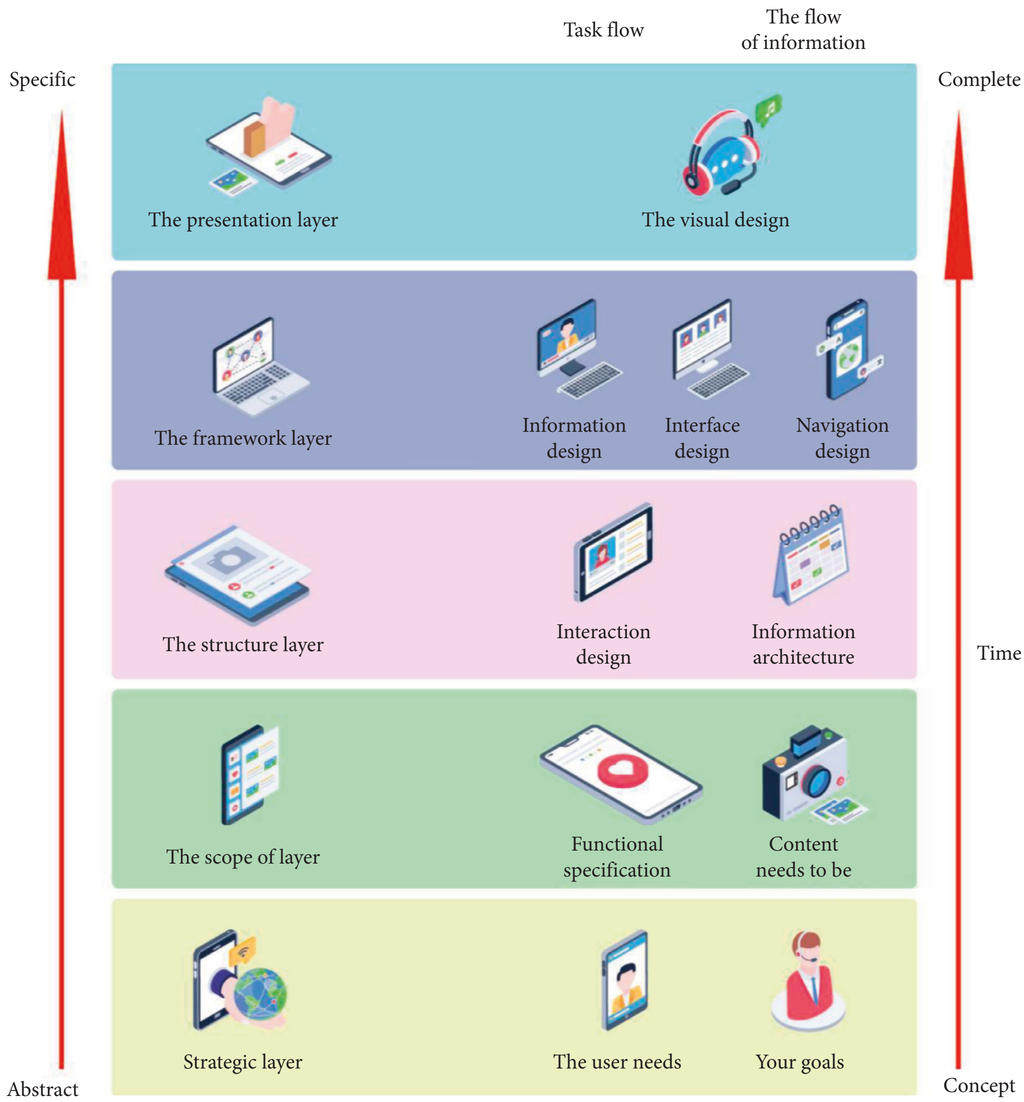


FIGURE 1: SWOT analysis.

importance of passenger experience, and the relevant theoretical research methods are emerging one after another. For example, Salim et al. introduced the concept of Yeli distance into the tourist experience research of heritage tourism and believed that low Bili distance will create a more specific and situational concept, and high Tun and Li distance will create a macro and abstract internal perception of heritage objects. Figure 2 shows the relationship between industrial heritage and industrial heritage tourism.

Based on the current research, the concept of combining the "three-line" industrial heritage and rural tourism image is proposed, and the feasibility analysis method of developing the city is comprehensively evaluated. At the same time, according to which industrial heritage is suitable for tourism development and how to develop, the evaluation standards of industrial heritage tourism and rural tourism are constructed. The value and significance of industrial heritage tourism and rural tourism are studied in detail. In the evaluation layer of tourism development conditions, the development potential is particularly prominent. The development potential is the characteristic of the third tier industrial heritage tourism of a city. The development of the third tier industrial heritage tourism of a city must be combined with the local characteristics to highlight the differences.

3. Method

The essence of evaluation is a kind of intelligent activity of people. Generally speaking, it has the characteristics of nonlinearity. A large number of evaluation practices also prove that the uncertainty of evaluation work leads to the nonlinearity of evaluation, so the nonlinear evaluation model is more in line with the reality of evaluation. In a general sense, all the evaluation problems should be nonlinear, and the linear evaluation is only an approximation of the nonlinear evaluation in a certain range. This paper evaluates the value of first-level and multilevel fuzzy industrial heritage tourism and rural tourism.

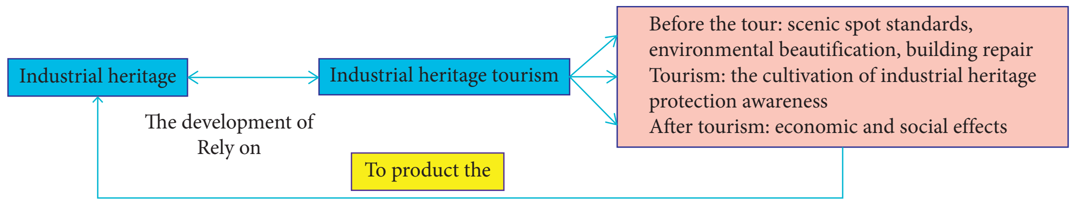


FIGURE 2: Relationship between industrial heritage and industrial heritage tourism.

3.1. One-Level and Multilevel Fuzzy Comprehensive Evaluation Method. Fuzzy comprehensive evaluation is a method to make a comprehensive decision on a thing by using fuzzy transformation for a certain purpose under the fuzzy environment and considering the influence of multiple factors. Fuzzy comprehensive evaluation can be divided into one-level evaluation and multilevel evaluation.

3.1.1. Mathematical Model of One-Level Fuzzy Multiobjective Decision-Making. Let $U = \{x_1, x_2, \ldots, x_n\}$, $V = \{y_1, y_2, \ldots, y_m\}$ be two finite comments: U is the factor set, which represents the set composed of multiple factors of multiobjective decision-making. V is the comment set or evaluation set, which represents the set composed of multiple decision objectives. Generally speaking, the factors in the factor set have different effects on the things to be judged, so each factor has its own importance distribution, which is called weight distribution. It is a fuzzy vector on U, which we record as

$$A = \{a_1, a_2, \ldots, a_n\} \in F(U), \tag{1}$$

where a_1 represents the weight of the ith factor in U and meets the requirements $\sum_{i=1}^{n} a_i = 1$. In addition, in the fuzzy environment, m comments are not absolutely positive or negative. Therefore, the result of comprehensive decision-making can be regarded as a fuzzy set on V, which is recorded as

$$B = \{b_1, b_2, \ldots, b_m\} \in F(V), \tag{2}$$

where b_j indicates the position of the j-th comment in the overall V of the evaluation target.

If $R = (r_{ij})_{n\times m}$ is a fuzzy relation matrix from U to V, a fuzzy transformation T_R can be obtained by using R. Therefore, the mathematical model structure of fuzzy multiobjective decision-making is as follows.

Factor set:

$$U = \{x_1, x_2, \ldots, x_n\}. \tag{3}$$

Comment set:

$$V = \{y_1, y_2, \ldots, y_m\}. \tag{4}$$

Construct fuzzy transformation:

$$\begin{aligned} T_R\colon F(U) &\longrightarrow F(V), \\ A &\longmapsto A \circ R, \end{aligned} \tag{5}$$

where R is the fuzzy relation matrix $R = (r_{ij})_{n\times m}$ from U to V.

In this way, (U, V, R) ternary body constitutes a mathematical model of fuzzy multiobjective decision-making. At this time, if a weight assignment $A = \{a_1, a_2, \ldots, a_n\} \in F(U)$ is input, a comprehensive decision $B = \{b_1, b_2, \ldots, b_m\} \in F(V)$ can be obtained through fuzzy transformation T_R. That is,

$$(b_1, b_2, \ldots, b_m) = (a_1, a_2, \ldots, a_n) \circ \begin{bmatrix} r_{11} r_{12} \ldots r_{1m} \\ r_{21} r_{22} \ldots r_{2m} \\ \ldots \\ r_{n1} r_{n2} \ldots r_{nm} \end{bmatrix}. \tag{6}$$

Using Zadeh operator:

$$b_j = \bigvee_{i=1}^{n} \left(a_i \wedge r_{ij}\right), \quad j = 1, 2, \ldots m. \tag{7}$$

If $b_k = \max(b_1, b_2, \ldots, b_m)$, according to the principle of maximum subordination, the comprehensive decision on the matter is b_k [13, 14]. The fuzzy multiobjective decision-making system composed of fuzzy transformation T_R as the converter is shown in Figure 3.

The core of fuzzy comprehensive evaluation is to synthesize the results of various factors. As we all know, it is easy to make decisions on things determined by single factors. However, when things involve multiple factors, it is necessary to comprehensively consider the impact of many factors on things, so as to make a decision close to the reality and avoid the one sidedness caused by judging from only one factor, which is the characteristic of multiobjective decision-making.

It should be noted that people often synthesize things in different ways. Sometimes only the single factor is required to be the best (called the main factor). Sometimes the main factors are highlighted and other factors are taken into account. Sometimes it requires the maximum sum. These situations can be realized by different operations.

The decision result of Zadeh operator $(\wedge, \vee)$ is mainly determined by the factor with the largest value, and the change of the value of other factors in a range does not affect the evaluation result. Therefore, we call it a principal factor determinant operator [15].

Generalized operators $(\vee, \bullet)$ and $(\oplus, \wedge)$ are called principal factor prominent types. They are close to Zadeh operator, the difference is that they are a little more refined than Zadeh operator, and their decision results can reflect indicators that are not main to a certain extent [16].

The generalized operator $(\oplus, \bullet)$ is called the weighted average type, which embodies the overall characteristics in the evaluation, because it gives balanced consideration to all factors according to the weight [17].

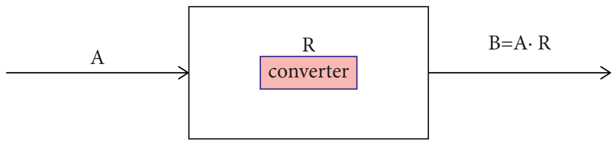


FIGURE 3: Fuzzy multiobjective (one level) decision system.

The decision result can be obtained by using only one fuzzy transformation, which is called one-level fuzzy multiobjective decision-making. It is generally used when the number of elements in the factor set is small.

3.1.2. Multilevel Fuzzy Multiobjective Decision-Making. For complex systems, many factors need to be considered. At this time, there will be two problems. First, there are too many factors, and it is difficult to determine their weight distribution. Even if they are determined, the weight of each factor will be very small, so there will be a phenomenon that valuable results will not appear after calculation. Second, factors may have categories or levels, and it is difficult to determine the weight at the same level [18]. For example, in the problem of fracturing well and layer selection, the influencing factors mainly include production characteristics x_{raw} and physical properties x_{things}; that is, factor set $U = (x_{\text{raw}}, x_{\text{things}})$. The production characteristic factors include four subfactors: formation pressure, oil well production, production differential pressure, and water cut; namely, $x_{\text{raw}} =$ {formation pressure, oil well production, production differential pressure, and water cut}. And $x_{\text{things}} =$ {permeability, porosity, saturation, and effective thickness} also includes four subfactors. It is obviously inappropriate to consider the eight factors of these two categories at one level. At this time, multilevel fuzzy multiobjective decision-making system can be used. The following takes the two-level fuzzy multiobjective decision-making as an example to illustrate its detailed steps.

Step 1. Divide the factor set $U = \{x_1, x_2, \ldots, x_n\}$ into S subfactor sets $u_1, u_2, \ldots, u_s$ according to certain attributes, where

$$u_i = \{x_{i1}, x_{i2}, \ldots, x_{im}\}, \quad (i = 1, 2, \ldots, s). \tag{8}$$

And meet

$$\begin{aligned} &n_1 + n_2 + \ldots n_s = n,\\ &u_1 \cup u_2 \cup \ldots \cup u_s = U,\\ &u_i \cap u_j = \varphi, \ (i \neq j). \end{aligned} \tag{9}$$

Step 2. Make one-level fuzzy multiobjective decision for each subfactor set. Set the comment set $V = \{y_1, y_2, \ldots, y_m\}$, and the weight distribution of each factor in u_i to V is

$$A_i = \{a_{i1}, a_{i2}, \ldots, a_{\text{im}}\}. \tag{10}$$

R_i is set as a single factor evaluation matrix, and the one-level evaluation vector can be obtained as

$$B_i = A_i \circ R_i = (b_{i1}, b_{i2}, \ldots, b_{\text{im}}), \ (i = 1, 2, \ldots, s). \tag{11}$$

Step 3. Regard each u_i as a factor and remark as

$$K = \{u_i, u_2, \ldots, u_s\}. \tag{12}$$

In this way, K constitutes a factor set, and its single factor evaluation matrix is composed of one- level evaluation vectors:

$$R = \begin{bmatrix} B_1 \\ B_2 \\ \cdot \\ B_s \end{bmatrix} = \begin{bmatrix} b_{11}b_{12}\ldots b_{1m} \\ b_{21}b_{22}\ldots b_{2m} \\ \ldots \\ b_{s1}b_{s2}\ldots b_{sm} \end{bmatrix}. \tag{13}$$

As a part of U, each u_i reflects a certain attribute of U, and the weight distribution can be given according to their importance:

$$A = (a_1, a_2, \ldots, a_s). \tag{14}$$

Thus, two-level fuzzy multiobjective decision-making is obtained:

$$B = A \circ R = (b_1, b_2, \ldots, b_m). \tag{15}$$

If each subfactor u_i $(i = 1, 2, \ldots, s)$ also contains different levels or different types of subfactors, u_i can be further divided. Similar to the three-level decision-making model obtained from the two-level decision-making process, so is the four-level and five-level models.

3.2. Analysis of Tourism Resources of the Third Tier Industrial Heritage in City A. This paper deals with the distribution of the third tier industrial heritage in city A. In the third tier industrial heritage tourism development, we should pay full attention to the characteristics of tourism resources, respect its practical significance, and give full play to its value, so that the third tier industrial heritage tourism development can be carried out correctly.

3.2.1. Rich Types of Building Functions. According to the field investigation, there are many kinds of industrial buildings involved in this paper (as shown in Figures 4 and 5), such as factory buildings, offices, civil buildings, warehouses, etc. Plant, office, and warehouse buildings account for 70% of the total. Most of the indoor spaces of these three types of buildings are spacious and changeable. The building volume is large and more artistic. The rich architectural space provides strong plasticity for the transformation of the third tier industrial heritage and can attract people's attention. It also saves the development cost for the early investment of tourism development.

3.2.2. Rich Tourism Types. The third tier industrial heritage tourism enriches the types of tourism, and the traditional tourism can no longer meet the personalized needs of tourists. According to the data released by the tourism

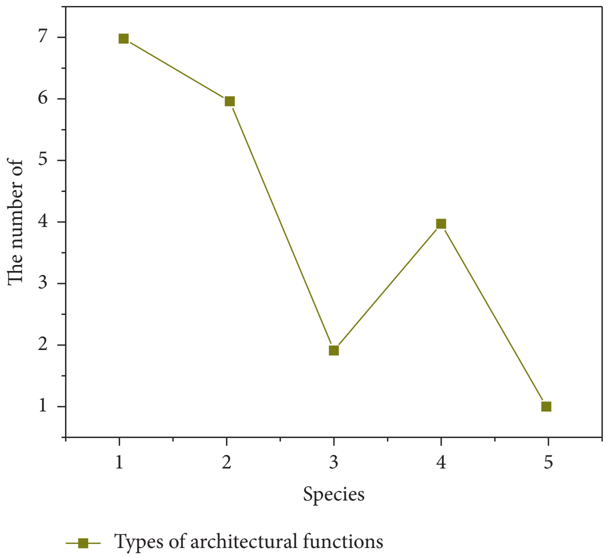


Figure 4: Types of building functions.

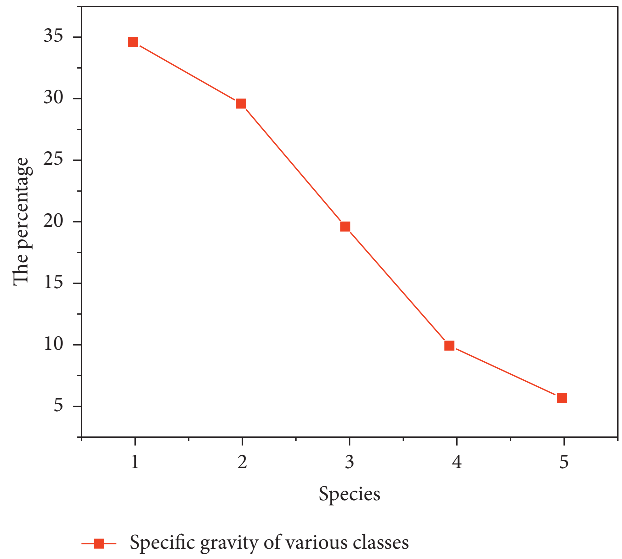


Figure 5: Proportion of building functions (from high to low, plant, office and for civil use, warehouse, commerce and others).

administration, tourists are getting rid of the traditional way of entering the scenic spot with tour groups. By 2015, the proportion of self-driving tour continues to rise, and the proportion of tourists entering the scenic spot through travel agencies has decreased from 60%–70% to 20%–30%. Free travel has become the main way for tourists to reach the scenic spot, accounting for 75% of the total number of tourists received in the scenic spot. Self-driving tour is one of the concrete manifestations of personalized tourism. The third tier industrial heritage tourism is a new form of tourism integrating leisure, entertainment, knowledge, and novelty. The timely emergence of this personalized tourism is intertwined with the strong demand of today's tourists, which will certainly attract people's attention and longing.

3.2.3. Publicize Corporate Culture. Corporate culture not only has the functions of guidance, cohesion, and restraint but also affects customers' consumption behavior. After customers recognize the corporate culture, they will increase their loyalty to their products. The existing third tier industrial heritage of a city is still in normal production. For example, the first automobile factory has experienced many years of baptism, and these enterprises have formed their own special products and corporate culture. Without affecting the normal production of the enterprise, tourists can participate in more experiential tourism contents such as product design, process flow, and production line visit, learning the enterprise culture in a relaxed and pleasant process. And the company has also captured more tourists to become potential consumers. Tourists understand the product and its culture with their most real experience and feelings; it will attract more attention from relatives and friends around and form a virtuous circle over time. Mercedes Benz carries out industrial tourism projects. Tourists enter the company's historical exhibition hall to understand the functions of automobile components, and even screw in a few screws, have lunch with employees, and participate in automobile design and other links, which not only brings happiness to tourists, but also enhances the recognition of the company's products and virtually plays a role in publicizing the company's image.

3.2.4. Improve the Economic Structure of Enterprises. In addition to the impact of emerging industries, another important factor is the unreasonable economic structure of traditional industries, which leads to the excessive dependence on a single product. Once there is any error in the product, it will bring irreparable losses to the company. Nowadays, the transformation and upgrading of enterprise products is to do a good job in products. At the same time, cross domain investment has become a new growth point of enterprise profits. The development of third tier industrial heritage tourism is a strategic idea to improve the economic structure of enterprises [19].

3.2.5. Tracing the Memory of the Industrial Age. In the current rapid change of science and technology and information, many things are changing all the time; the only constant is history, history cannot be duplicated, and industrial heritage tourism is just the confidence display of industrial history and culture. For Changchun, a heavy industry city, the industrial heritage is a continuation of history and also the representative of the industry in the early stage of New China. They made important contributions to changing the "poor" appearance of China at that time and leading the country on the road of industrialization. In the special period of Industrial heritage for the "five" "25" period after vicissitudes of life, the industrial heritage reflects Changchun people struggle days and passion burning years; the roar of the machine is the most true portrayal of the society, so far in the normal production of the factory is the witness of history. It can be seen that industrial heritage has long gone beyond its own scope and carries the historical burden. Reviewing these industrial memories is an important part of industrial heritage tourism. Through industrial heritage tourism, the real and vivid display of history is exactly what tourists need, and it is also the responsibility and obligation of industrial heritage tourism.

3.2.6. Publicize Corporate Culture. In addition to the role of guidance, cohesion and restraint, corporate culture also affects the consumption behavior of customers. After customers recognize the corporate culture, they will increase their loyalty to their products. The existing industrial heritage is still in normal production, such as the first automobile factory. After years of baptism, these enterprises have formed their own special products and corporate culture. Without disturbing the normal production, tourists can participate in product design, process, and production line visit experience to get strong tourism content. In the process of tourists' understanding of corporate culture, the company can also make more tourists become potential consumers. Tourists use their most authentic experience and feelings to understand the products and the culture behind them, which will further affect the attention of their surrounding relatives and friends and further increase the number of potential consumers. Foreign companies like Mercedes carry out industrial tourism projects, get the visitors into the company history exhibition hall, give them the opportunity to understand the function of car components and even personally twist a few screws, offer them lunch with staff, and let them participate in car design link, which not only brings happiness to visitors but also enhances the recognition of the company's products, virtually for the image of the company to play a propaganda role.

4. Results and Analysis

4.1. Development of Third Tier Industrial Heritage Tourism. If the comprehensive evaluation score is more than 6.000, it is a class I development object. From the perspective of tourism development, this kind of third tier industrial heritage has little difficulty in development and high social recognition. It is a stepping stone to open the third tier industrial heritage tourism market of a city and should be considered to be developed in 1–3 years. This kind of third tier industrial heritage has a certain tourism foundation and pleasant environment at this stage, with high experience and appreciation, such as FAW (First Automobile Works).

From the perspective of third tier industrial heritage protection, such third tier industrial heritage has high comprehensive value and has made important contributions to urban development, but the current operation situation is divided into two extremes. First, the enterprise is in good operation and is highly recognized by citizens and society, such as Changying studio. Second, the project has been in the state of no operation for a long time, has been idle for a long time, and faces the risk of demolition. The plant road planning and industrial buildings are well preserved and occupy a good geographical location, such as a tractor factory in a city. The specific application of the evaluation method takes FAW as an example, as shown in Table 1.

Through the table, we can draw the following development conclusions for FAW, and the items with high scores should be fully redivided and utilized to play its characteristics in the process of tourism development. The items with low scores should be paid attention to and developed in a balanced way.

(1) 9 points are for important tasks and events, which should be protected as one of the tourism selling points during tourism development. 10 points are for representativeness and social recognition. In tourism development, social organizations should be fully used to publicize the recognition degree and mobilize people's enthusiasm to participate in the development of third tier industrial heritage tourism. Due to the highest representative score, "FAW" should be developed as a city tourism card. As 10 points for combination and traffic convenience, FAW should cooperate with other tourism projects in the city to develop by using convenient traffic.

(2) The product progressiveness is 5 points. So we should pay attention to the product development and research and arouse the interest of tourists by using the sense of technology and mystery of the products. As experiential tourism has got 4 points, FAW tourism development should focus on strengthening the close interaction between the project and tourists.

4.2. SWOT Analysis of Third Tier Industrial Heritage Tourism: Advantages. SWOT analysis method is an analysis tool to determine the best feasible strategic combination through the analysis of the internal conditions and external environment of the research object, also known as situation analysis method. Through SWOT analysis, this paper analyzes the advantages, disadvantages, opportunities, and threats of developing the third tier industrial heritage tourism in a city, so as to provide theoretical support for the next development of the third tier industrial heritage tourism.

4.2.1. Great Potential of Tourist Market. Figure 6 shows the percentage of tourists in 2015. It can be seen that most tourists are between 20 and 30 years old, and this age group is mainly composed of students. At present, nearly 40 universities estimate that the number of students is about 600000, and the influx of college students provides a strong backing for the tourism market.

From 2011 to 2016, the total number of tourists received (as shown in Figures 7 and 8) has an average growth rate of 21% in the recent five years. The continuous growth of tourists also depicts a bright prospect for the third tier industrial heritage tourism. By the end of 2016, a city had a

Table 1: Evaluation scores of FAW third tier industrial heritage tourism development.

		Evaluation				score
		10	7-9	4-6	3-0	
Historical and cultural value	Age and integrity		8			0.6896
	Important people and events		9			0.3978
	Representativeness	10				0.741
Social value	Social recognition	10				0.751
	Resource scarcity		7			0.462
Artistic value	Integrity	10				0.0729
	Uniqueness			5		0.2875
Scientific value	Enterprise advanced nature		8			0.38
	Product advanced nature			5		0.2725
Entertainment value	Experiential			4		0.2296
	Ornamental		7			0.1827
Economic value	Development cycle			6		0.204
	Economic input			4		0.1464
Environment condition	Environmental capacity			5		0.114
	Traffic convenience	10				0.602
	Supporting services	10				0.131
	Supporting setting	10				0.305
Tap potential	Associativity	10				0.721
	Complementarity		8			0.3288
	Sustainability		7			0.336

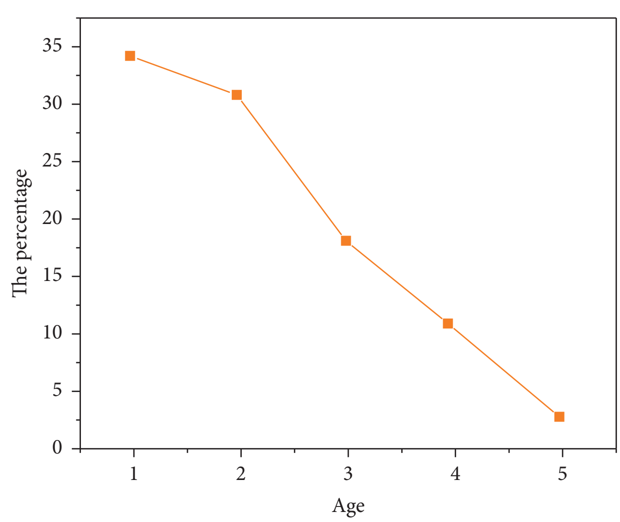


Figure 6: Percentage of tourist source age group (from high to low, 20–30 years old, 30–40 years old, 40–50 years old, over 50 years old, and under 20 years old, respectively).

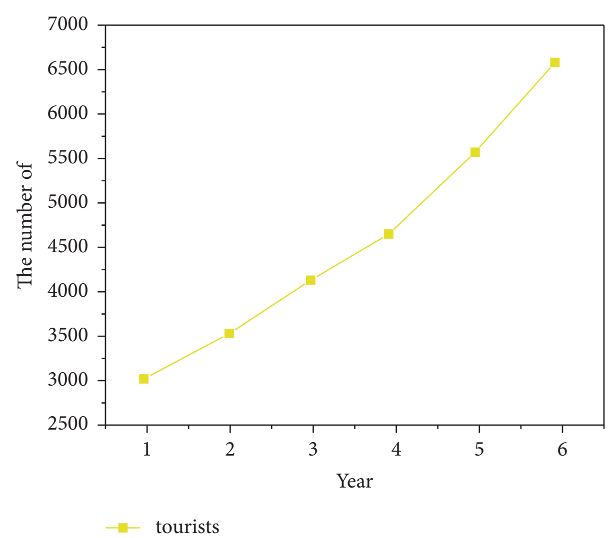


Figure 7: Total number of tourists received from 2011 to 2016.

total population of 7.729 million. Its large population base is also a huge advantage of the local tourist market. In particular, short-distance urban tourism will be the best choice for citizens.

To sum up, whether it is the high proportion of college students, the large base of local citizens, or the high growth rate of foreign tourists, all kinds of signs show the great potential of the tourist source market.

4.2.2. A City and Its Surrounding Third Tier Industrial Heritage Base Is Numerous. The third tier industrial heritage tourism takes industrial heritage as tourism resource. The quantity and quality of industrial heritage are the necessary factors for the success of the third tier industrial heritage tourism. After years of construction and development, an industrial system focusing on transportation and machining has been formed. The large base of the third tier industrial heritage in the province is a unique advantage for developing industrial heritage tourism. Moreover, these third tier industrial heritages involve manufacturing, transportation, machinery processing, and other fields, providing more choices for the tourism collocation of third tier industrial heritages. Moreover, some enterprises are still operating and producing, being at the top level in the industry in their field and more persuasive for tourists. For example, FAW has become one of the largest automobile enterprise groups in China. The passenger car factory is the largest R&D,

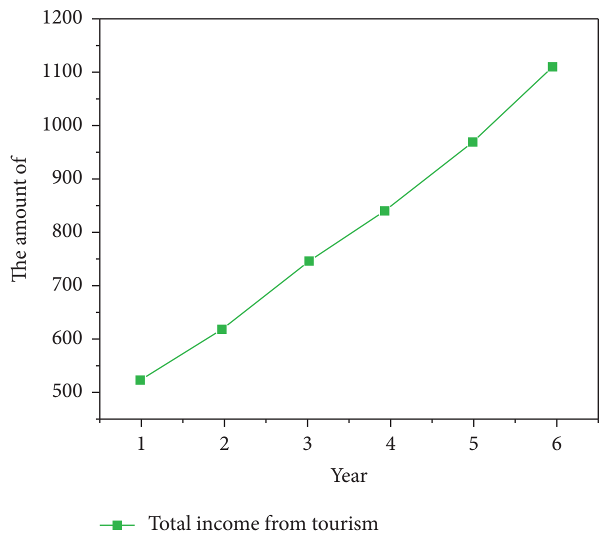


Figure 8: Total tourism revenue from 2011 to 2016.

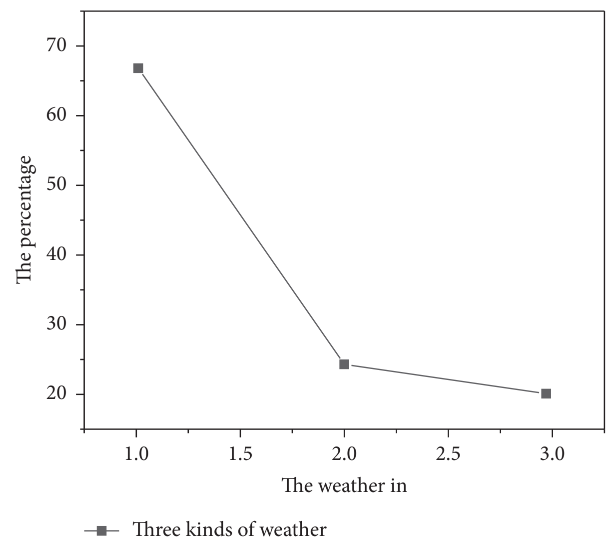


Figure 10: Proportion of weather conditions in 2018–2021.

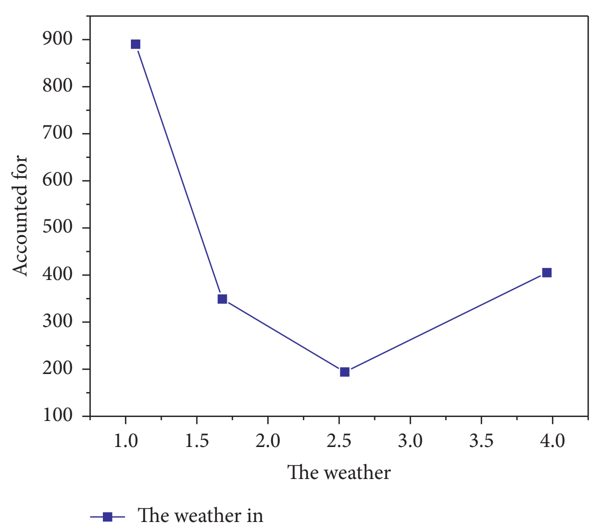


Figure 9: Weather conditions in 2018–2021.

Figure 11: Status of industrial heritage.

manufacturing, and export base of rail transit in China. In addition, there are modern enterprises such as modified pharmaceutical companies, like Yatai Group and Dacheng Group. Strong old industrial base and booming modern enterprises provide strong resource guarantee for the development of third tier industrial heritage tourism in a city.

4.3. SWOT Analysis of Third Tier Industrial Heritage Tourism: Disadvantages

4.3.1. The Weather Is Cold and Outdoor Tourism Is Limited. It is located in the north temperate continental monsoon climate zone, with long and cold winter. According to statistics, in 1828 days from January 1, 2018 to January 1, 2021 (as shown in Figures 9 and 10), there are 1242 sunny and cloudy days, but considering the most suitable travel temperature (outdoor temperature 25–28°C), it is only 324 days (fewer days if outdoor wind is considered), which means only two months a year are suitable for travel, concentrated in August and September. Cold weather will certainly have a great impact on outdoor tourism, and rainy and snowy weather will also bring a lot of inconvenience to tourists. The simultaneous arrival of a large number of concentrated tourists is not conducive to the guidance of tourists, making the scenic spot have hidden dangers on tourism safety, but it also brings great pressure to the management of the scenic spot. More importantly, it reduces the visiting quality of tourists and thus the effect of tourism experience is poor.

4.3.2. The Third Tier Industrial Heritage Tourism Infrastructure Is Weak. It is self-evident that the infrastructure around the scenic spot plays an important role in the scenic spot, which is often an important factor determining the success or failure. Only when the relevant supporting facilities meet the basic use needs of tourists can the scenic

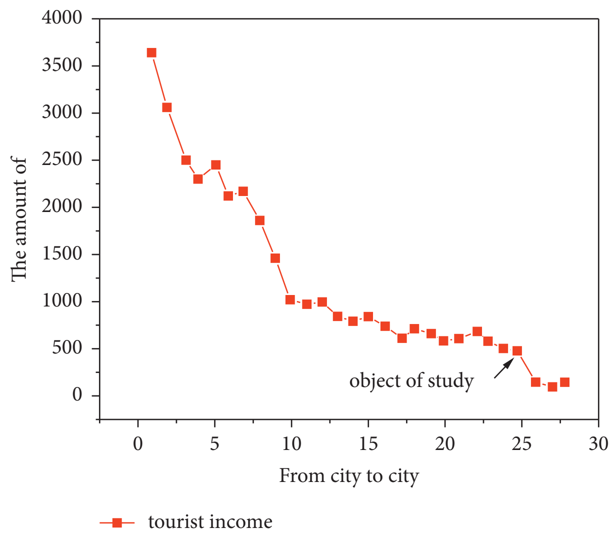


Figure 12: Tourism revenue statistics of a province in 2020.

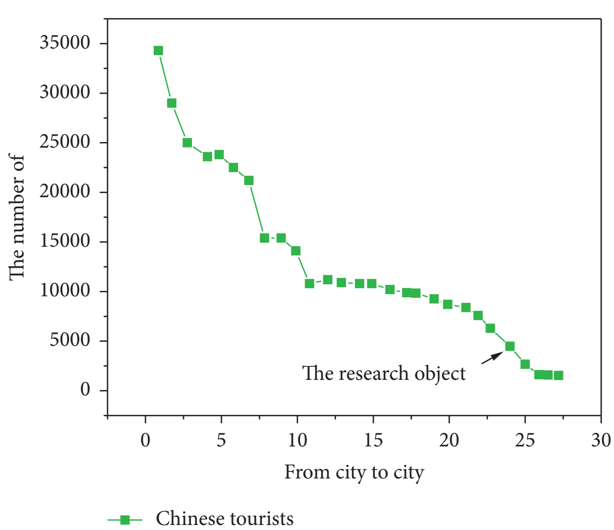


Figure 13: Statistics of Chinese tourists in a province in 2020.

spot be attractive. However, 35% of the existing third tier industrial heritage in a city has been idle for a long time (as shown in Figure 11). The plant has been left unattended for a long time, the hospital is overgrown with weeds, and the remaining problems of industrial pollution have yet to be solved, let alone the surrounding infrastructure. Another 30% of buildings is forced to be used for other auxiliary functions, such as warehouses. In addition, public transport, guidance signs, and other service systems also need to be strengthened. Poor infrastructure hinders the further development of third tier industrial heritage tourism.

4.4. SWOT Analysis of Third Tier Industrial Heritage Tourism: Opportunities

4.4.1. Third-line Industrial Heritage and Rural Tourism Potential. In terms of the general international tourism

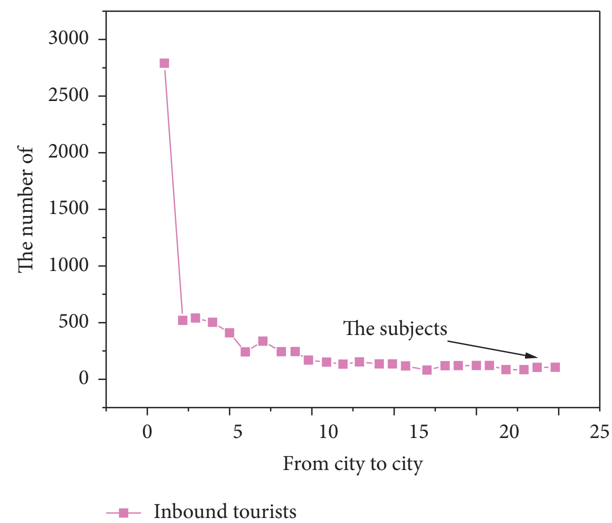


Figure 14: Statistics of inbound tourists of a province in 2020.

trend. Development and peace must be the development direction of the future world. On this basis, with rich material conditions, rural tourism has become one of the sunrise industries developing rapidly. It is predicted that by 2020, global travel trips will exceed 1.6 billion and reach $200 billion. In the near future, rural tourism capacity will continue to expand, and the annual growth rate of tourists and consumption will be higher than that of the world economy, indicating that tourism growth will continue. For the Chinese market. According to the 2020 Rural Tourism Development Report (as shown in Figures 12–14), the development of rural tourism in a province is at the bottom in the country, and tourism income, domestic tourists, and inbound tourists have not reached the average level of China, which shows the great development potential of tourism. On the other hand, the report mentioned a province maintained the good momentum of sustained and rapid development; by 2020 the province reception number is expected to reach 260 million people, and three-line industrial heritage and rural tourism revenue reached 500 billion yuan, from provincial into domestic, with ecology, ice, summer, and border tourism as the theme of leisure resort center and tourism distribution center.

4.5. SWOT Analysis of Third Tier Industrial Heritage Tourism: Threats

4.5.1. Imminent Industrial Heritage Protection in Third Tier. As the value of the third tier industrial heritage is gradually recognized by people, the protection awareness of relevant departments is gradually strengthened, but only buildings and industrial products have been protected, and there is no deeper thinking and research on how to reuse these third tier industrial heritage. On the contrary, the government has to spend a lot of extra money on maintenance every year. Take Kant's electric mill in a city as an example. Its predecessor was Yajosin electric mill, the ancestor of a city's electric mill. After local demolition in 2007, it was rated as a municipal cultural relics protection unit by a city's People's Government in 2009. However, the protection of Kant's fire mill ends there. Construction waste is everywhere and structural reinforcement is exposed. This situation is not an example in the existing third tier industrial heritage of a city. They have experienced the baptism of years. The building structure and wall are seriously damaged. They should be in urgent need of protection or reuse transformation, but the protection of relevant departments is only that. This "listing" protection is tantamount to the destruction of the third tier industrial heritage in the dimension of time. As an important carrier of industrial heritage tourism, the third tier industrial heritage initially settled on the edge of the city. Affected by the process of urbanization, the factories were forced to move out or close down due to poor management. Some valuable sites of third tier industrial heritage have been seriously damaged without due protection. If the third tier industrial heritage does not exist, why should it be restored later. At that time, the third tier industrial heritage tourism is only empty talk.

5. Conclusion

This paper puts forward the research on the development model of the combination of "third tier" industrial heritage and rural tourism under the concept of urban image, explains and expounds the comprehensive evaluation method, and applies it to the comprehensive evaluation of the tourism value of industrial heritage. Firstly, according to the current situation and characteristics of industrial heritage in a city, this paper puts forward the evaluation standards and significance of industrial heritage tourism. Secondly, SWOT analysis is used to analyze the feasibility of carrying out industrial heritage tourism and comprehensive evaluation of industrial heritage tourism. This paper expounds the comprehensive value of industrial heritage tourism in detail and further expounds the necessity of developing industrial heritage tourism in a city. The future research on urban image can understand the people's emotional cognition and functional needs of the city through in-depth investigation and research on residents, strengthen the research on urban image, analyze the functional needs of the city from the personality level, carry out urban planning to truly realize the construction of livable city, improve the urban living environment, and establish urban civilization, so as to make the urban planning and construction more in line with the law of sustainable development.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by Periodical Achievements for the Major Program of Philosophy and Social Sciences in the Colleges and Universities in Hubei Province (21ZD077).

References

[1] Y. Xu and Z. Sheng, "Small third-line industrial heritage development and rural cultural tourism industry integrated development -- take Anhui Mount Tianzhu as an example," *Jiangxi Social Science*, vol. 40, no. 11, pp. 138–145, 2020.

[2] J. Lu, "The characteristics, value, protection and utilization of the third-line industrial heritage," *Urban and Rural Planning*, vol. 6, pp. 54–62, 2020.

[3] M. Zhou, "Third-line construction and urban development in mainland China (1964-1980)," *Economic history of China*, vol. 1, pp. 142–151, 2014.

[4] Z. Zhang, "An analysis of the value and type of rural industrial heritage from the perspective of integration of Culture and tourism," *Beauty and the Times*, vol. 11, no. I, 2021.

[5] O. G. Petrova and A. B. Malkhasyan, "On the need for state support for the development of rural tourism as a type of non-agricultural activity in the pskov region," *IOP Conference Series: Earth and Environmental Science*, vol. 723, no. 2, Article ID 022107, 2021.

[6] A. O. Daoud, A. A. Tsehayae, and A. R. Fayek, "A guided evaluation of the impact of research and development partnerships on university, industry, and government," *Canadian Journal of Civil Engineering*, vol. 44, no. 4, pp. 253–263, 2017.

[7] A. Zhang, Y. Yang, T. Chen, J. Liu, and Y. Hu, "Exploration of spatial differentiation patterns and related influencing factors for national key villages for rural tourism in China in the context of a rural revitalization strategy, using gis-based overlay analysis," *Arabian Journal of Geosciences*, vol. 14, no. 2, p. 83, 2021.

[8] L. Cheng and J. Xu, "Benefit-sharing and residents' subjective well-being in rural tourism: an asymmetric approach," *Journal of Destination Marketing & Management*, vol. 21, no. 5, Article ID 100631, 2021.

[9] Y. Wan, "Study on the development path of rural tourism under the strategy of rural revitalization," *Meteorological and Environmental Research*, vol. 11, no. 03, pp. 36–41, 2020.

[10] P. Coratza, V. Vandelli, and M. Soldati, "Environmental rehabilitation linking natural and industrial heritage: a master plan for dismissed quarry areas in the emilia apennines (Italy)," *Environmental Earth Sciences*, vol. 77, no. 12, p. 455, 2018.

[11] I. Kurtyka-Marcak and J. Janowskabiernat, "Opportunities and barriers to the development of tourism in rural areas," *Annals of the Polish Association of Agricultural and Agribusiness Economists*, vol. XXII, no. 3, pp. 153–166, 2020.

[12] T. Li, Q. Li, and J. Liu, "The spatial mobility of rural tourism workforce: a case study from the micro analytical perspective," *Habitat International*, vol. 110, no. 7, Article ID 102322, 2021.

[13] R. Wang, M. Dai, Y. Ou, and X. Ma, "Residents' happiness of life in rural tourism development," in *Journal of Destination Marketing & Management*, T. Feike, Y. Mamitimin, L. Lin, and R. Doluschitz, Eds., vol. 20, no. 1, Article ID 100612, 2021.

[14] B. Xiong, X. Zhong, and J. He, "On sustainable development of rural tourism in jiangxi province from the perspective of all-for-one tourism," *IOP Conference Series: Earth and Environmental Science*, vol. 651, no. 3, Article ID 032109, 2021.

[15] H. Ziyi, "Protection and reuse of the third-line Industrial Heritage: a case study of Duyun Dongfang machine tool works," *Industrial Design*, vol. 5, pp. 133-134, 2020.

[16] A. I. Zyrianov and V. A. Semiglazova, "Rural tourism: from geographical constructs to models of development," *Geography and Natural Resources*, vol. 42, no. 1, pp. 24–31, 2021.

[17] J. Yang, R. Yang, M. H. Chen, C. H. J. Su, Y. Zhi, and J. Xi, "Effects of rural revitalization on rural tourism," *Journal of Hospitality and Tourism Management*, vol. 47, no. 4, pp. 35–45, 2021.
[18] M. J. Lin, "Evaluation of the role of rural tourism industry in promoting economic transformation based on intelligent svm classification algorithm," *Journal of Physics: Conference Series*, vol. 3, Article ID 032039, 2020.
[19] J. Lv, "Current situation and research countermeasures: focusing on the protection and utilization of the industrial heritage of third-line construction," *Southern Cultures*, vol. 3, p. 7, 2019.

Hindawi
Scientific Programming
Volume 2022, Article ID 2792428, 12 pages
https://doi.org/10.1155/2022/2792428

Research Article

The Flipped Classroom Model of Japanese Teaching Based on Intelligent Decision-Making System

Xiaodong Wang,[1] Zhaohui Li ,[2] Lin Dong,[1] and Wanting Li[1]

[1]*School of Foreign Languages and Literature, Changchun Humanities and Sciences College, Changchun 130117, Jilin, China*
[2]*College of Foreign Languages, Changchun University of Finance and Economics, Changchun 130122, Jilin, China*

Correspondence should be addressed to Zhaohui Li; gaos83@ccu.edu.cn

Received 7 April 2022; Revised 10 May 2022; Accepted 25 May 2022; Published 15 June 2022

Academic Editor: Ahmed Farouk

Invert the model of learning in the classroom as a new model in the field of education as modern Internet technologies develop and the concept of learning is updated. It is widely used and promoted in various disciplines. Scholars and front-line teachers have begun to try to introduce the flipped classroom teaching model into language classrooms. With this opportunity, practical studies on flipping classes in foreign languages have emerged. At the same time, the study of the learning process in the classroom has become a problem that needs to be urgently addressed. At present, the linguistic field generally regards the specific teacher-student discourse interaction and verbal communication patterns in the teaching process as a research trend. For the Japanese teaching field, the research on the specific characteristics and patterns of teacher-student verbal communication in classroom discourse is a top priority. Drawing on previous research theories and research methods, the two key research topics are combined. Taking the foreign language curriculum under two different classroom teaching modes as the empirical research object, this paper studies the specific classroom teaching process by using the interaction theory of sociology. At the same time, it uses the Flanders Interaction Analysis System (FIAS) to conduct detailed quantitative research on the interaction of teachers and students in classroom discourse, and analyze and discuss the statistical results. The relevant teaching suggestions for the application of the Japanese flipped classroom teaching mode are put forward, and the problems that must be paid attention to in the practical application are pointed out, in order to provide meaningful reference and reference for the construction of the Japanese teaching mode.

1. Introduction

With the popularization of the Internet, the deep integration of intelligence, digital technology, and education has become possible, which can change the classroom learning mode and has been widely used in college classroom teaching. Figure 1 shows the comparison between flipped classroom and traditional classroom. Traditional foreign language teaching in colleges and universities has common problems of varying degrees, which is time-consuming and inefficient, and the teaching quality is always uneven. It is difficult to make significant progress and breakthroughs in the teaching effect, resulting in a decline in students' enthusiasm for learning. In the era of big data, the flipped classroom is in line with the characteristics and demands of the times, learning resources are richer, and exchange mechanisms are becoming more sophisticated. Especially with the strong support of the school and the protection of mature network technology conditions, it can fully give students the autonomy of learning and the right to explore. It highlights bidirectionality, democracy, and communication; brings a new teaching experience; and realizes the comprehensive internalization of learning Japanese knowledge. The interpretation of flipped classroom by many scholars is not uniform, mainly due to the different expressions and definition angles. In essence, the connotation and implementation process of flipped classroom tend to be the same. On the one hand, the process from learning knowledge to internalizing knowledge is still the main theme. No matter how innovative it is, it is the structure rather than the process that is flipped [1]. Active learning becomes the norm, and communication, interaction between teachers and students in the classroom

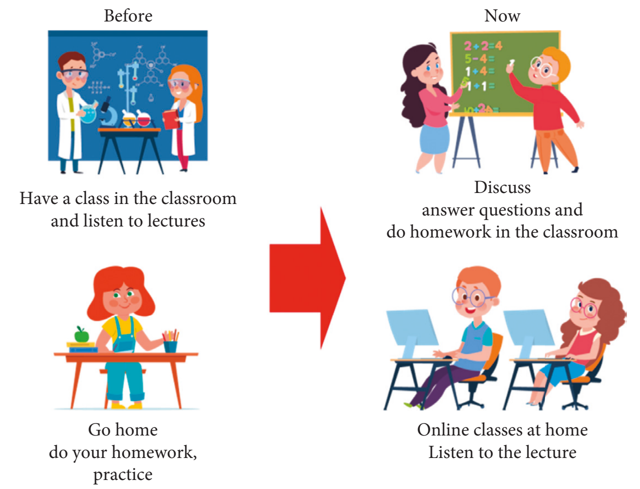


Figure 1: Comparison of flipped classroom and traditional classroom.

deepens even more. While inverting the classroom as opposed to a networked education model, such as a microclassroom, it is still necessary for learners to acquire knowledge that interaction in the classroom guarantees. Invert the classroom subverts the traditional mode of learning, rescheduling time both inside and outside the classroom. First of all, it follows the principle of taking students as the center; investigates the basic situation of students; and produces, develops, and selects corresponding teaching resources. Students develop an interactive learning mechanism through self-learning before class, and form a personalized learning atmosphere. Based on the network information platform, relying on classroom display of learning results, and the effective use of the values and benefits of modern information technology helps students complete the process of internalizing knowledge. The transformation of the roles and functions of teachers and students is extremely beneficial to the cultivation of students' autonomous learning ability, which not only conforms to the trend and actual needs of language teaching but also greatly increases the enthusiasm of students.

2. Literature Review

Flip class is also a concept and teaching method rising in recent years. Zhou et al. stated that the so-called flipped classroom is to reverse the original classroom style and readjust the teaching mode inside and outside the classroom, which is a revolution to the traditional classroom "paradigm" [2]. Zhang et al. believe that it subverts the traditional teaching process. The traditional teaching mode is that teachers teach in class, and students digest and improve through self-practice after class. The flipped classroom is to let students become the main body and lead, self-learning and personalized learning before class, while teachers become guides and assistants to guide students to internalize knowledge in the classroom. The teaching reform based on the concept of flipped classroom has received extensive attention and research from the teaching field [3]. For example, Feng, T. et al. discussed the design of the teaching model of the knowledge internalization process in the flipped classroom, and proposed that according to the characteristics of progressive knowledge internalization and the three components of the flipped classroom, three levels of macro, meso, and micro should be considered comprehensively [4]. Afrilyasanti et al. aimed at the construction of the teaching quality evaluation system of the flipped classroom, and put forward the theoretical basis, basic principles, and construction of the evaluation system for the teaching quality evaluation system of the flipped classroom by referring to the analysis of the construction process of the evaluation system of the CDIO education model which is successful in the world [5]; Zhou et al. refined the process model of flipped classroom in six primary and secondary schools, analyzed the current practice form of flipped classroom, and reflected on the current situation of practice. Only when a suitable educational culture is formed in the school, the reverse order innovation can truly become the conclusion of a good recipe for teaching reform practice [6]; Liu et al. proposed that under the guidance of "student-centered" thinking, the inherent teaching thinking and curriculum teaching design concept should be changed to enhance students' ability to think independently and obtain information, and analyzed the "flipped classroom" perspective. Three practical dimensions of the teaching reform of the next course [3]. Yulian et al. stated that with the promotion and application of information technology, intelligent decision-making systems are playing an increasingly important role in various fields, and it will also have a profound impact and change in the field of education [1]. Ekmekci et al. believe that how to make full use of the intelligent decision-making system combined with the teaching concept of flipped classroom, improve the problems existing in traditional classroom teaching, optimize and perfect the teaching content and structure, is the current main research direction [7]. Abdullah and others believe that traditional classroom teaching completely relies on teachers' subjective judgments of students' learning status and learning progress to formulate and adjust teaching. Most of them rely on teachers' personal experience and subjective factors, and are easily affected by the external environment. The teaching decision based on the intelligent decision-making system mainly depends on the information reflected by the data. Through statistics and analysis of a large number of collected teaching data, objective conclusions are drawn based on the analysis and mining of big data of students' autonomous learning behavior [8]. Dincer and others believe that this decision-making method can better grasp the learning effect of students and the degree of mastery of knowledge, so that the teaching content and process can be adjusted in time to achieve a more flexible and accurate teaching model [9].

3. Method

3.1. Design of Flipped Classroom Teaching Mode Based on Intelligent Decision-Making System

3.1.1. Overall Frame Design. The intelligent flipped classroom is an intelligent classroom teaching system based on the network resource database platform, teachers and

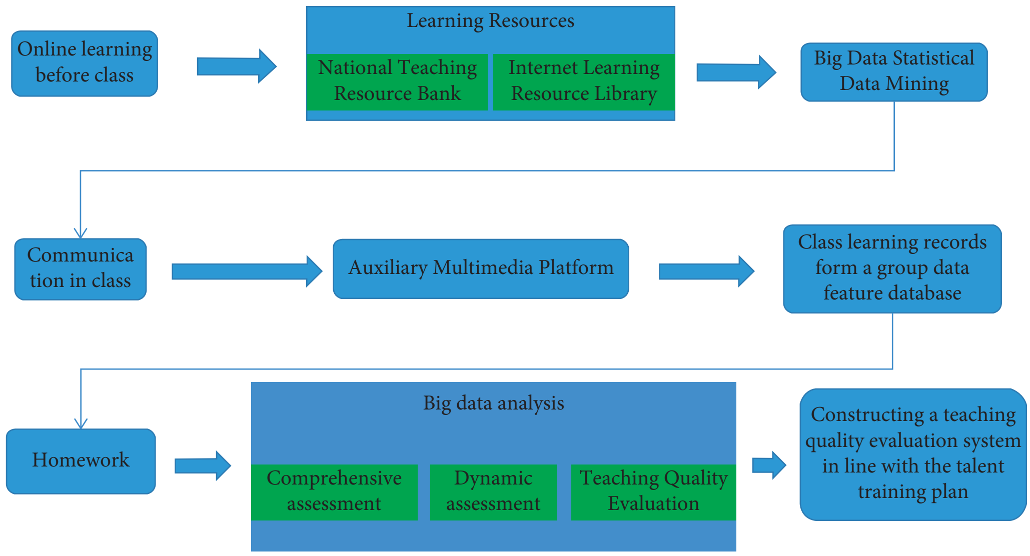


Figure 2: Intelligent flipped classroom teaching system architecture based on big data learning analysis.

students, and learning activities. Its general structure is shown in Figure 2. The smart flip class architecture includes the whole class flip-learning process, network learning resources, auxiliary multimedia platform, and big data analysis in 4 parts.

The whole process of flipped classroom teaching: the whole learning process is based on the idea of flipped classroom learning and divides classroom learning into 3 parts before, in the classroom, and after class. The pre-class stage includes knowledge preview, teaching design, and student situation analysis; the in-class stage includes learning discussion, knowledge introduction, real-time monitoring, summary evaluation, and answering questions; and the post-class stage includes after-class practice, micro-class learning, and summary feedback.

Online learning resource platform: relying on the national teaching resource library, the platform takes a school as the main organizer and organization unit, and cooperates with many well-known colleges and universities across the country to jointly build hundreds of thousands of professional teaching resources such as courses, micro-courses, and material centers. There are thousands of professional courses, training courses, and micro courses on the Internet as a platform for users to learn, work, and reflect. It can meet the needs of users at different levels, such as students, teachers, and social educators. At the same time, teachers can also timely adjust the curriculum and content according to this platform in real time to master the student and the state [10, 11]. Based on this platform, pre-class online learning is carried out, using Internet links to update learning resources, and assigning heuristic questions before class. Teachers guide the exchange and learning of the online resource library platform in class, use the platform to arrange homework, set up open-ended questions and interest modules, guide students to broaden their horizons, enhance the interaction between teachers and students, and improve students' enthusiasm for learning and discussion [12–14].

Auxiliary multimedia platform: the auxiliary multimedia platform is an application environment for intelligent flip class, an application platform for teachers and students, and an educational application support platform. It provides auxiliary learning, management and application service functions, and realizes support for teaching communication, resource transmission, and information services before, during, and after class.

Big data analysis. This part is the main part of the design and is mainly based on big data analysis technology, which allows scientific assessment of the quality of teaching and learning, final assessment and diagnostic analysis in decision-making, including testing systems, learning quality assessment systems, and dynamic assessment analysis.

3.1.2. Instructions of Teaching Process Design. Analysis and processing of data: the research group selected the main courses in the basic stage of Japanese majors—Japanese intensive reading, Japanese audio-visual, Japanese reading, and Japanese overview courses for reform attempts. Using Excel and Infographic as the basic data analysis tools, it can realize the analysis and processing of data type classification, cluster screening, and so on. Excel is the most commonly used information visualization tool, which can present the information contained in the data in the form of intuitive curve graphs, bar charts, or radar charts, and other analytical graphs. Infographic is a technology for visual display of information data, which can organically integrate information and images. Through information visualization, teachers can understand the hidden information content in complex data through intuitive information graphs, so as to scientifically grasp students' learning situation and status information in a shorter time. At the same time, based on Excel and Inforgraphic statistics of student data, and using the feature selection algorithm in machine learning to eliminate redundant and incomplete data, build a feature set library for students' individual learning, which is conducive for personalized guidance for students' learning conditions. At this stage, with the help of data mining technology and big datasets, by searching, extracting, and exchanging big data, integrating data of various types and structures, performing correlation analysis on various data, presenting statistical results in the form of visual interactive charts and mathematical models, and creating a database for analysis and learning, the database can also be used for analysis by other researchers in the field of education [15].

Independent study before class: the learning platforms of the national learning libraries are predominantly dominated in combination with Internet links that update the learning resources of the Internet. The national-level teaching resource library is favored by students in higher vocational colleges because of its professionalism, comprehensiveness, and interaction, and plays an active exemplary role in integrated teaching practice, vocational training, resource digitization, multimedia, and knowledge expansion. Students select the corresponding course resource library on the national teaching resource library platform, including various multimedia resources (pictures, texts, rich texts, web pages, engineering files in other formats, etc.). This allows learners to be familiar with relevant background knowledge and concepts in advance. By using students to study on the teaching resource library platform, the corresponding data records can be collected and statistics. For example, course subscription on the library platform, number of clicks, most visited type of resource, teacher-student interaction information, student feedback on issues, and more. Big data analysis draws the above data into a visual dynamic data graph, enabling educators to continuously improve the learning library according to students' learning needs and habits, as well as the challenges encountered in the preclass learning process so as to timely adjust courses and learning contents, achieve the best learning efficiency, and make it more in line with students' needs. Once students complete a self-paced course, they will be able to take an online test on the library platform. The data analysis tools Rapidminer and data mining tools are used to analyze the main learning problems of students. Through data collection and statistics, each data indicator is classified and analyzed to obtain common problems reflected by students [16]. Among them, one type of data indicator is the overall data information of the students, including the average score of the class, the accuracy rate of each question, and the number of revisions of each question; the other type of data indicators is the individual data information of the students, including answer time of each question, the score of each type of question, etc. Through data analysis, the results of statistical analysis are fed back to teachers. If the systematic analysis result obtained by a student is that the theoretical guidance score is higher than the average score, the free-play questions take a long time to answer, and the number of revisions is large, then under the guidance of data analysis, the teacher can understand the student's pre-class learning status and basis. It can be concluded that the student has a solid foundation, but the actual hands-on design ability is weak and lacks practice judgment in this regard. Teachers can adjust teaching content and methods accordingly, provide targeted guidance to students, and formulate personalized teaching plans that meet students' learning conditions and needs, so as to truly teach students in accordance with their aptitude. Teachers can also classify the characteristics formed by the data indicators, and use Infographic to draw a clear data analysis diagram. Comparing the learning situation of a specific student with the overall feature database can help students reflect on their own learning process and learning methods, adjust their learning habits, and help students develop a scientific and autonomous way of learning Japanese.

Guided learning in class: according to the conclusions drawn from big data and data mining analysis, teachers can guide and explain the common problems in the course of class learning, and use group discussions, hands-on exercises, project-driven and other methods to enable students to complete knowledge in class of confusion, consolidation, and internalization. At this stage, teachers focus mainly on the breakthrough in emphasis and learning content difficulties and provide targeted mentoring to students in need based on the findings of the feedback that was based on earlier big data. For example, some students have a weak foundation, and teachers need to use simple and easy-to-understand language when explaining theoretical explanations, and use vivid examples to deepen their understanding; some students have weak hands-on ability, and teachers can give more training in the practical stage chance. At the same time, teachers should also track and record students' learning situation and group discussions in a timely manner to form diversified and multi-type data information. This information constitutes a big data collection of students' classroom learning status. By mining students' learning behaviors and habits, and analyzing each student's different reactions to the classroom teaching contents at different explanation stages, teachers can clearly grasp which contents need more time to explain, which contents need to strengthen teaching, and which teaching examples and resources can stimulate students' interest and enthusiasm [17]. The learning behavior of each student may have particularity, but big data gather a large amount of data, and mine and present the implicit laws and trends of the overall data through data mining methods. By analyzing such laws and trends, we can get better classroom teaching effect, and improve teaching quality and teaching efficiency. Students in the Japanese learning stage can query different databases in the basic Japanese network according to their learning needs, and obtain information such as voice, vocabulary, grammar, articles, historical background, cultural background, etc., so as to solve problems in learning and realize independent learning in the classroom.

Consolidate learning after class: this stage is mainly for students to consolidate and expand their knowledge. According to the teaching content and students' mastery of learning, teachers arrange comprehensive exercises that meet the training objectives of the course, so that students can apply what they have learned, and can further consolidate and strengthen the learning effect. A professor's course is used as an example to illustrate. Familiarize yourself with the basic grammatical structures of database instructions in the pre-course phase so that students know commonly used instruction forms. In the class, he focused on explaining database management skills, and carried out WEB database management operations based on actual engineering projects. In the post-class consolidation stage, by arranging exercises and conducting extended training for the problems that arise in the actual management process, students can freely implement a similar database management process to achieve the effect of analogy. Teachers use data analysis tools, graphs, and mathematical models to analyze student learning performance throughout the process. In addition, these data have good reference and reference value for other courses and educators.

3.1.3. Implementation Effect Analysis. The object of this study is a college of students, a total of 150 people. In order to understand whether the intelligent classroom learning model is useful for the overall learning process of students, a survey was conducted mainly on three aspects: whether it is effective to help students improve their independent learning ability, whether it is effective to help students improve their practical ability and internalize knowledge. The survey was conducted in a multimedia training classroom that can promote intelligent flipped classroom teaching. The survey results show that 74.58% of the students believe that this teaching mode is very helpful to improve their autonomous learning ability; 9.47% of students believe that this teaching mode is helpful to improve their autonomous learning ability. And, 89.28% of the students think this teaching mode is very helpful to improve their practical ability; 10.62% of the students think it is helpful (as shown in Figure 3). The results of the survey on knowledge internalization ability show that 82.46% of students believe that they have a deeper understanding of the knowledge they have learned and grasp it more firmly; 76.41% of students believe that it can stimulate their interest and enthusiasm for learning; 75.09% of the students thought that the improvement of knowledge internalization ability was helpful to improve the ability of learning, cooperation and exploration (as shown in Figure 4).

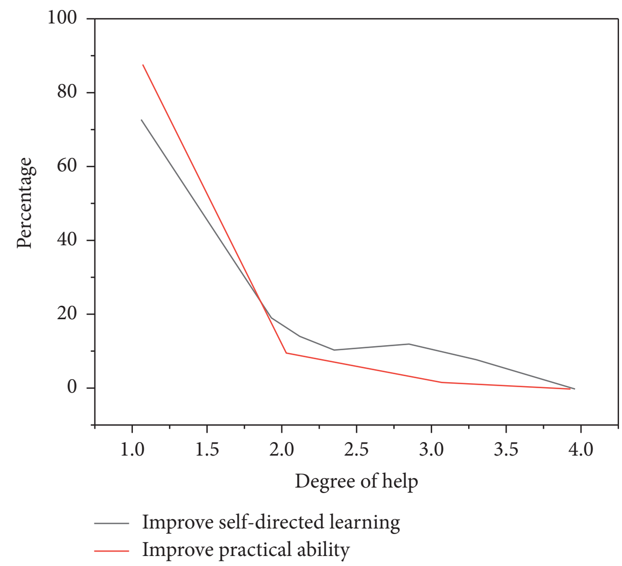


Figure 3: Statistical results of the survey on the help of learning ability. *Note.* The abscissas 1–4 are very helpful, certainly helpful, generally helpful and unhelpful, respectively.

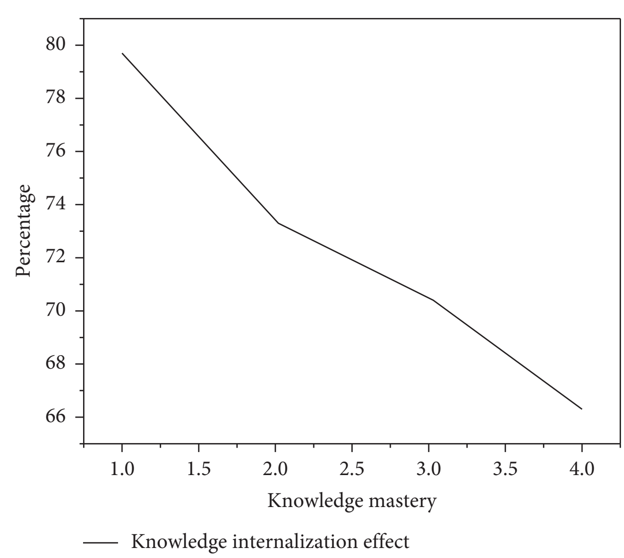


Figure 4: Statistical results of the investigation on the effect of knowledge internalization. *Note.* The abscissas 1–4 represent deeper knowledge understanding, firmer grasp, more interest, and longer memory time.

3.2. Introduction of Flanders Interactive Analysis System (FIAS)

3.2.1. Composition of FIAS. The Flanders Interaction Analysis System (FIAS) consists of three parts: (1) a set of coding systems that describe classroom interaction behaviors. (2) A set of prescribed standards for the coding of observations and records. (3) A matrix table used to display data, analyze data, and achieve research purposes.

3.2.2. Interactive Categories for FIAS. This system divides all teacher-student language interactions in the classroom into 10 categories, and these 10 categories belong to 3 major sections: teacher language, student language, and invalid language [18]. Among them, codes 1 to 7 are teacher language, that is, the type of speech teachers speak to students; codes 8 to 9 are student language, that is, the type of speech students speak to teachers; and the last code 10 is invalid language, that is, the quietness or confusion that may occur in the classroom, etc. The detailed interactive category introduction is shown in Table 1.

3.2.3. Determination of FIAS Speech Acts. The "indirect influence" behavior in teachers' language can be divided into four categories. These behavioral categories belong to a more open teaching style. The first 3 categories are driven by students and can often cause students to actively express

Table 1: Classification of Flanders Interactive Analysis System.

Classification			Code	Content
Teacher language	Indirect effects	Student driven	1	Receiving student emotions: receiving and clarifying students' attitudes or emotional tone in a nonthreatening way. This category, in which student emotions can be positive or negative, also includes projections or retrospectives of student emotions.
			2	Praise or encourage student behavior: including jokes that ease tension without hurting people. Nod, or "ah," or "go on."
			3	Accept or use student ideas: refine, expand, or develop opinions or ideas expressed by students. This category includes teachers who expand the opinions or ideas of students, but are they in the fifth category when teachers show more personal opinions or ideas.
	Direct impact (teacher initiative)		4	Ask students questions: based on the opinions or ideas of teachers, ask students questions about content or steps and expect answers from them.
			5	Teachers' explanation: provides facts or insights on steps or content; expresses the teacher's own ideas, presents the teacher's own interpretation, or cites the opinion of an authority (nonstudent).
			6	Give instructions or orders: this type of behavior has the function of expecting students to obey.
			7	Critically criticize students or maintain authority: the content of the statement is an attempt to change the behavior of students and move from an unacceptable form to an acceptable one; scold students; explain why teachers behave in this way with extreme self-reference.
Student language	Teacher driven		8	Student discourse: the student speaks passively, such as answering the teacher's questions. Teachers develop student responses, either by provoking them to speak or script dialogue, and students' free expression of their ideas is limited.
	Student initiative		9	Student discourse: students speak on their own initiative; express your thoughts, bring up new topics; freely express their opinions and ideas, as if they were asking questions of a conceivable nature; beyond the existing architecture.
Invalid language	Quietness		10	Quiet or chaotic; temporary pause, silence of time or chaos; so observers cannot understand the communication between teachers and students.

their wishes, while the "direct influence" behaviors, namely, the 5th, 6th, and 7th subcategories, belong to the structural teaching style, which is actively issued by teachers. Sometimes it restricts the range and emotions of students' expression, and becomes a single cycle of one question and one answer. The static state in "invalid language" sometimes needs to be determined according to the actual classroom teaching situation, such as "reading the text with the recording, dictating," and so on. Although they are classified as "invalid language," they are actually meaningful for classroom learning but meaningless for teacher-student speech behavior observation. According to the actual teaching in the classroom in the experimental class in the flip class mode in the Chinese Teachers' Training Center of a specific college, this paper codes the segments every 3 seconds, and identifies the difficult-to-determine behaviors in the classroom speech behaviors of teachers and students as follows:

(1) If there are multiple classroom behaviors in the same 3 seconds, then according to the design requirements of this study, the main behaviors that occurred in these 3 seconds were recorded.

(2) If the student's question is only to clarify the teacher's question, although he or she speaks actively, the question is generated in the dialogue situation given by the teacher, so it is still recorded as "8."

(3) There are three definitions of "invalid language": (1) In the dozens of seconds before the start of the class and after the end of the class, the classroom behavior of teachers and students with static or chaotic footsteps is recorded as "10," that is, "invalid Language." (2) While studying the text link, the teacher allows the students to follow the text to record; the students appear motionless while listening to the record, also written as "10." (3) In the game link, if a situation arises when the student uses the native language of his or her country for explanation, and the teacher cannot understand the meaning in it, and the observer cannot recognize the connection between the teacher and the student, write it as "10."

(4) During the interaction between teachers and students in the speech act class, students act on their own initiative without provoking the teacher, such as asking questions to teachers and expressing their own opinions. These instances are recorded as "9," that is, "students take the initiative to speak."

(5) The words that the teacher uses to give instructions during the exercise, including the teacher's question, the teacher's request to repeat it, or the request to continue, are recorded as "6," that is, "instruction."

(6) Correction of errors made by the teacher to the words of students in the classroom, mainly consists in timely correction of students' pronunciation, word errors, grammatical errors, and so on, and are recorded as "7," that is criticism. However, in most cases, teachers' criticism is based on encouragement, which is very

different from teachers' criticism of students' learning attitude in the general sense, which has never been seen in the flipped classroom experimental class teaching.

3.2.4. Improvements of the Flanders Interactive Analysis System (FIAS). The Flanders interactive analysis system has obvious structural and quantitative characteristics, and is an ideal technology for analyzing classroom behavior. However, this interactive analysis system also has major limitations in practical application, such as requiring observers to take samples every 3 seconds in the field and immediately write down the code. This is too difficult for the observer, and in most cases it cannot be done normally. With the leap of modern information technology to make data recording more accurate, Chinese scientists have made two improvements to Frances interactive analysis technology:

(1) The assignment method of the observation code is changed. The original on-site observation, sampling every 3 seconds, was changed to classroom record observation. Also taking 3 seconds as an observation unit, by constantly comparing the video and classroom records, we can find the meaning of the classroom language behavior corresponding to each time segment, and finally assign a value to the language behavior in each time segment.

(2) The analysis process is computerized. Most of the researchers have specially designed computer analysis programs according to the research content, completed the input and analysis of coding assignments, made tables according to the calculation results, and drawn the dynamic characteristic curves of the main parameters to make them more vivid and intuitive.

3.2.5. Variable Analysis with Flanders Interactive Analysis System (FIAS). Flanders (1970) combined the interaction analysis matrix method, and proposed the use of variable analysis method to further analyze the obtained data. He lists 13 indicators (i.e., variables) to explain the hidden meaning behind each teaching behavior. In the process of practical research, it is found that not every index is suitable for the research of this paper, so the author will select 6 of them for variable analysis. Then, according to the results of various data analyses, make a further summary, and try to summarize the interaction mode of Japanese classroom discourse under the flipped classroom teaching mode [19]. The Chinese translations of the variable names, English abbreviations, and norm of FIAS are shown in Table 2.

4. Results and Analysis

4.1. Analysis of the Implementation of Flipped Classroom

4.1.1. Course Resources. An important feature of the flipped classroom is that teachers provide students with resources such as course learning videos and tests before the course starts. In the survey, statistics were made on the sources of teachers' curriculum resources, and teachers were asked to select 3 main source channels in sequence according to their actual situation from the 8 main source channels provided. Then, we weighted and ranked the results selected by teachers according to the importance of the options, and calculated the weight of each source channel. A higher ranking of weights means greater prevalence. As can be seen from Figure 5, among the main sources of teachers' curriculum resources, "self-made video" ranks first, followed by "online search teaching video" and "school purchased teaching video resource library." 85% of the respondents list "self-made video" as the first source of curriculum resources. At the same time, in the supplementary open questions, some teachers mentioned that the main source channels of their course videos are relatively concentrated. So there will not be multiple sources. In addition, some teachers also choose free resources of open courses at home and abroad to meet their teaching needs.

After the statistics of "how much course content has been converted into video," it is found that there are significantly more people with a conversion rate of less than 50% than those with a conversion rate of more than 50%. At the same time, among those with a conversion rate of less than 50%, the majority of them chose 0–20%, and 11 teachers chose not to convert the course content into videos. In general, the rate of conversion of course content into video is not very high for the surveyed subjects [20].

4.1.2. Participation before Class. Different from the traditional classroom, in the flipped classroom teaching method, students need to study the course content before class. To this end, we investigated the students' participation before class, mainly to understand the amount of tasks students studied before class and the frequency of video viewing. Judging from the statistical results of the time to complete pre-class learning tasks, the practice reported by the surveyed teachers for students to complete pre-class tasks is generally concentrated in 20 to 40 minutes, accounting for 45% of the total. 6% of the total tasks took more than 80 minutes to complete. 22% of the teachers surveyed also control the time for students to complete pre-class tasks to less than 20 minutes. There is a certain connection between teachers' control of students' task time before class and their own understanding of the role of pre-class learning. It should be noted that the time for the students to complete the pre-class tasks here is the result of the teacher's estimation, and there will be a certain deviation from the actual completion time of the students. The actual degree of deviation needs to be known through surveys of students. Judging from the statistical results of the frequency of watching courses (Figure 6), the students who "required to watch a video before every class" and "required to watch a video every two classes on average" accounted for the majority, reflecting the high frequency of watching the course video. In addition, there are also groups who choose to watch lessons less frequently or even never watch videos. This reflects that teachers may still have different understandings on the form and meaning of flipped classrooms.

Table 2: FIAS variables, calculation formula, meaning, and norm.

variables	Abbreviation	calculation formula	meaning and norms
Teacher speaking rate	TT	$[\sum_{i=1}^{7} \text{Row}(i)] \times 100 \div \text{Total}$	The rate of teacher speaking during the teaching period. The higher the data, the higher the rate of teacher speaking during class. The norm is about 68.
Student speaking ratio	PT	$[\sum_{i=8}^{9} \text{Row}(i)] \times 100 \div \text{Total}$	The rate of students speaking during the teaching period. The higher the data, the higher the rate of students speaking during the class. The norm is about 20.
Ratio of teachers' indirect influence to direct influence	I/d ratio	$[\sum_{i=1}^{3} \text{Row}(i)] \times 100 \div \sum_{i=6}^{7} \text{Row}(i)$	The ratio formula is used when the number of observations is greater than 1000. When the data are greater than 100, it means that teachers use the words and time of indirect influence more than the words and time of direct influence.
	I/D ratio	$[\sum_{i=1}^{4} \text{Row}(i)] \times 100 \div \sum_{i=5}^{7} \text{Row}(i)$	This formula is used when the number of observations is less than 1000.
Quiet or chaotic ratio	SC	$\text{Row}(10) \times 100 \div \text{Total}$	Quiet and chaotic situations during teaching. The higher the teaching evidence, the less poor quality of oral interaction between teachers and students. The norm is about 11 or 12.
Teacher question ratio	TQR	$\text{Row}(4) \times 100 \div \sum_{i=4}^{5} \text{Row}(i)$	The teacher's tendency to use a question-based approach to guide discussions. The higher the data, the more frequently teachers use questions to guide discussions in class. The norm is about 26.
Student spontaneous ratio	PIR	$\text{Row}(9) \times 100 \div \sum_{i=8}^{9} \text{Row}(i)$	The proportion of student utterances initiated by students. The higher the data, the more courageous the students are to express their opinions actively. The norm is about 34.
Teacher prompt question ratio	TQR	$[\sum_{i=8}^{9} \text{cell}(i,4)] \times 100 \div [\sum_{i=3}^{9} \sum_{j=4}^{5} \text{cell}(i,j)]$	The teacher uses the student's point of view to immediately respond to the annoyance of the student's words by asking questions. The higher the data, the more the teacher can ask the students' words in real time. The norm is about 44.
Steady state region ratio	SSR	$[\sum_{i=j=1}^{10} \text{cell}(i,j)] \times 100 \div \text{Total}$	The tendency of teachers and students to stay in the same behavior category for more than 3 seconds. The higher the data, the more stable the interaction between teachers and students. The norm is around 50.
Student steady state area	PSSR	$[\sum_{i=j=8}^{9} \text{cell}(i,j)] \times 100 \div \sum_{i=8}^{9} \text{Row}(i)$	The oral behaviors that students speak for more than 3 seconds account for the proportion of all oral behaviors of students. The higher the data, the more stable the students' speaking style. The norm is around 35 or 40.

4.1.3. Evaluation. The effect of flipped classroom implementation is the aspect that this survey is very concerned about. We start from the three perspectives of teachers' evaluation of the effect of course practice, evaluation of their own satisfaction, and whether they will continue to use the flipped classroom to understand teachers' attitudes and action tendencies towards the flipped classroom teaching method. Figure 7 is the statistical result of the data of the teacher's evaluation of the effect of curriculum implementation. It can be seen that most teachers believe that students can benefit from the flipped classroom teaching method. Among them, flipped classroom has significant positive effects in "improving students' motivation and interest," "promoting students' knowledge and skills mastery," and "improving students' self-confidence in learning." At the same time, more than half of the respondents agree that students of all levels can benefit from flipped classrooms. Compared with the above evaluation results, teachers' choices in "improving students' performance" are more conservative. Although the group that believes that there is no benefit accounts for a small part, the group who chooses significant and above benefits also does not account for the majority. More people opted for the "somewhat benefited" option, partly reflecting vague attitudes about it. The relationship between flipped classroom teaching and student achievement still needs to be discovered through further investigation and research. From the statistical results of teachers' job satisfaction change data (Figure 8), it can be found that most of the surveyed teachers' evaluation of their own work is positively affected by flipped classroom teaching, and 85% of the total number of teachers think that it has an improvement effect, of which the significantly

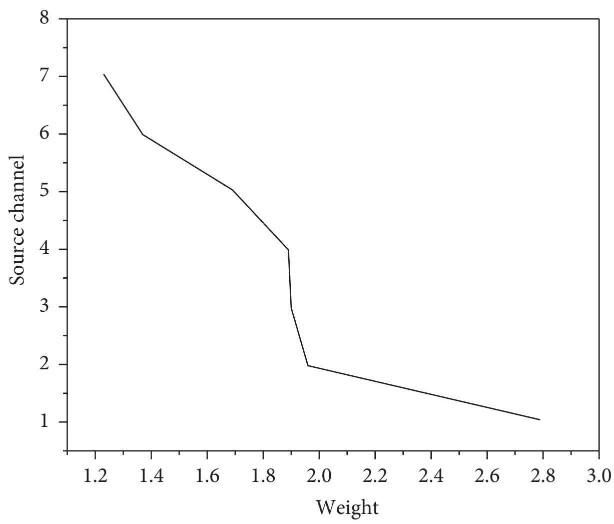


Figure 5: Main sources of teachers' curriculum resources. Note. The ordinates 1–7 are the students' homework, such as project demonstration videos; nonteaching videos, such as TV news, etc.; teaching materials supporting videos; videos of other teachers in the same school; teaching videos in the resource library purchased by the school; Instructional videos found on the Internet; videos they made themselves.

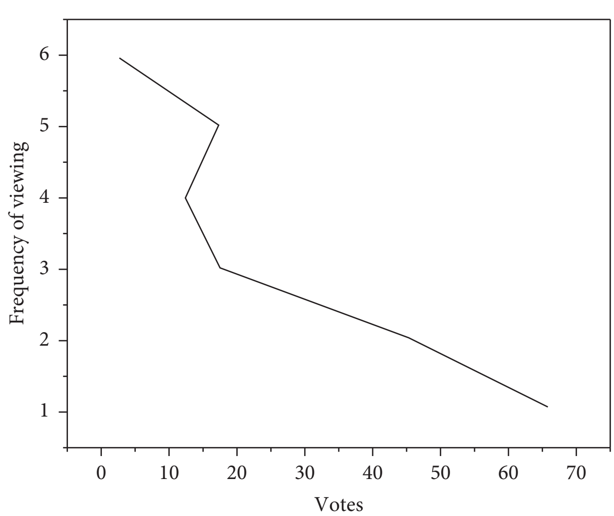


Figure 6: How often students are asked to watch videos? *Note.* The ordinates 1–6 are never watching the video, the frequency is lower than once every four classes, one time every four classes, one time every three classes, one time every two classes, every class.

improved 42% and 43% slightly improved. At the same time, some teachers (15%) believe that the flipped classroom has not improved or even lowered their job satisfaction. When asked whether they would continue to use the flipped classroom teaching method, the vast majority of teachers (98%) chose to continue to use it, and a small number (2%) of teachers chose not to use it. In general, in the evaluation of the implementation effect, teachers generally give positive feedback to the flipped classroom, which shows that the current flipped classroom has achieved certain results. However, we also see

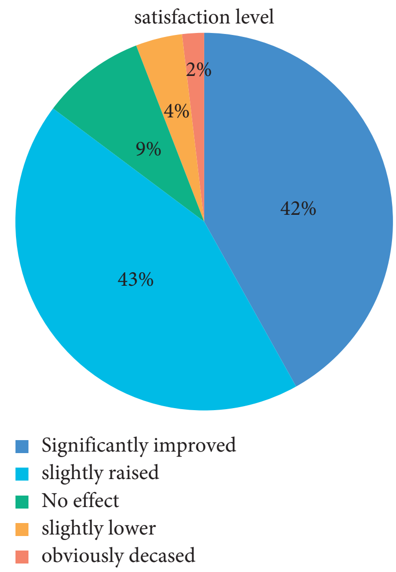


Figure 7: The degree of influence of teachers' job satisfaction.

that some teachers think that the implementation effect of flipped classroom is not satisfactory, and gives negative evaluations. For such results, we also need to further explore the reasons for their formation, so as to have a more comprehensive understanding of the practical difficulties in the implementation of the flipped classroom.

4.1.4. Existing Challenges. Although teachers have a positive attitude towards the flipped classroom teaching model, contradictions and challenges also exist in the implementation process. Figure 9 shows the results of teachers' selection of possible challenges. Among them, "course design and content production require time and energy," which pose a major challenge to most teachers. Implementing the flipped classroom means saying goodbye to the traditional teaching design method, and teachers need to reexamine the existing curriculum framework to formulate lesson plans and produce curriculum resources. Moreover, the use of technical means imposes higher requirements on the competence of teachers in the field of information technology. This, to a certain extent, increases the burden on teachers. Evaluating the effectiveness of the practice of flip classes is also not very difficult for teachers. The evaluation of students in traditional paper-based tests is more at the level of memory and abstract application of concepts. The development of advanced level skills through the application and practice of knowledge is not well assessed in this way. This may be one of the possible reasons for the difficulty of flipped classroom evaluation. More than half of the major and above challenges included "searching for high-quality teaching resources related to course content," "environment and equipment for shooting video courses," "learning new technologies to support flipped classroom teaching," "have students complete curriculum tasks in front of the class," such as "watching the instructional video, making good use of class time," and "transitioning from a teacher- to a student-centric model." This reflects the teachers' demand for

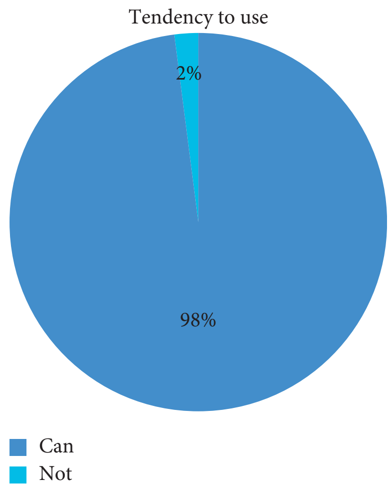


Figure 8: The tendency of teachers to continue to use the flipped classroom.

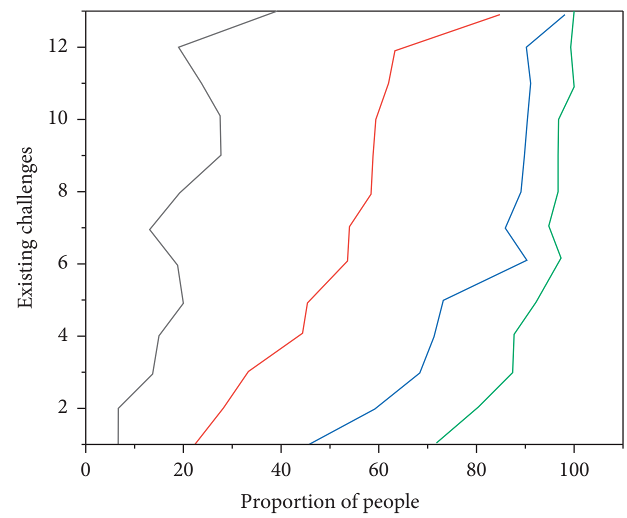


Figure 9: Challenges faced in the implementation of the flipped classroom model.

three types of support, one is the demand for high-quality course resources, the second is the demand for software and hardware equipment and technical support, and the third is the demand for instructional design and organization methods under the flipped classroom model. In the flipped classroom, the lectures that used to occupy the dominant position in the classroom are placed before the class. This side makes higher demands on the independence of students in learning, and the other side on the ability of teachers to develop and organize learning activities in the classroom. When teachers switch from traditional teaching to flipped teaching, and from teacher-centered to student-centered, they also face problems in methods and strategies.

4.2. Statistical Results

4.2.1. Statistical Results. Based on the results of a quantitative analysis of the practical lessons of teaching Japanese in the flip-learning mode in the classroom, we made a characteristic curve of the relationship of discourse in the classroom between teachers and students, as shown in Figure 10.

4.2.2. Meanings of Each Data. Combined with the Flemish variable analysis method, the value of the ratio of each variable was analyzed, and compared with the value of the norm ratio, so as to further analyze the significance of each data. as shown in Figure 11.

(1) (TT) The teacher speaking ratio is 40.98 (norm is about 68).

(2) (PT) The student speaking ratio is 52.34 (norm is about 20).

(3) (i/d ratio) The ratio of teachers' indirect influence to direct influence is 121.02 (the norm is about 100).

(4) (SC) Quiet or confused ratio is 6.68 (norm is about 11 or 12).

(5) (TRR) Teacher feedback ratio is 54.76 (norm is about 42).

(6) (TQR) teacher questioning ratio is 39.13 (norm is about 26).

Referring to Table 1 and Table 2, we try to summarize the interactive mode of classroom teaching of elementary Japanese skills [21]:

(1) Teacher discourse is the language used by the teacher in the learning process, and teacher discourse in the classroom is closely related to the successful implementation of the curriculum, and also has to do with whether the student can easily access a clear entrance, which has a direct impact on students' language acquisition to which they are directed. Compared with Japanese teachers, the teaching task is to teach Japanese. Teachers' discourse bears the dual tasks of realizing teaching goals and language input. It can be seen from the above teacher discourse ratios that the Japanese teachers' classroom discourse under the flipped classroom model is more concise, which is consistent with the Japanese teaching principle of "speaking carefully and practicing more." Reflects that teachers placed the main emphasis on students in the process of interaction in the classroom, and makes full use of the time in the classroom to achieve the effectiveness of interaction in the classroom.

(2) For many Japanese teachers, it is common for students to be afraid to speak and fail to learn about the actual learning of students to the extent that it affects the completion of the entire curriculum. If the students dare to speak up and actively cooperate with the teacher's guidance to carry out a large number of repetitive or inspiring language exercises, then the teacher-student classroom interaction under the guidance of the teacher is of high quality and effective. It can be seen from the abovementioned

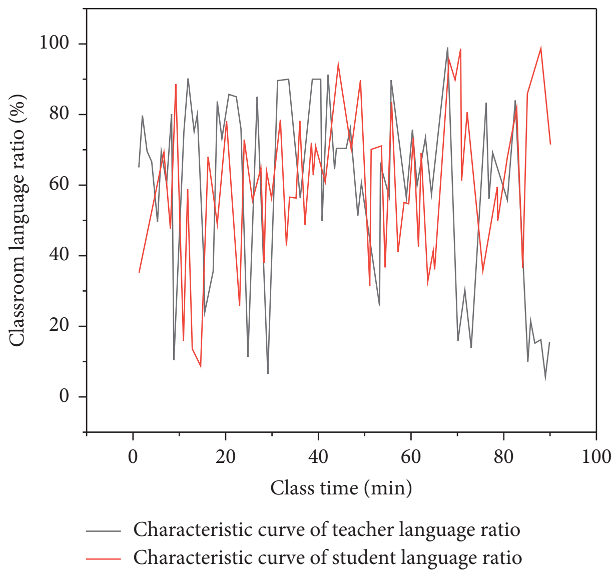


Figure 10: Dynamic distribution of teachers and students' discourse volume in the flipped classroom experimental class.

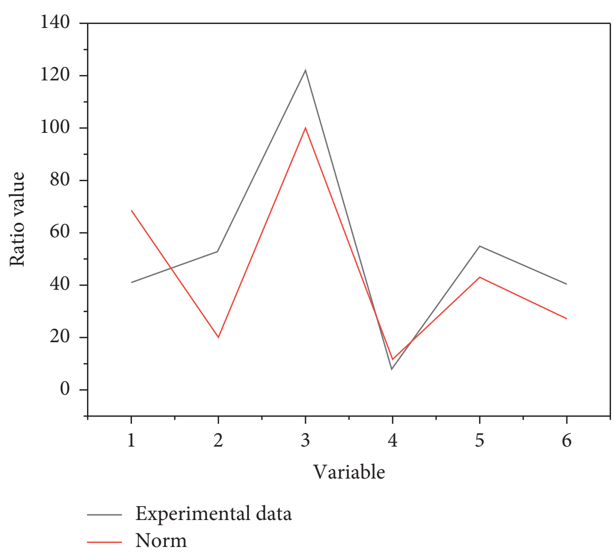


Figure 11: Comparison of variable value and norm.

student discourse ratio that the teacher's discourse ratio in the experimental class is much lower than the norm, while the student's discourse ratio is much higher than the normal teaching standard, more than double that of the norm. From this it can be seen that the interaction in the classroom between teachers and students in teaching Japanese in the flip-class mode is more effective than in a regular class.

(3) The indirect influence factors of teachers' discourse are larger than the direct influence factors, and the ratio of the two is 12 percentage points higher than the norm. It can be seen that in the teaching process, teachers inject more emotion and give more praise and encouragement in teaching. Teachers are not mechanical orders or instructions, nor are they filled with individual performances, nor are they simply and rudely criticizing students and trying to change their behavior. Instead, they are good at accepting students' emotions and accepting or using students' ideas to guide them. Teachers generally set up their own situations and clarify their ideas, and then ask students about relevant content, so as to obtain positive answers from students. In the classroom under this teaching mode, the teacher's words can greatly encourage students to participate in the classroom, improve the students' discourse volume, and promote the improvement of students' expression ability.

(4) The teacher's questioning ratio accounts for a relatively large proportion, which is higher than the norm. This shows that in the course of teaching, teachers can grasp the problems in time, frequently use the questions to trigger students' responses, and conduct questions and communicative question-and-answer interactions on the content of the text and the students' real grasp of the situation in a question-and-answer process.

(5) Teacher feedback rates are also higher than the norm. This shows that teachers adopt positive feedback attitudes when constructing teacher-student dialogue scenarios, and can make more accurate judgments on students' responses, which not only arouses students' desire for free expression but also responds to students' opinions and feelings. It increases the interest of classroom teaching and promotes participation in classroom discussions [22].

5. Conclusion

The flipped classroom teaching mode has brought development impetus to deepening the teaching reform. This article uses the study of action as an invader, creates a flirty class teaching mode in teaching Japanese linguistics, and applies some teaching strategies to achieve the goal of teaching the course. After the contrast between the classroom learning mode and the traditional learning mode, it is concluded that the flip classroom learning mode can improve the teaching effect of Japanese. A teacher-centric learning mode from the beginning is transformed into a student-centered learning mode that captures students' attention and interest in learning, maximizes their enthusiasm for learning, streamlines their learning approach, improves Japanese application skills, and enhances learning efficiency. Of course, the model also imposes new requirements on the professional qualities of teachers: teachers must not only have a high level of professionalism and operational competence but also teaching and research methods and modern teaching aids. Teachers can only use the flip classroom mode to improve the teaching effect if they constantly update the philosophy of teaching and learning, improve the knowledge structure, and improve professional qualities.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interests.

Authors' Contributions

All authors have read the manuscript and approved.

References

[1] L. Liu, "Research on it English flipped classroom teaching model based on spoc," *Scientific Programming*, vol. 2021, Article ID 7273981, 9 pages, 2021.

[2] A. T. Tulgar, "The effects of a study-abroad experience on pre-service foreign language teachers' teaching philosophies," *Sustainable Multilingualism*, vol. 12, no. 1, pp. 62–87, 2018.

[3] S. Zhou and T. Zhang, "Research on the construction of flipped classroom model for English teaching based on spoc," *Revista de la Facultad de Ingenieria*, vol. 32, no. 14, pp. 267–273, 2017.

[4] J. Zhang, "Research on college English teaching model based on flipped classroom," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 15, pp. 517–522, 2017.

[5] T. Feng, "Research on teaching model of mooc-based college English flipped classroom," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 20, pp. 503–508, 2017.

[6] R. Afrilyasanti, B. Y. Cahyono, and U. P. Astuti, "Indonesian EFL students' perceptions on the implementation of flipped classroom model," *Journal of Language Teaching and Research*, vol. 8, no. 3, pp. 476–484, 2017.

[7] R. Yulian, "The flipped classroom: Improving critical thinking for critical reading of efl learners in higher education," *Studies in English Language and Education*, vol. 8, no. 2, pp. 508–522, 2021.

[8] E. Ekmekci, "The flipped writing classroom in Turkish efl context: A comparative study on a new model," *The Turkish Online Journal of Distance Education*, vol. 18, no. 2, pp. 18–20, 2017.

[9] M. Y. Abdullah, S. Hussin, and K. Ismail, "Does flipped classroom model affect efl learners' anxiety in English speaking performance? supyan hussin, kemboja ismail," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 16, no. 1, pp. 94–107, 2021.

[10] A. Dincer, "Review of flipping academic English language learning: Experiences from an american university," *Language, Learning and Technology*, vol. 24, no. 2, pp. 41–43, 2020.

[11] R. A. Ramadan, "An improved group teaching optimization based localization scheme for WSN," *International Journal of Wireless and Ad Hoc Communication*, vol. 3, no. 1, pp. 08–16, 2021.

[12] C. A. T. Romero, J. H. Ortiz, O. I. Khalaf, and W. M. Ortega, "Software architecture for planning educational scenarios by applying an agile methodology," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 8, pp. 132–144, 2021.

[13] N. O. García, M. D. Velásquez, C. T. Romero, J. O. Monedero, and O. Khalaf, "Remote academic platforms in times of a pandemic," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 21, pp. 121–131, 2021.

[14] S. Ivanaj, G.-B. Nganmini, and A. Antoine, "Measuring E-learners' perceptions of service quality," *Journal of Organizational and End User Computing*, vol. 31, no. 2, pp. 83–104, 2019.

[15] Z. Ke, Y. Yuan, C. E. Montenegromarin, and S. N. Kadry, "Or-based intelligent decision support system for e-commerce," *Journal of Theoretical and Applied Electronic Commerce Research*, vol. 16, no. 4, pp. 1150–1164, 2021.

[16] A. S. Ohta, "Increasing diversity of Japanese language teachers: Approaches to teaching-related professional development for college students in north America," *Japanese Language and Literature*, vol. 54, no. 2, pp. 399–414, 2020.

[17] A. V. Bykov, A. A. Burmaka, S. N. Korenevskaya, and D. S. Rodionov, "An intelligent decision support system for managing patients with lower limb ischemia based on hybrid fuzzy models," *Biomedical Engineering*, vol. 52, no. 4, pp. 271–274, 2018.

[18] J. Pan, H. Zhu, J. Gao, Z. Lin, and H. Cai, "Study of intelligent decision making technology for relay protection setting notification based on information fusion," *Dianli Xitong Baohu yu Kongzhi/Power System Protection and Control*, vol. 46, no. 21, pp. 182–186, 2018.

[19] M. Sudha, "Intelligent decision support system based on rough set and fuzzy logic approach for efficacious precipitation forecast," *Decision Science Letters*, vol. 6, no. 1, pp. 95–106, 2017.

[20] J. Winch, "An investigation of students' preferences in Japanese teaching and learning," *Global Journal of Foreign Language Teaching*, vol. 10, no. 1, pp. 72–84, 2020.

[21] D. W. Yogyanti, A. B. Pertama Sari, and D. Iswahyuni, "Second language acquisition of the professional Japanese tour guides as the core of Japanese teaching development for tourism students," *Izumi*, vol. 9, no. 1, pp. 83–103, 2020.

[22] D. Handayani, E. W. Winarni, A. Sundaryono, M. L. Firdaus, and M. Alperi, "The implementation of a flipped classroom model utilizing a scientific approach and flipbook maker e-module to improve student learning outcomes," *Erudio Journal of Educational Innovation*, vol. 8, no. 1, pp. 73–82, 2021.

Hindawi
Scientific Programming
Volume 2022, Article ID 2022757, 9 pages
https://doi.org/10.1155/2022/2022757

Research Article

Ecological Village Planning and Green Building Design from the Perspective of Rural Environmental Aesthetics

Hua Wang

School of Arts, Hubei Polytechnic University, Huangshi 435000, Hubei, China

Correspondence should be addressed to Hua Wang; 205124@hbpu.edu.cn

Received 22 March 2022; Revised 3 May 2022; Accepted 16 May 2022; Published 14 June 2022

Academic Editor: Ahmed Farouk

The society is making continuous progress, and the results of urban planning and construction are obvious to all. However, there are still many problems in the planning and construction of villages and towns, resulting in relatively backward development. The purpose of this article is to study the planning of ecological villages and towns and the design of green buildings from the perspective of rural environmental aesthetics. This article briefly introduces the principles and problems of ecological village planning through literature research and investigation and puts forward some suggestions on ecological village planning. Through investigation and experiment, the energy problem, structural material problem, and planning problem in green building design are analyzed. The results show that due to various limitations, the use and promotion of solar energy are blocked. Only by helping farmers solve their difficulties can clean energy be used in green buildings and the burning of straw be reduced. Nationwide, the proportion of brick-concrete structures, brick-wood structures, and reinforced concrete structures in rural housing reached 57.2%, 26%, and 12.5%, respectively. Many rural buildings pursue reinforced concrete structures, but brick and wood structures may be more suitable for most rural areas.

1. Introduction

With China's rapid economic development and scientific and technological progress, China's ecological civilization construction and environmental protection have also been further strengthened [1]. The main structural units in China's rural areas are towns and villages. Towns and villages are closer to the natural ecological environment. In the process of ecological civilization construction, villages and towns are the main construction subjects of ecological civilization [2]. In the development process of rural human settlement environment construction, not only the horizontal development of human settlement environment but also the vertical development of rural human settlement environment should be considered [3]. However, the current rural construction, especially the housing construction, has many problems and often does not meet the ecological requirements. Housing construction faces problems such as farmers' wishes and funds.

The basic workflow of township planning and construction mainly includes four stages. The first stage is preliminary communication. Early exchanges were mostly conducted in the form of meetings, at which the working ideas, materials to be investigated, work schedule, and other issues should be put forward [4]. The second stage is on-site investigation. An on-site survey requires the preparation of paper topographic maps and digital cameras in the form of on-site communication. The purpose of the site survey is to be familiar with the local environment, topography, and local development and clarifying basic information such as road name and site width and layout of important infrastructure [5]. The third stage is the current investigation stage. The on-site investigation stage is mainly to submit the on-site investigation report, mainly including the summary of relevant plans and targeted analysis, population status, social and economic environment analysis, etc. The fourth stage is the planning stage. At this stage, it is necessary to submit a plan statement. The content of the planning description includes basic planning concepts, regional development goals, analysis of important factors affecting regional planning, and planning evaluation [6]. After the plan is completed, the plan shall be submitted [7].

There have been many scholars who have conducted research on environmental aesthetics, ecological research, urban planning, and green buildings. Almeida studied the issues of education and promotion in rural planning and put forward suggestions for rural planning with family farms as the mainstay [8]. Wang selected Hongjie town, Changwon County, as a case study, discussed the background of local rural transformation and related environmental factors, and investigated the income and quality of life of local farmers [9]. Li's research found that the interaction between agricultural structure adjustment based on market demand and rural transformation is a modern transformation to improve the quality and efficiency of agricultural products [10]. Joan found that since the second half of the 20th century, the farming and grazing patterns of Spanish rural buildings have changed. Due to economic needs, they have made great changes to the countryside. From the petrification or destruction of assets to the harmony and coexistence between tradition and modernity in the heritage, it reflects the contemporary nature of Spanish rural architecture [11]. Naohiko conducted a study on the planning and layout of rural buildings in historical landscape reserves [12]. Taking the town to the west of Shi as an example, based on the framework of ground feature ecology, this article constructs the temporary land use planning in rural-urban fringe and discusses the importance and challenges of integrating sensory information into the process of rural and urban ecological planning [13]. The data of these studies are not comprehensive, and the results of the studies are still open to question, so they cannot be recognized by the public and thus cannot be popularized and applied.

This article is organized as follows: Section 1 systematically summarizes the main research contents of this study. Section 2 introduces the principles and problems of ecological town planning and puts forward relevant suggestions. Section 3 introduces the design principles and concepts of green buildings. Section 4 is related research, which analyzes the use of energy in rural housing through data query and related experiments. Section 5 is the analysis of the data. Through the specific survey data and research results, the energy problems, structural materials problems, and planning problems in green building design are analyzed. The results show that due to various limitations, the use and promotion of solar energy are blocked. Only by helping farmers solve their difficulties can clean energy be used in green buildings and the burning of straw be reduced. Nationwide, the proportion of brick-concrete structures, brick-wood structures, and reinforced concrete structures in rural housing reached 57.2%, 26%, and 12.5%, respectively. Many rural buildings pursue reinforced concrete structures, but brick and wood structures may be more suitable for most rural areas. The most common type of roads in rural areas is cement roads, accounting for 80.9%, but there are still many roads covered with silt and stones. Most of these roads are roads in front of farmers' homes. The reason is that there are contradictions between town planning and rural residential design, which do not match well with each other. Section 6 is the summary and suggestion of this article, which is the summary and prospect of the article's achievements.

2. Principles and Problems of Ecological Village and Town Planning

2.1. Ecological Planning Principles

2.1.1. Protect the Environment. Poor environmental conditions will pose a threat to the physical health of the human body. In an uncomfortable ecological environment, people's life and health will be impossible to talk about. We look up the history of China and the world and find that the opposition between man and nature is the main relationship in each historical period. There is a cycle that is often repeated in history. First, the natural environment is damaged and uncontrolled. To a certain extent, many disasters will occur in nature, damaging human life. Especially in agricultural production, this kind of confrontation is most obvious. The influence of nature on human production and life is first reflected in agriculture. If we do not find a way to live in harmony with nature, then one day human beings will be unable to resist the retaliation of nature. Therefore, the protection of villages and towns is the basis for the smooth progress of ecological civilization.

2.1.2. Respect Residents' Living Customs. China has a very large number of ethnic groups. Besides the Han nationality, there are also 55 ethnic groups. Many ethnic groups have their own living habits and customs. The lives of many ethnic minorities are somewhat different from those of the Han nationality, and the proportion of the Han nationality is very large. The relevant construction personnel in many places are mainly Han nationality. Therefore, misunderstanding caused by improper understanding may occur. In order to avoid this situation, we must know the local people's life and customs in advance and invite them to participate in the local construction as much as possible. After all, the local people have a deeper understanding of the local culture. If we ignore or copy the same plan, it will probably make the local people feel uncomfortable and hinder the construction of villages and towns.

2.1.3. Ensuring Infrastructure Construction. Ensuring infrastructure construction sounds easy, but it is actually a very difficult thing. First of all, infrastructure construction requires a large amount of funds, and development varies from place to place. It is not easy to fully guarantee infrastructure construction. Second, infrastructure construction must take ecological environment protection as the theme. Many people regard ecology as a primitive environment and greening, which is very wrong. The construction of an ecological environment requires a lot of science and technology and design concepts. In the process of construction, the effective use of space, the convenience of residents, and the cooperation between production must be considered. If the construction process has adverse effects on production and life, it may be unqualified. At the same time, the construction of infrastructure also requires certain high and new technologies.

2.2. Problems in Village and Town Planning

2.2.1. The Lack of Planning for Rural Housing Renovation. In the planning process of villages and towns in our country, the characteristics of different rural areas or the characteristics of rural infrastructure are often ignored. Therefore, the planning and model of villages and towns in China are similar, and it is difficult to highlight the characteristics of villages and towns in different regions. Meeting the wishes and needs of local rural areas has gradually reduced the traditional factors and characteristics of our villages and towns. For example, cave dwelling and semi-cave dwelling in the central and western regions of China are very characteristic buildings with great representativeness. These ancient and traditional farmhouses are permeated with scientific principles and make effective use of surface heat energy. They are relatively warm in winter and relatively cool in summer. They have the basic characteristics of energy conservation and comfort and have unique shapes and beautiful appearance.

2.2.2. Lack of Purposiveness in Urban and Rural Energy Construction. The State Grid Corporation of China has invested 30 billion yuan to allow remote and poor rural areas to use high-quality electricity. Even if the actual situation is different, the amount of investment may still be exceeded, which also means that each farmer can enjoy an investment of about 30,000 yuan. However, the same amount can be used to install a solar photovoltaic cell system for each rural resident, or to raise funds for the construction of a wind power plant, so as to realize the green power consumption of rural residents and can also greatly save the state's consumption in power grid construction [14]. Due to practical considerations, on the basis of the existing, if you want to apply the urban power supply mode to remote mountainous villages, it will inevitably consume a large amount of energy.

2.2.3. Rural Ecological Environment Pollution. The overall ecological environment in our country is not good, and the pollution in many places is a bit serious. The ecological environment in rural areas should have been much better than that in cities, but this is not the case. Some pollution in rural areas may be more serious than that in cities. The most common pollution in rural areas is mainly water pollution, soil pollution, and air pollution. These three kinds of pollution directly affect people's health. Some investigations show that unclean drinking water and harmful substances in the air are the main causes of many diseases. Water pollution in rural areas not only affects people's drinking water health and safety, but also affects the irrigation of fruits and vegetables. This is very similar to soil pollution, which brings hazardous substances into the human body through people's diet. Water pollution is mainly caused by the random discharge of pollutants from factories, many of which are deliberately built in remote places [15]. On the one hand, because the rural labor force is cheaper, and, on the other hand, because remote places are often difficult to supervise, they can take this opportunity to secretly discharge sewage into rivers. In addition to pollution from factories, there is also the problem of fertilization in the process of farmers' planting. Many farmers feel that fertilization can increase production and make more money, so they apply fertilizer in large quantities, resulting in soil pollution. During irrigation or on rainy days, these pollutants will enter the water bodies. The pollution of water bodies will cause the pollution of other lands and turn into a vicious circle. Air pollution is also mainly caused by the random emission from factories, which requires strong supervision.

3. Green Building Design Principles and Concepts

3.1. Design Principles

3.1.1. The Principle of Keeping the Nature of the Countryside Unchanged. The purpose of building new rural houses is to make the countryside look brand-new, not to turn the countryside into non-countryside. The construction of new rural housing is based on the original rural housing. New rural housing construction is different from small town construction, and urbanization. The construction of new rural housing pays attention to the fact that the house can be changed, but the nature of the house cannot be changed.

3.1.2. The Principle of Protecting Farmers' Rights and Interests as the Center. In our country's new rural housing construction, the fundamental goal is to improve the rural economic and social conditions, better protect the rights and interests of farmers, and continuously improve the interests of farmers. Whether it is conducive to promoting the legitimate rights and interests of farmers is an important criterion to measure the construction of new rural housing. As long as it is the new rural housing construction that cannot promote the rights and interests of farmers, it must be stopped. In the new rural construction, we must ensure the farmers' production and living conditions.

3.1.3. The Principle of Ecological Planning First. The planning of new rural housing construction should take the protection of the original rural ecology as the standard, and the planning should not damage the original rural ecology. The new rural housing construction planning must follow the principle of protecting the rights and interests of farmers. The new rural housing construction plan cannot change the current situation of farmers' use of housing. The scope of the plan is limited to houses that farmers do not use, dilapidated and uninhabited houses, and idle houses. The houses that farmers need to live are the foundation of their lives. When building new rural houses, farmers cannot dispose of them without providing them with existing alternative housing.

3.2. Design Concept

3.2.1. Rational Use of Space. Excellent planning and architectural design programs play an important leading role in improving the appearance of villages. They also play a positive role in improving the status quo of random construction and imitation in the process of new rural construction, changing the appearance of villages and improving the living conditions of farmers. As a nonrenewable resource, land is in short supply. New rural planning should aim at intensive use of land, save land as much as possible, and leave enough space for long-term rural development.

3.2.2. Considering Individual Differences. Due to the particularity of rural domestic farming and the relatively large building area, courtyards are usually built in rural self-built houses to facilitate clothes drying, livestock raising, storage of farm tools, firewood, etc., and even to build melon sheds and grow vegetables. Common courtyard forms include a front courtyard, backyard, side courtyard, vestibule backyard, and front courtyard with side courtyard, while the form to be adopted should refer to natural conditions, local customs, area size, and economic situation.

3.2.3. Protecting Cultural Traditions. The design of rural housing should continue to maintain its tradition and beauty. In today's flood of traditional culture and modern civilization, we should maintain the essence of traditional culture, innovate in inheritance, and maintain characteristics in innovation. Traditional dwellings have many distinctive local features. The harmonious coordination between the rural settlements and the natural environment forms a beautiful rural landscape, which is very attractive. Whether in layout, structure, or plastic arts, traditional Chinese dwellings have condensed the wisdom of previous generations to adapt to and transform nature.

3.2.4. Adjust Measures to Local Conditions. Local materials and local conditions are direct and effective ways to reflect the region. Most of the local materials are simple and elegant, and the combination with traditional methods can reflect the rich rural flavor and the life flavor of rural dwellings. For example, local specialty bamboo products are used to make blinds and bamboo curtains. Bamboo is cool, low in heat, and low in water absorption. It is very suitable for rainy and hot weather in the south.

4. Experiments

4.1. Object of Investigation. In order to understand the current situation of China's rural development as comprehensively as possible, we have separately selected some villages in several cities in the four major regions of China for investigation. China's economic region is divided into four major regions: the east, the middle, the west, and the northeast. The eastern region includes Beijing, Tianjin, Shanghai, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, Taiwan, Guangdong, Hong Kong Special Administrative Region, Macao Special Administrative Region, and Hainan. The central region includes Shanxi, Henan, Hubei, Anhui, Hunan, and Jiangxi provinces. The western region includes Inner Mongolia Autonomous Region, Xinjiang Uygur Autonomous Region, Ningxia Hui Autonomous Region, Shaanxi Province, Gansu Province, Qinghai Province, Chongqing City, Sichuan Province, Tibet Autonomous Region, Guangxi Zhuang Autonomous Region, Guizhou Province, and Yunnan Province. The northeast China includes Heilongjiang Province, Jilin Province, and Liaoning Province.

As there is a certain gap between the economic development of various provinces and cities, it is necessary to have certain pertinence when choosing. The specific options are as follows: The survey objects in the eastern region are Baoding City in Hebei Province and Shantou City in Guangdong Province. Baoding was chosen because Baoding has a large population and its economic development in Hebei province is on the middle level, which is typical. Shantou was chosen because Guangdong's economic development is among the best in China, while Shantou's economic ranking in Guangdong province is at a medium level. Shantou is more suitable as a research city for urban and rural development in the eastern region. The choice of cities in other regions is basically based on the development of urban and rural areas and the level of economic development. The survey objects in the central region are Xicheng City in Henan Province and A Qing City in Anhui Province. The survey objects in the western region are Yan'a City in Shaanxi Province and Nanchong City in Sichuan Province. The objects of investigation in the northeast region are Liaoyang City in Liaoning Province and Tong Hua City in Jilin Province.

4.2. Contents and Steps of Investigation. In this article, the research on green buildings mainly starts with the use of various energy sources in rural buildings and the proportion of structural materials in rural housing. The study of ecological town planning mainly starts with road traffic.

4.2.1. Energy Investigation and Analysis. The core of the green building is not the neat appearance, but the use of energy in the building. The energy survey is mainly divided into three parts. The first part is to ask the relevant departments about the use of rural energy and obtain relevant data from the third national agricultural census. The second part is on-the-spot investigation to understand the energy usage in each village and to conduct a questionnaire survey on farmers' friends. From the relevant departments, we know that straw and solar energy are currently a controversial item in rural energy, so the survey mainly focuses on straw and solar energy, including the usage and the advantages and disadvantages of straw and solar energy in the eyes of farmers. The third part is a survey of the solar energy industry. The industry survey selected five-star solar energy manufacturers in Guangdong and Sang Le.

4.2.2. Investigation and Analysis of Structural Materials. For the investigation of rural housing, the method of on-the-spot investigation is mainly adopted, and the structure and materials of rural housing are counted through shooting, observation, recording, and other methods. During the investigation, we found that there are mainly four kinds of structural materials for rural housing, including reinforced concrete, brick and concrete, brick (stone) wood, bamboo, and grass adobe. Although the proportion is very small, there are also housing forms such as basements and caves. Due to the different sizes of housing areas, we have divided all kinds of housing into three groups from small to large according to their areas and floors, with corresponding scores of 1, 2, and 3, respectively. The survey shows that the reinforced concrete construction area and floors are often relatively large, mostly belonging to the 3-point group. According to the corresponding scores, the sum of the scores is obtained, and then the percentage is calculated to obtain the rural housing structural materials.

4.2.3. Road Traffic Investigation and Analysis. In the field investigation, we also investigated the road traffic. The main methods are shooting, observation, measurement, drawing, and recording. During the field investigation, it was found that the rural roads are mainly cement roads, asphalt roads, and sand roads, and there are also few yellow mud roads and roads covered with weeds. For the statistics of pavement, the length is mainly recorded, and the length of various pavements is recorded to obtain the total length of each pavement, thus calculating the percentage. In addition, the distribution of pavement types was recorded.

Due to the difficulty of measurement in the process of investigation, the method of combining the existing data and observation data is adopted. For example, in the road traffic investigation and analysis, the data of the length of the main roads are available, and the measurement data are mainly village roads. Statistical results are obtained by combining the two data .

4.3. Survey Results. The main uses of energy in rural buildings are firewood, coal, combustible gas, methane, electricity, solar energy, etc. The data obtained from the field survey of energy use are generally similar to those from the third national agricultural census. As the data given by relevant departments are more comprehensive and authoritative, we have collated the data of the third national agricultural census. According to the instructions of relevant departments, each household can choose 2 items for this content, thus the sum of percentages exceeds 100%. Because the data source is authoritative and the calculation method is special, some data are too small to study and compare after conversion, so the conversion is not carried out and the original data are retained. The collation results of the survey data are shown in Table 1.

Nationwide, the use of firewood is 44.2%, with the highest proportion reaching 84.5% in the northeast and the lowest in the east, with only 27.4%. The use of coal nationwide was 23.9%, with the highest rate in the eastern region reaching 29.4%. The use of combustible gas in the whole country was 49.3%, reaching a maximum of 69.5% in the eastern region. The use of biogas in the whole country is 0.7%, and the highest in the western region is 1.2%. The use of electricity in the whole country is 58.6%, similar in all regions, exceeding 57%, and slightly higher in the western region. The use of solar energy is 0.2% in the whole country and is relatively low in all regions, with a maximum of 0.3%.

Table 1: Various types of energy use in rural buildings (%).

Area	Nationwide	Eastern	Midland	Western	Northeast
Firewood	44.2	27.4	40.1	58.6	84.5
Coal	23.9	29.4	16.3	24.8	27.4
Gas	49.3	69.5	58.2	24.5	20.3
Biogas	0.7	0.3	0.7	1.2	0.1
Electricity	58.6	57.2	59.3	59.5	58.7
Solar energy	0.2	0.2	0.3	0.3	0.1
Other	0.5	0.2	0.2	1.3	0.1

Protecting the environment can be said to be the most important task premise at present. The design of green buildings should follow the principle of ecological planning first, thus increasing the use of renewable energy sources, such as biogas and solar energy. At the same time, we should reduce the use of nonrenewable energy or more polluting energy, such as firewood and coal. However, we should also follow the principle of protecting the rights and interests of farmers as the center. We should not ignore the interests of farmers for the sake of environmental protection. We need to solve the difficulties of farmers in the process of ecological construction. Only by adhering to the concept of ecological environment protection to build villages and towns and adopting new methods, new technologies and advanced concepts can high-yield and high-efficiency economic production be maintained without damaging the environment.

5. Discussion

5.1. Analysis of Green Building Energy Problems. Many researches on green buildings have ignored the energy problem, but if we only look for green environmental protection in appearance, but ignore the long-term energy problem, it will inevitably be lacking. The energy use of rural buildings largely reflects the development trend in green buildings. In order to facilitate research, we draw the relevant data into a bar graph, as shown in Figure 1.

From the data in the above figure, it can be seen that the use of electricity in rural buildings is the most common nationwide, reaching 58.6%, and the use of electricity in various regions has exceeded 55%, which is also the result of China's vigorous development of electricity for many years. Due to the authority of the data source and the special calculation method, the original data are not processed for the accuracy and convenience of experimental research, and the sum of percentages is more than 100%. However, firewood is also widely used. From a local perspective, the use of firewood is less in the eastern region, and the northeast

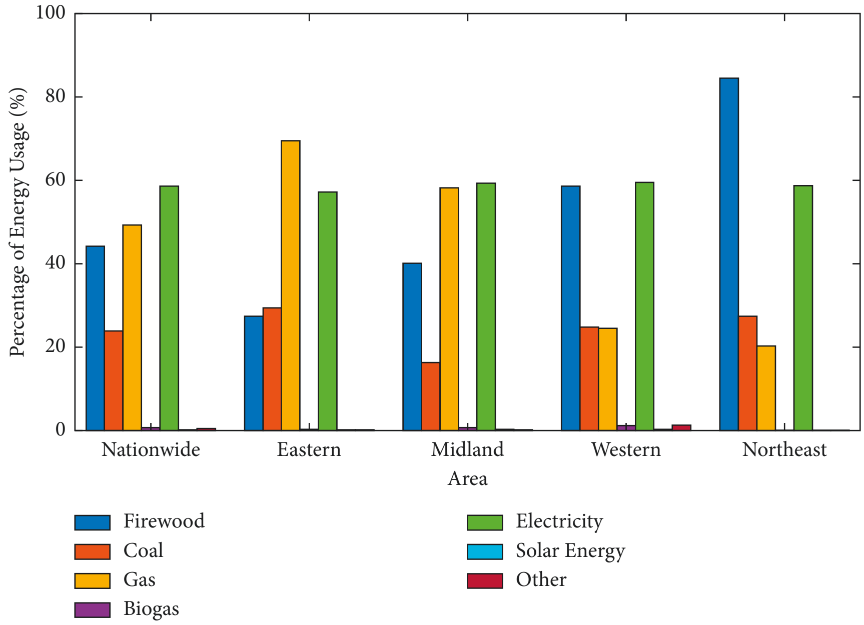


Figure 1: Various types of energy use in rural buildings.

region is extremely dependent on firewood, with 84.5% of the total energy being firewood. The extensive use of firewood is extremely unfavorable to the rural ecological environment.

The use of solar energy in rural areas is rare, with only 0.2% nationwide. A large part of the reason is that many people in the countryside have moved out, and the rest are mainly elderly children. They do not know much about the use of water heaters, and they have poor safety awareness. It is difficult to use solar water heaters. In order to explore the specific use of solar energy, we made a line chart of the growth rate of solar water heaters and solar stoves in recent years, as shown in Figure 2.

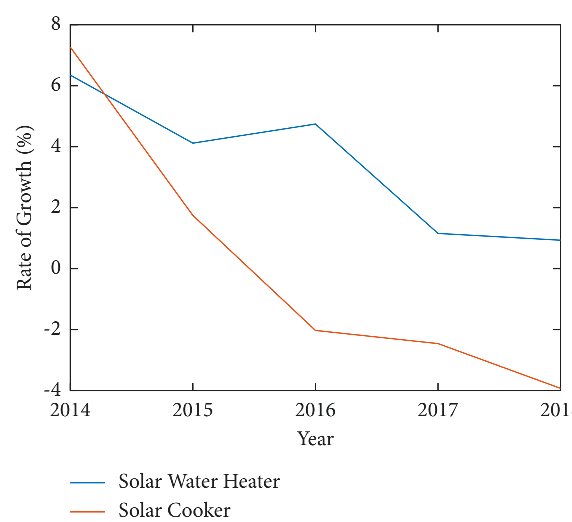


Figure 2: Annual growth rate of solar products.

The annual growth rate of solar water heaters and solar stoves generally shows a downward trend, and the decline rate is relatively fast. According to a survey, the use area of solar water heaters in 2018 was about 88.054 million square meters, which was an increase of only 0.94% compared with the use area of 87.235 million square meters in 2017, the lowest growth rate for the year. In 2018, the number of solar stoves used was about 2.136 million units, which was not only not increased compared to 2.223 million units used in 2017, but decreased by 3.91%. In fact, since 2016, the number of solar cookers has been growing negatively. Earlier we analyzed the reasons why solar water heaters are no longer hot. So, what is the reason why the solar stove was eliminated?

We visited the manufacturers of solar stove products and the friends of farmers who use solar stoves and found that the reasons are like the reasons for solar water heaters. There are roughly the following three points: First, it is because of cost issues. When using solar energy, if you want to get a certain conversion power, you often need a large area of collection and conversion equipment, which is relatively expensive. The second is instability. Due to the limitations of natural conditions such as day and night, season, geographical latitude and altitude, and the influence of random factors such as sunny, cloudy, cloud, rain, etc., the solar irradiance reaching a certain ground are intermittent. It is also extremely unstable, which adds difficulty to the large-scale application of solar energy. In order to make solar energy a continuous and stable energy source, and eventually become an alternative energy source that can compete with conventional energy sources, it is necessary to solve the energy storage problem well, that is, the solar radiation energy is stored in clear daytime as much as possible for night or rainy days, but current energy storage is also one of the weaker links in solar energy utilization. However, green buildings in rural areas cannot avoid the problem of solar energy. If there is no clean energy, green buildings will be impossible to talk about. However, subject to the development of technology and economy, it is not feasible to completely rely on solar energy. Although, at present, power assist methods can be used for solar water heaters, the utilization rate of solar energy is still not high enough, especially when the solar energy is enough in summer, a lot of solar energy is still wasted. Therefore, when designing green buildings, attention should be paid to the collection and storage of solar energy. When building green buildings, the use of solar energy and electrical energy should be designed together to make solar energy and the building itself more closely integrated. This can not only reduce the trouble of subsequent construction and save costs, but also greatly enhance the aesthetics of the building.

5.2. Analysis of Green Building Structural Materials. During the production and use of buildings, a large amount of energy consumption and environmental pollution may also occur. Nowadays, most cities have reinforced concrete structures. With the economic development, there are more and more reinforced concrete buildings in rural areas. However, these reinforced concrete buildings have met with opposition and condemnation from some people. For subsequent research and analysis, we first make statistics on the structural materials of the current rural buildings, and the results are shown in Table 2.

In order to facilitate research, we draw the relevant data into a bar graph, as shown in Figure 3.

As can be seen from the data in the above figure, the most common rural area is still the brick-concrete structures. Nationwide, the proportion of rural housing brick-concrete structures reached 57.2%, and the highest proportion in the central region reached 65.3%. The generality of the brick-concrete structures is expected, because the brick is the smallest standardized component and has low requirements on the construction site and construction technology. It can be built into walls of various shapes and can be produced everywhere and has good durability, chemical stability, and atmospheric stability. It can save cement, steel, and wood, no formwork is needed, and the cost is low. The construction technology and construction equipment are simple.

The utilization rate of brick-timber structures ranks second. Nationwide, the proportion of rural housing brick-timber structures reached 26%, and the highest proportion in the northeast region reached 42.5%. This was followed by reinforced concrete structures, which accounted for 12.5% of the total nationwide and 15.7% in the eastern regions. At present, many rural buildings are aligned with the city and pursue reinforced concrete structures. People generally think that reinforced concrete structures are better, but this is not the case. Reinforced concrete naturally has its advantages: it can be designed and made into various shapes and sizes according to needs; it has good integrity, good resistance to shock, explosion, and vibration; at the same time, it has good durability, normal use conditions, and good fire resistance. It does not require frequent maintenance and repair.

However, during the construction of reinforced concrete housing, a lot of environmental pollution is prone to occur and excessive energy is consumed. In contrast, the brick-wood structure is more suitable for rural areas. However, the brick-wood structure is often misunderstood. Many people think that wood construction is not durable. In fact, building standard wood is a very stable and durable material. In addition, the brick-wood structure has many unparalleled advantages. Such as diversified design styles, thermal insulation and sound insulation, energy saving, best seismic resistance, green environmental protection, comfortable living, etc. Therefore, one should not choose reinforced concrete material blindly, the best material is the best, and it is very important to choose the right building material according to the local situation and the situation of farmers. However, most of the current rural houses are built by the farmers themselves. Therefore, construction materials suitable for local houses should be selected, and then the relevant knowledge should be popularized for the farmers to let them choose.

5.3. Analysis of Village Planning and Housing Design. We mentioned the problems and points of attention of village and town planning in the previous article, in which road traffic is a very important part. Most of the houses in rural areas are privately constructed, which does not seem to have much connection with the planning of villages and towns. In fact, this is not the case. If the construction of housing in rural areas does not match the main roads in the village, farmers need to pave their own roads. Due to the differences between farmers, the appearance of the road is often different, which seriously affects the appearance. To this end, we investigated the types of roads in rural areas and plotted them into a fan-shaped diagram, as shown in Figure 4.

The most common type of rural roads is cement roads, accounting for 80.9%, followed by asphalt roads accounting for 8.6%. But we also found that many roads are still silt and stones, and most of these roads are the roads in front of the farmers' own houses. The reason is that there are contradictions in township planning and rural housing design, and they are not well matched with each other.

Table 2: Proportion of rural housing structure materials (%).

Area	Nationwide	Eastern	Midland	Western	Northeast
Reinforced concrete	12.5	15.7	13.5	9.5	5.3
Brick-concrete	57.2	57.9	65.3	50.6	47.8
Brick (stone) wood	26.0	25.1	18.9	30.9	42.5
Bamboo and grass adobe	2.8	0.9	1.5	5.9	3.6
Other	1.5	0.4	0.8	3.1	0.8

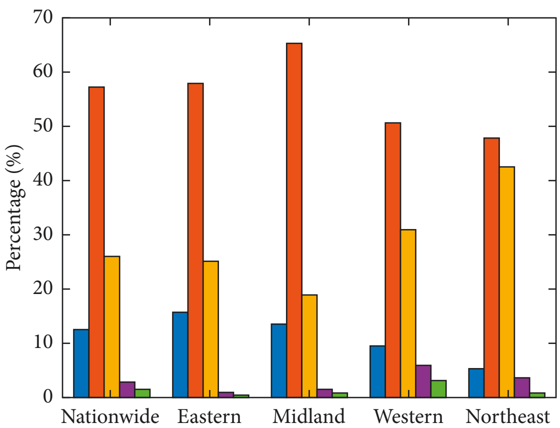


Figure 3: Proportion of rural housing structure materials.

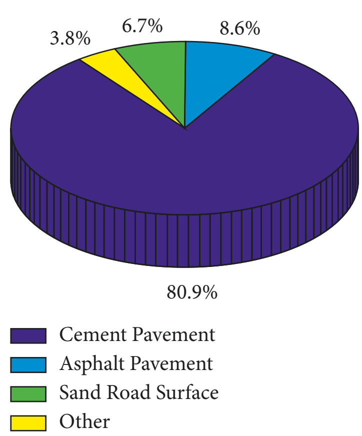


Figure 4: Rural road pavement type.

6. Conclusions

This paper introduces the principles and problems of ecological village and town planning, explains the purpose and significance of the research and the current situation of the research, and puts forward suggestions for ecological village and town planning. The main problems in village and town planning are: lack of planning in rural housing reform; lack of purpose in urban and rural energy construction; and serious pollution of rural ecological environment. The suggestions for village and town planning include: planning the urban system and setting up functional zoning; protecting the environment and coordinating development; deepening reform to promote the overall development of towns and villages; and strengthening the construction of township infrastructure.

Through literature research and survey, the principles and concepts of green building design are introduced. Design principles: the principle of keeping the nature of the countryside unchanged; the principle of protecting farmers' rights and interests as the central principle; the principle of prioritization of ecological planning. Design concept: rational use of space; consideration of individual differences; protection of cultural traditions; adaptation to local conditions, etc.

Carrying out experiments and data analysis, the results show that due to various limitations, the use of solar energy is hindered, helping farmers solve difficulties in order to use clean energy in green buildings and reduce the burning of firewood straw. Nationwide, the proportion of brick-concrete structures in rural housing reached 57.2%, the proportion of brick-wood structures reached 26%, and the proportion of reinforced concrete structures was 12.5%. Many rural buildings pursue reinforced concrete structures, but brick-wood structures may be more suitable for most rural areas. The most common type of rural roads is cement roads, accounting for 80.9%, but there are still many pavements made of silt and stones. Most of these roads are roads in front of the farmers' houses. The reason is that there are contradictions in township planning and rural housing design, and they are not well matched with each other.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by the research base of Humanities and Social Sciences in Hubei Province Colleges and Universities; the research center of mining, metallurgy, culture and economic and social development in the middle reaches of the Yangtze River (Project no. 2015kyb10); and Study on Ecological Landscape in Urban Transformation-A Case Study of Huangshi.

References

[1] A. Gaunand, A. Hocde, S. Lemarie, M. Matt, and E. Turckheim, "How does public agricultural research Impact society? A Characterization of various patterns," *Research Policy*, vol. 44, no. 4, pp. 849–861, 2015.

[2] J. A. Kornelsen, L. Barclay, S. Grzybowski, and Y. Gao, "Rural health Service planning: the need for a comprehensive Approach to costing," *Rural and Remote Health*, vol. 16, no. 4, p. 3604, 2016.

[3] M. Sireni, "When urban planning Doctrine meets low Density countryside," *European Countryside*, vol. 8, no. 3, pp. 189–206, 2016.

[4] M. De Rosa and L. Bartoli, "Adoption of rural development Policies in rural areas of Italy: between family and farm Strategy," *Agricultural Economics Review*, vol. 17, no. 2, pp. 70–81, 2016.

[5] K. Yogalakshmi and G. Latha, "Entrepreneurial Creativity: can it Be a Strategy for Entrepreneurial development in rural Indian Context?" *Proceedings of SPIE*, vol. 8, no. 1, pp. 387–390, 2016.

[6] X. Xiang, Q. Li, S. Khan, and O. I. Khalaf, "Urban water resource management for sustainable environment planning using artificial intelligence techniques," *Environmental Impact Assessment Review*, vol. 86, Article ID 106515, 2021.

[7] S. Lestari, "Rural development Strategies through Bangga Mbangun Desa Policy (a study in Cimrutu village Cilacap Regency)," *International Research Journal of Social Sciences*, vol. 5, no. 7, pp. 268–280, 2018.

[8] D. Almeida, R. B. Peres, and A. N. Figueiredo, "Rural environmental planning in a family farm: education, extension and Sustainability," *Ciência Rural*, vol. 46, no. 11, pp. 2070–2076, 2016.

[9] Z. E. Wang, X. N. Zhou, Y. Yang, and Z. Y. Liu, "Effect of Jian'erle Granule on Thl7/Treg Imbalance of Asthma Mice," *Chinese Journal of Integrated Traditional and Western Medicine*, vol. 36, no. 12, pp. 1510–1514, 2016.

[10] E. Li, Y. Xu, Y. Yajun, and L. Wei, "Agricultural structure adjustment and rural transformation development in China: Taking Gongyi city and Yanling county as examples," *Progress in Geography*, vol. 37, no. 5, pp. 698–709, 2018.

[11] J. C. Vilà and M. P. Curos Vila, "Contemporaneity of Spanish rural architecture Intervention and economic Sustainability," *Art and Design Review*, vol. 05, no. 01, pp. 52–72, 2017.

[12] N. Yamamoto, K. Hirao, and A. Miyauchi, "Building layout inside rural house Compounds in special Preservation areas for historic landscape," *Journal of Architecture and Planning (Transactions of AIJ)*, vol. 81, no. 721, pp. 675–685, 2016.

[13] L. Shi, H. Zhao, S. Zheng, T. Yu, and R. Dong, ""Landsenses" ecological planning for urban-rural Ecotones," *Acta Ecologica Sinica*, vol. 37, no. 6, pp. 2126–2133, 2017.

[14] K. Guo, "Research on location selection model of distribution network with constrained line constraints based on genetic algorithm," *Neural Computing & Applications*, vol. 32, no. 6, pp. 1679–1689, 2020.

[15] S. Shen, P. Yue, and C. Fan, "Quantitative assessment of land use dynamic variation using remote sensing data and landscape pattern in the Yangtze River Delta, China," *Sustainable Computing: Informatics and Systems*, vol. 23, pp. 111–119, 2019.

Hindawi
Scientific Programming
Volume 2022, Article ID 1123535, 10 pages
https://doi.org/10.1155/2022/1123535

Research Article

Cultural Differences of Basketball between China and the United States and Its Concept in Basketball Teaching under the Background of Wireless Network Intelligence Technology

Ke Wu,[1] Jiwei Wang,[2] Weisong Yang,[3] and Xuebing Ruan[4]

[1]*Department of Leisure Services and Sports, Paichai University, Daejeon 35345, Chungcheongnam-Do, Republic of Korea*
[2]*Xuchang Experimental Primary School, Xuchang 461000, Henan, China*
[3]*Institute of Physical Education, Henan Institute of Science and Technology, Xinxiang 453000, Henan, China*
[4]*College of Physical Education and Health, Linyi University, Linyi 276000, Shandong, China*

Correspondence should be addressed to Xuebing Ruan; ruanxuebing@lyu.edu.cn

Received 12 April 2022; Revised 18 May 2022; Accepted 25 May 2022; Published 7 June 2022

Academic Editor: Ahmed Farouk

The increasingly extensive socialization trend has led to the comprehensive innovation of sports. The development of Chinese basketball should be based on the successful experience of the development of professional basketball in the United States. The development of China's basketball has a solid cultural and mass foundation, but we should not be proud and arrogant. It is necessary to make full use of the critical and inherited attitude to learn and absorb the excellent and advanced knowledge of American basketball culture. At present, there are still some problems that need to be further explored. The purpose of this paper is to research and discuss the cultural differences of basketball between China and the United States and their concepts in basketball teaching based on the background of wireless network intelligence technology. This paper firstly analyzes and introduces the difference between the wireless network and wireless sensor network. The main design goal of traditional wireless networks is to improve service quality and efficiently use bandwidth and then consider energy saving, while the main design goal of sensor networks is to use energy efficiently, which is one of the most important differences between sensor networks and traditional networks, to analyze the differences between Chinese and American basketball cultures, to understand the impact of Chinese and American basketball cultural differences on basketball teaching concepts, and to compare and study the differences between Chinese and American basketball culture and their teaching philosophy in basketball. Using the method of this article, through the analysis of experimental data, we understand the impact of Chinese and American basketball cultural differences on basketball teaching concepts and find that Chinese and American basketball cultural differences play an important role in basketball teaching concepts, with a satisfaction rate of 66%. Through theory and experiments, based on the data, it is analyzed that the impact of the differences between Chinese and American basketball cultures on basketball teaching concepts reaches 50%. The research results show that the differences between Chinese and American basketball cultures play an important role in basketball teaching concepts and can be used to promote the development of basketball culture and skills.

1. Introduction

Today, China's basketball has a certain foundation and has achieved good results. However, compared with American basketball, there is still a big gap, and China needs continuous efforts to promote the development of Chinese basketball culture. There are great differences between Chinese and western sports cultures in terms of cultural basis, basic model, and value orientation. Chinese and Western sports culture is the two main types of world sports culture [1]. The basic models of Chinese traditional sports culture are health care, skills, and performance, while the basic models of Western sports culture are competition, utilitarianism, and entertainment. The Chinese sports culture is influenced by the ancient Chinese traditional culture, and Confucian culture and is based on the philosophy of "heaven and man are united." Western sports culture is influenced by the Western Renaissance, the modern industrial revolution, and cultural enlightenment [2, 3]. Chinese sports culture advocates courtesy, tolerance, and peace, while Western sports culture is more targeted, faster, higher, and stronger. Although basketball is a worldwide sport, the connotation of basketball is also different due to the influence of Chinese and Western cultural backgrounds. Chinese ancient culture is vast and profound. Ancient Confucian and Taoist cultures had a significant impact on the emergence and development of Chinese traditional sports culture. In Chinese sports culture, there are static concepts of "mindfulness and foresight" and "mindfulness of inactivity" in the complementary culture of Confucianism and Taoism [4]. Although China's basketball culture has been formed, it still has certain differences compared with the American basketball culture. Different national cultures form different basketball cultures, which also have different promoting effects on the development of basketball culture.

Basketball entered China earlier, but its development was slow, its promotion was narrow, competition was low, and its overall level was low. After the founding of New China, although Chinese basketball has made a breakthrough in development, the development process of the Chinese professional basketball league CBA is relatively short, and the system is not perfect. The western sports culture is based on the western "sports philosophy" philosophy and attaches importance to sports. Western professional basketball starts early, develops rapidly, spreads widely, and has a high degree of industrialization and commercialization [5, 6]. Stable guarantee conditions are more conducive to the development of players and personnel training. The famous American professional basketball league NBA has a history of more than 100 years, has a complete industrial chain and commercial chain, and a sound operating mechanism. The NCAA has a long history and there is more than one in these areas [7]. In China, most people who like basketball and participate in basketball are students and some young people. In school, basketball is more popular and popular with most students, but once they work, many people give up basketball. The main competition and struggle of western sports culture. Americans believe that the basketball court is a battlefield and a place to show personal value, which is more conducive to the personalized development of players [8]. Westerners hope to cultivate young people's will and quality through various exercises, making them more tenacious, tenacious, and extremely agile. Americans believe that winning or losing depends on the number of balls in the opponent's basket. It is a collective sport that promotes the overall development of people. Although basketball training methods are different, their thinking is the same. They all cultivate their feelings and responsibilities through basketball [9, 10].

The differences between Chinese and Western cultures have led to different understandings of basketball between China and the United States. Chinese traditional sports culture emphasizes collectiveness, neglects individuals, emphasizes the responsibility of intermediate subjects, and demands individual rights. The author believes that basketball is a team project and a project that wins honor for the country. He emphasized the cooperation of the entire team. From training to competition, it is relatively rigid, and there is very little fierce competition. Based on western individualism and liberal philosophy, western sports culture pays more attention to individual rights and liberalism. Americans consider the basketball court to be a stage for self-expression, pay attention to the display of personality, and consider the basketball court to be a place to realize self-worth [11]. When they have a chance, they will show their superb skills, followed by the game. They are full of confidence in the game. They often see passionate matches, which brings us an audiovisual feast. Under the influence of Chinese traditional sports culture, Chinese basketball is based on the integration of mind and nature. It is relatively calm and harmonious, with weak physical confrontation and competition awareness and weak performance on the court. Westerners' cheerful personalities and attitudes towards self-worth have a great influence on them [12]. They have a strong sense of competition and resistance. The physical differences between Chinese and American players are also huge. China and the United States have different talent training systems. Chinese basketball players often abandon their studies early for basketball. From being selected as a young basketball players to becoming gifted basketball players, they have followed an unobstructed path with good treatment and priority, which has ultimately led to the low overall quality of Chinese professional basketball players. With the continuous development of basketball, only athletes with higher cultural quality can better grasp the rules of basketball and better understand basketball tactics, so as to improve their basketball level and extend the basketball life of athletes [13]. Therefore, the training system of Chinese basketball talents is not perfect and needs to be further improved to narrow the gap with the world's top teams. In the United States, whether it is high school league, college league, or various basketball training camps, there is a complete training plan and selection system. The United States pays attention to the cultivation of the comprehensive qualities of basketball players [14].

This article uses the method of experimental research to understand the impact of Chinese and American basketball cultural differences on basketball teaching concepts, as well as a comparative inquiry before and after the application. Through theoretical analysis and experimental exploration, find out the role of Chinese and American basketball cultural differences in basketball teaching concepts; Process the data through data recording, sorting, calculation, mapping, analysis, and simulation through the statistical data set of the differences between Chinese and American basketball cultures and their basketball teaching concepts. Combined with the data, the empirical analysis of Chinese and American basketball cultural differences is The role of basketball teaching ideas, combined with effective data, summarizes and analyzes the role of the differences between Chinese and American basketball cultures in basketball teaching ideas. The results show that with the method of this paper, the recognition rate reaches 35%, which is faster and 12% faster than others.

The innovations of this paper are that it (1) introduces the difference between wireless network and wireless sensor network; (2) introduces Chinese basketball culture and American basketball culture. (3) analyzes the development of Chinese and American basketball culture; (4) conducts an experimental analysis on the American NBA professional basketball culture and China's CBA professional basketball culture.

2. Proposed Method

2.1. Difference between Wireless Network and Wireless Sensor Network. In a broad sense, wireless ad hoc networks usually have two organizational forms: infrastructure networks and infrastructure-free networks. The so-called wireless network refers to a network that can realize the interconnection of various communication devices without wiring.

The infrastructure network is a general-purpose, public, packet-switched network supplementary facility that provides a network environment with high security, flexibility, and high-quality services for enterprises and demanding private users. Infrastructure networks, also known as central fabric networks, consist of networks that contain fixed wired gateways. Within the wireless coverage, the mobile host communicates with the base station (fixed wired gateway) and can move during the communication process. When the mobile host leaves the wireless coverage of the original base station, it can establish a connection with another base station and continue to communicate through this base station. In this networking and communication mode, the location of the base station is fixed.

Infrastructure-free networks are also known as wireless mobile ad hoc networks. Among them, no infrastructure network has the following characteristics: independence, distributed characteristics, communication bandwidth, and so on. An infrastructure-free network is a multihop mobility peer-to-peer network composed of dozens to hundreds of nodes, using wireless communication and dynamic networking. Its purpose is to transmit multimedia information flows with quality of service requirements through dynamic routing and mobility management techniques. Nodes usually have a continuous power supply.

Although sensor networks have similarities with wireless ad hoc networks, they also have great differences. A wireless ad hoc network is a multihop mobility peer-to-peer network that is composed of dozens to hundreds of nodes, adopts wireless communication, and is dynamically networked. The sensor network is a network system that integrates monitoring, control, and wireless communication [15, 16]. The number of nodes is larger (thousands or even tens of thousands), and the nodes are more closely distributed; due to environmental impact and energy exhaustion, nodes are more prone to failure. Environmental disturbances and node failures can easily cause changes in network topology; usually, most sensor nodes are stationary. In addition, sensor nodes have limited energy, processing capacity, storage capacity, and communication capacity. The primary design goal of traditional wireless networks is to improve service quality and efficient use of bandwidth and then to consider energy conservation, while the primary design goal of sensor networks is to use energy efficiently, which is one of the most important differences between sensor networks and traditional networks [17, 18]. Wireless sensor network is a distributed sensor network, a wireless network composed of a large number of stationary or moving sensors in a self-organizing and multihop manner to cooperatively sense, collect, process, and transmit the information of the sensed objects in the geographical area covered by the network, and finally send the information to the owner of the network.

2.2. Chinese Basketball Culture. Basketball culture refers to the institutionalized condensation of the way of thinking and behavior of people who watch and participate in basketball. It is a general term for basketball knowledge, skills, customs, and systems.

Due to historical changes in thousands of years in China, ancient Eastern countries have their own civilization and culture and are deeply influenced by Confucianism, family thinking, and Buddhist thinking. Such moral norms are "benefits," "righteousness," "ceremony," "belief," and the unified view of heaven and human life [19]. Its performance is fair and reasonable, and harmony is nonutilitarian. The formation and thinking mode of thousands of national traditional cultures are formed in the course of historical evolution and will not be easily replaced by foreign cultures. Therefore, Chinese basketball is deeply influenced by Chinese culture, which is mainly reflected in basketball activities and basketball players themselves. In order to innovate and surpass the strong teams, we must absorb and learn from the excellent foreign basketball culture, change the way of thinking, learn from each other, enrich the connotation, and develop in a diversified and modernized direction [20, 21]. Modern basketball has been introduced to China for more than a century. For more than 100 years, basketball has been widely popularized and developed in the world and in China. It has transformed from a simple competitive game in the past to a new cultural carrier integrating political influence, economic productivity, social affinity, and cultural communication.

After basketball entered China, in the process of collision, selection, and fusion of Eastern and Western cultures on Chinese soil, basketball, and its American basketball culture also began to be accepted by Chinese people gradually. The impact of foreign basketball culture on Chinese basketball culture has a certain impact, and there are different forms of inheritance in material and spiritual culture. Constant innovation and integration can stand on the forefront of world basketball. For example, from the perspective of Chinese basketball values, we are mainly concerned with fitness, education, and entertainment functions; in competition, we focus on harmonious and friendly competition concepts; in terms of technology and tactics, we focus on individual cooperation with the overall attack and pay attention to collective cooperation. In the values, the national interest is higher than the collective interest, and the collective interest is higher than the personal interest. In the arena, we are concerned that due to the influence of traditional Chinese culture, athletes are introverted, uninhibited, lacking passion, and kingliness [22].

The national cultural patterns, national psychology, and mode of thinking that have been deposited over the past millennium have made great achievements in the course of history. These achievements cannot easily be replaced by the introduction and collision of foreign cultures. Therefore, the basketball culture derived from the development of Chinese basketball has national traditional characteristics. Reflected in the sports career of basketball and competitive athletes. Those who grew up in the land of China, those who love the splendid culture of the Chinese nation created by their ancestors, cannot get rid of it, nor can it disappear, because it is wealth, spirit, and characteristics [23]. But in order to innovate and catch up, we cannot ignore the absorption and organic integration of foreign excellent basketball culture. In the process of carrying forward the Chinese basketball culture formed by the traditional view of history, it is necessary to change the way of thinking, to get rough and refined, to enrich the connotation, and to develop in the direction of diversification and modernization. Today, China's basketball culture is inherited in different forms, both spiritually and materially. It has inherited both domestic experience and foreign experience. Without the integration and innovation of the essential concept of basketball and the scientific concept of development, it will be difficult to stand at the forefront of basketball in the world [24, 25]. In terms of basketball values, we usually pay attention to the fitness, education, and psychological training functions of basketball; in competitive games, we focus on the concept of friendship; in sports law, we focus on offensive and defensive balance, and in an orderly game; in tactical guidance, we focus on the spirit of collectivism. In the tactical cooperation, we focus on the overall combination of attacks, and individual tactical actions obey the overall tactical requirements, showing a certain degree of high concentration; in team management, we focus on the intensive management of the overall action; the practice of values emphasizes national interests first; personal interests obey collective interests; we pay attention to traditional customs and nonpersonalized colors in the form and behavior of auxiliary sports events; the image of the logo team of each club; Chinese athletes are introverted and lack passion because they pay attention to adjusting mentality and emotional changes [26].

2.3. American Basketball Culture. Some also cover entire websites and grid equipment, similar to a large cage. Affected by weather conditions, the winter temperature in Massachusetts, USA, is low, and outdoor sports activities that students like cannot be performed, so James Smith Nai put indoor basketball games and improved the game, the suspension frame was initially placed on the ground, about 10 off the ground feet and divided personnel into two teams to launch offensive and defensive confrontations. Then the bottom of the basket was removed and the gondola was mounted on a special post, which basically established the prototype of basketball sports [27, 28].

In the first stage, in the 1890s, there were no competition rules for basketball. There is no limit to the size of the court or the number of participants. Only two peach baskets were hung at the ends of the narrow open space. Because there were no rules at the time and the venue was not standardized, the competition between the two sides was very fierce, so the moves were rude. The second period was a period of gradual improvement and popularity of basketball, around the 1930s and 1940s. At the end of the 1930s, basketball was rapidly popularized and developed in many countries such as Africa, Europe, Asia, and Australia, and the technical level of basketball was also continuously improved. The fighting form gradually changed from singles to cover and auxiliary defense. The third period is the period of popularization and development of basketball, mainly referring to the 1950s and 1960s. During this time, basketball was very popular around the world. With the continuous development and innovation of basketball technology and tactics, the height of players is also increasing, forcing the existing rules, technologies, and tactics to constantly restrict and promote each other. Height has become one of the important factors in modern basketball games. The fourth period is the period of overall promotion of basketball, mainly after the 1970s. During this period, with the development of basketball, the basketball game gradually became a giant game. This phenomenon has promoted the further improvement of basketball tactics and formed an offensive defense-half-court man-to-man defense and mixed defense tactics, showing a new high power system. The fifth stage is the innovation and climbing stage from the 1990s to the present. The performance of modern basketball techniques represented by super basketball players Jordan, Johnson, etc. makes this sport technique more complete, concise, and more practical. In modern basketball, both men and women will develop in the direction of "high," "smart," "fast," "full," "quasi," "ruthless," and "change," and both technology and tactics will move towards using technology. Different styles and game rules will develop in the new direction of high memory, high business, high appreciation, and high cultural display [29]. Street basketball culture is the most distinctive basketball culture in the United States. There are basketball courts on the street and in the courtyard, and basketball is everywhere.

The reason why the United States is so powerful is that it has a complete training system. The game system for basketball matches from elementary school to professional teams is relatively complete. American children have been playing basketball since the age of six. Middle and primary schools have become an important stage for students' basic skills training. During the holidays, students will also set up basketball summer camps, which will be guided by professional coaches and outstanding players to improve students' solid basic skills. At the high school level, their main task was to learn cultural knowledge and technical tactics. With the continuous progress of science and technology, only players with higher cultures can master and learn advanced strategies and tactics for their own use. American basketball culture is inseparable from its own national culture, which is reflected in basketball. Basketball players in the United States see the basketball court as a stage to show their physical fitness, personal capabilities, and basketball talent. From Chamberlain to Jabal and Michael Jordan, they have brought us into the world of basketball and made an indelible contribution to the rapid development of American basketball. The main value of American basketball culture is to lay the foundation for its formation and development, organically combine the material wealth and spiritual wealth created by basketball, and create the brand effect of American basketball.

2.4. Development of Chinese and American Basketball Culture. There are great differences between Chinese and western sports cultures in terms of cultural basis, basic model, and value orientation. Chinese and Western sports culture is the two main types of world sports culture [30, 31]. The basic models of Chinese traditional sports culture are health care, skills, and performance, while the basic models of Western sports culture are competition, utilitarianism, and entertainment. The Chinese sports culture is influenced by the ancient Chinese traditional culture Confucian culture and is based on the philosophy of "heaven and man unite." Western sports culture is influenced by the Western Renaissance, modern industrial revolution, and cultural enlightenment. Chinese sports culture advocates courtesy, tolerance, and peace, while Western sports culture is more targeted, faster, higher, and stronger. Although basketball is a worldwide sport, it has different connotations due to the influence of Chinese and Western cultural backgrounds.

First, there is a profound difference between the "static view" and the "motion view" in ancient Chinese culture. The ancient Confucian and Taoist cultures had a great influence on the production and development of traditional Chinese sports culture. In the complementary culture of Confucianism and Taoism, there exist static concepts such as "harmony and distance" and "stillness without movement" in Chinese sports culture. Basketball entered China earlier, but its development was slow, its promotion was narrow, the competition was low, and its overall level was low. After the founding of New China, although Chinese basketball has made a breakthrough in development, the development process of the Chinese professional basketball league CBA is relatively short and the system is not perfect. The western sports culture is based on the western "sports philosophy" philosophy and attaches importance to sports. Western professional basketball starts early, develops rapidly, spreads widely, and has a high degree of industrialization and commercialization. Stable guarantee conditions are more conducive to the development of players and personnel training. The famous American professional basketball league NBA has a history of more than 100 years, has a complete industrial chain and commercial chain, and a sound operating mechanism. The NCAA has a long history, and there are more than one in these areas.

Secondly, the difference between "harmony and symmetry" and "struggle" is influenced by the Confucian culture of "use of etiquette and the value of etiquette." Chinese sports culture is based on the concept of harmonious sports and civilization as the theme of solving people's health problems. In China, most people who like basketball and participate in basketball are students and some young people. In school, basketball is more popular and popular with most students, but once they work, many people give up basketball. The Chinese consider basketball to be a place of emotional exchange and friendship. The slogan of "friendship first, competition second" severely restricted the athletes' individuality. The ancient Greek philosopher Heraclitus once said: "Struggle is the father of all, war is the boat of all." The main competition and struggle of Western sports culture. Americans believe that the basketball court is a battlefield and a place to show personal value, which is more conducive to the personalized development of players. Westerners hope to cultivate young people's will and quality through various exercises, making them more tenacious, tenacious, and extremely agile. Distinguish between "intuitive thinking" and "analytic thinking." As an important feature of traditional Chinese culture, Confucianism, Taoism, and Buddhism are proposed, which is conducive to the dynamic grasp of the entire world, but it does not focus on quantitative analysis and inaccurate and rigorous conclusion. Western culture is based on "analytic thinking," pays attention to quantitative analysis, and draws precise and rigorous conclusions. Two different ways of thinking have led to different concepts of "heavy ball and light people" and "heavy ball and light people" in Chinese and American basketball. Americans believe that winning or losing depends on the number of balls in the opponent's basket. It is a collective sport that promotes the overall development of people.

Chinese basketball culture is deeply influenced by Chinese traditional culture. The development of Chinese basketball culture needs to establish a symbol of basketball culture representing China so as to expand the international influence of Chinese basketball culture.

3. Experiments

3.1. Research Object. This article mainly takes the comparison of American NBA professional basketball culture and Chinese CBA professional basketball culture as the research object, using sports theory, culture, and sociology as the theoretical basis, and compares and analyzes the current status of Chinese and American professional basketball culture. Through the development model and social culture of basketball culture, through in-depth research of similarities and differences, the advantages and disadvantages of Chinese and American professional basketball culture, and the main characteristics and influencing factors of Chinese professional basketball culture, this article provides theoretical references to promote improvement and sustainable and healthy development. The level of professional basketball in China achieves the cultural level from the sports level.

3.2. Research Methods

(1) Literature method: refer to the literature to understand basketball culture in China and the United States professional basketball culture, strategy, development and management, teaching materials and works, analyze and summarize more in-depth research results, extract new ideas for this article, stimulate new ideas, and find new parameters to enrich the article. Relevant databases come from the data information provided by Weipu Database, China Periodicals Network, China Knowledge Network, Sports Periodical Literature Search Database, NBA official website, and CBA official website.

(2) Logical reasoning method: analyze the formation of basketball from the aspects of humanities, society, culture, etc. According to the development of culture, sports, and sociology, use logical principles to analyze the characteristics, influencing factors, and development status of sports reasoning analysis.

(3) Comparative research method: This paper mainly uses the collected data and the data of Chinese and American professional basketball culture to find the similarities and differences between national culture and Chinese and American professional basketball culture. Based on a comparative analysis of the above two, further analyze the influencing factors and values of Chinese professional basketball culture so as to provide a theoretical basis and countermeasures for the development of Chinese professional basketball culture.

(4) Mathematical statistics: Mathematical statistical processing is performed on the data to be found in this article and the data contained in the content to provide convincing empirical data for the completion of this research.

4. Discussion

4.1. Analysis of Chinese and American Basketball Coaches

4.1.1. Comparison of Academic Qualifications of Chinese and American Basketball Coaches. According to the analysis of statistical data, as shown in Figure 1 and Table 1, the level of education depends on the learning experience of receiving scientific and cultural knowledge training. The coach's level can reflect whether he can use the knowledge of other disciplines to guide the training of athletes. In the CBA, there are 6 coaches with a bachelor's degree, accounting for 38% of the total; 10 coaches with a high school degree, accounting for 62% of the total. The number of coaches with junior college, master's, and doctoral degrees is zero, and the educational structure is unreasonable. The NBA has 28 coaches with a bachelor's degree, accounting for 93% of the total number, 2 masters, accounting for 7% of the total number, 0 high school, college, and doctoral degree coaches, and a reasonable academic structure. These coaches have a set of scientific training guidance methods and can also use advanced equipment on athletes to improve athletes' sports skills. Compared with American professional basketball coaches, the gap between Chinese professional basketball coaches and American professional basketball coaches is obvious. To train an excellent team, there must be a professional coach team, and the professional coach team must have a high education. Only in this way can the coaching team have excellent professional quality and technology, rich theoretical knowledge, and scientific training methods, and build a strong team. The coaching team of our professional basketball team needs such a high-level coaching team. On the one hand, it is necessary to improve the educational background of the coach. On the other hand, it is more important to change the training method and system. In the final analysis, this is a change in people's mindset, not only a change in the mindset of the coach but also a change in the sense of leadership of the supervisor.

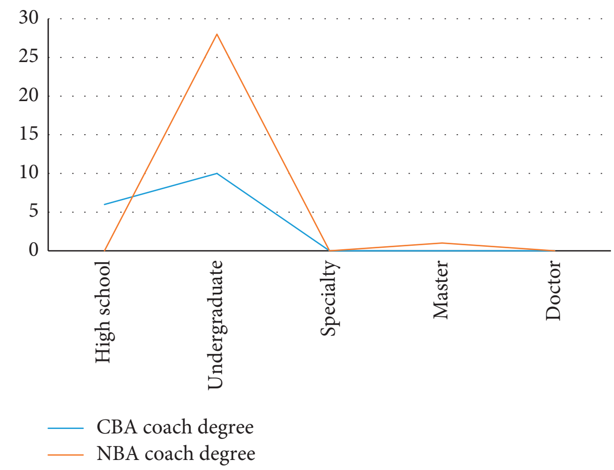


Figure 1: Comparison of coach education.

Table 1: Comparison of coach education.

	CBA coach degree	NBA coach degree
High school	6	0
Undergraduate	10	28
Specialty	0	0
Master	0	2
Doctor	0	0

4.1.2. Comparison of Coaching Experience between Chinese and American Coaches. According to the statistical data analysis, as shown in Figure 2 and Table 2, by searching for information on the website, the coaching situation of professional basketball coaches in China is sorted out. 37.9% of Chinese professional basketball coaches do not have the experience guidance of former assistant coaches, which has also led to these new coaches not having the experience of leading a team. His experience mainly comes from past thought coaches, his experience in games and some of his books, reading, etc. In addition to his own opinions, it has become a group plan for his team, which is a disadvantage of the team and he lacks experience in controlling the game in

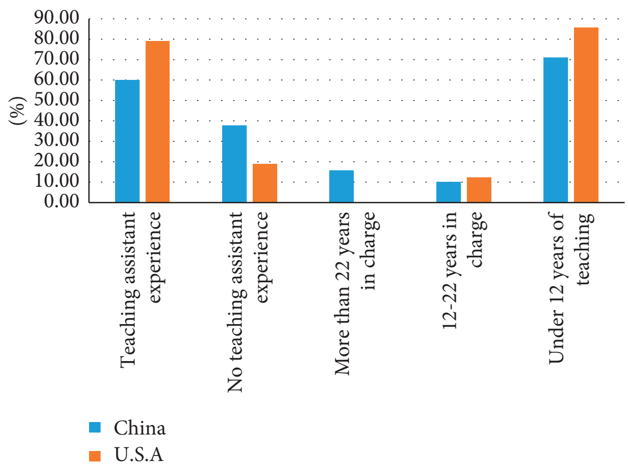


Figure 2: Comparison of coaching experience.

Table 2: Comparison of coaching experience.

	China (%)	USA
Teaching assistant experience	60.10	79%
No teaching assistant experience	37.90	19%
More than 22 years in charge	15.70	0
12–22 years in charge	10.10	12.30%
Under 12 years of teaching	71.20	85.70%

the fierce competition process. 60.1% of basketball coaches have the experience of assistant coaches, laying a solid foundation for becoming head coach assistant coaches. Through early learning and guidance, they have the rich practical experience and theoretical foundation. In order to be able to deal with the problems of the team or players in a timely manner when encountering dangers in the future during difficult matches. In order to solve the problem of players or players in future training. The professional basketball coaching team in the United States has 79% of its coaching assistant experience, reflecting the good theoretical and practical foundation of American coaches. I have my own ideas and views on training and games. In terms of years of coaching, 15.7% of Chinese coaches have been coaching for 22 years or more. 10.1% of Chinese coaches coached 12–21 years, 12.3% of American coaches coached 12–21 years. 71.2% of Chinese coaches have coached less than 12 years, and 85.7% of American coaches have coached less than 12 years. There is a big gap between Chinese professional basketball coaches and American professional basketball coaches in various indicators. First of all, the percentage of coaches with assistant coaching experience in China is very low. Compared with the professional coaching business in the United States, there is a big gap. In addition to professional competence, coaching experience is also a very important aspect.

4.2. Analysis of Chinese and American Basketball Culture

4.2.1. Comparison of Chinese and American Basketball Cultures. According to statistical data analysis, as shown in Figure 3, the United States emphasizes independence and individualism by 46%, encourages confrontation by 34% during training, the team has outstanding personal abilities, and the confrontation ability is as strong as 14%. Parents encourage students to participate in exercise for up to 6%. In contrast, China emphasizes independence and individualism by less than 35%, encourages confrontation by 27% during training, the team's individual ability is outstanding, confrontation is strong by 12%, and parents encourage students to participate in exercise up to 26%. Culture has a profound influence on the formation of a country and its national basketball style. Basketball is not a single sport but a sport that can rise to a cultural level. It requires cultural support. The accumulation and formation of culture take time. Basketball without culture is tantamount to insider information without basketball. This kind of basketball will become a net without vitality and tension. It is easy to be broken. There is no solid at all. In the highly mixed "mixed" culture of the United States, the words "independence" and "individualism" represent the unique basketball culture of the United States, and realizing its value to society is the main purpose of the American thinking model. For example, coaches in the United States encourage athletes to engage in physical contact and confrontation at all stages. They focus on the application and development of physical confrontation exercises. Showing self-competence through confrontation and performance can reflect self-worth, which is very consistent with the concept of competitive sports. Chinese basketball culture has undergone an evolution from tradition to modernity, and its thinking is the golden mean. This traditional way of thinking is as follows: Do not go to extremes and advocate not going on both sides. In addition, the education received by the Chinese from an early age is to take into account both the collective and the country and emphasize the "collective concept" everywhere. Therefore, athletes were cultivated in such an environment during their youth, forming features such as performance methods. During the game, athletes do not particularly advocate fierce confrontation but use speed, flexibility, and cooperation between players to replace some physical contact. To a certain extent, our tactics have achieved the characteristics of "quick" and "clever." But on the other hand, it also caused bad confrontation for the team. Historically, it has a lot to do with our social system and historical heritage. On the other hand, with the development of China's economy, the conditions of national families have greatly improved. Children are often the object of parental care and love in the family. This is a normal situation in most families in China. In such an environment, children who grow up in sports are not only vulnerable to giving up but also overprotected by their parents and lack the courage to study hard. In competitive sports, confrontation and physical contact can easily be injured or uncomfortable. At this time, parents often do not understand or encourage them, which has a negative impact on training and a negative impact on the training of young people. Therefore, for basketball culture, China should inherit fine traditions and abandon bad habits. The long-form basketball style and style of play should be appropriately adjusted according to the general trend and direction of the

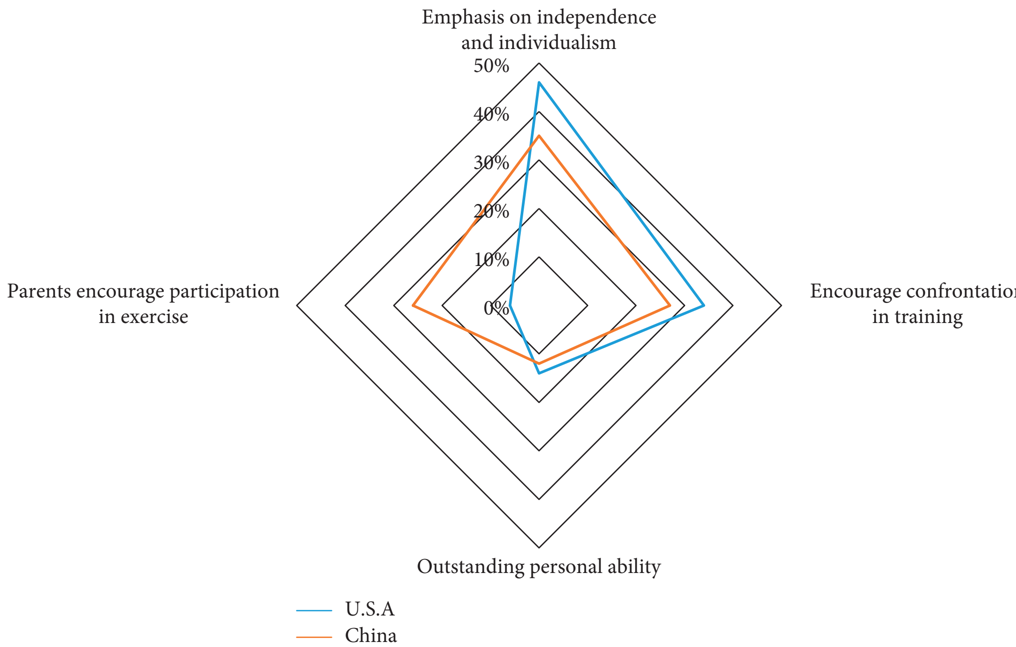


Figure 3: Chinese and American basketball culture.

development of the world's basketball and cannot be static. In addition, countries with high-level basketball development should actively research and summarize, summarize their own needs to improve the success of others, combine their own characteristics and characteristics to absorb the cultures of other countries, and establish the cornerstones of their own basketball characteristics.

4.2.2. Comparison of Chinese and American Basketball Training. According to statistical data analysis, as shown in Figure 4 and Table 3, the training time of American college basketball teams is usually concentrated in the afternoon. According to a survey by basketball teams, their average training time and time are 3.55 hours and 5.2 times, respectively. In addition, the United States has participated in training competitions more often, with a total of 40 times, and China has fewer 14–24. Basketball team training is usually scheduled in the afternoon. Sometimes, in order to prepare for important matches, they also perform a period of concentrated training. The training time and load intensity of American basketball players are significantly higher than those of Chinese college athletes. The training time and time of most basketball players in China are difficult to meet the needs of sports training development. There are many reasons for this. Most high-level athletes have low education levels and have more learning difficulties after entering school. If we only focus on learning, it will affect training, and the contradiction between the two is very prominent. Due to insufficient funds and the inability to deploy high-tech training equipment, most basketball players in China still use traditional experience training methods. It is difficult to make great innovations in traditional training methods. Without scientific training methods, athletes' technical and tactical levels cannot be improved rapidly. Even if the training takes longer, it can only complete half of the work and even have the opposite effect. This left a group of better-conditioned athletes abandoned. The long-term training plan of basketball players and athletes is not perfect. Many basketball players do not attach importance to regular training and are unexpected when the game is approaching. This is also one of the reasons for the poor sports performance of athletes. Because American basketball players implement a "lenient entry and strict exit" education policy, the academic system is not very strict. In fact, many college athletes are free to extend their four-year school hours, so their education management system can also help alleviate the contradiction between perennial training time and cultural learning. American basketball players attach great

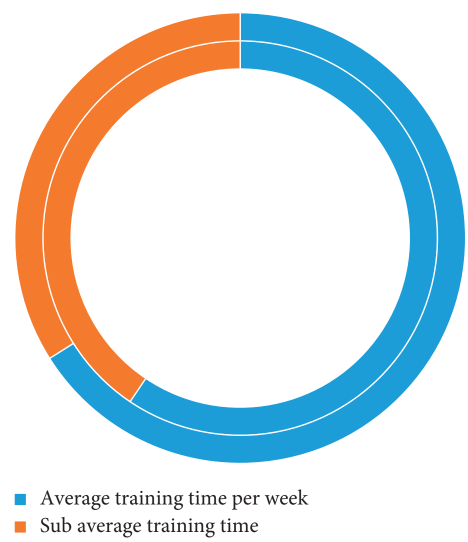


Figure 4: Basketball training time.

Table 3: Competition statistics.

Country	Various invitational competitions	State competitions	NCAA/CUBA organize a contest	Total number of sites
USA	10	9	21	40
China	4–7	2–4	8–13	14–24

importance to the cultivation of athletes' competitive ability and attach great importance to the connection between training and competition. They see competition as an important part of training. Sports competitions for American college students are quite frequent. In addition to the various levels of the competition organized by the College Student Sports Association, states and even regions often organize high-level leagues, invitational tournaments, and exhibition matches. Check the training level through the competition, enhance the confrontation ability, and enrich the competition experience. Comparing the average number and type of basketball matches between the American basketball team and the Chinese basketball team, there is a large gap between the number of matches between Chinese basketball players "high-level basketball teams and the Chinese and American basketball players" basketball culture. Too little competition is also one of the main reasons affecting the training level of basketball players. No matter how good the sports technique is in normal training, it is worthless to test it without participating in the game. The skills we usually master can only be consolidated and improved if they are used in competitions. Lack of school funding is another reason for lack of competition. Secondly, basketball players' basketball levels are uneven, and the comparability among basketball players is poor. Some high-level colleges and universities have no competitors in the province and do not have sufficient funds to carry out activities outside the province. In the long run, it is difficult to improve their technical and tactical levels. Therefore, we must increase the number and time of matches for high-level basketball team of basketball players, strengthen cultural propaganda in China, training and games are closely linked, and we must promote the improvement of high-level basketball training levels for basketball players.

5. Conclusions

(1) The training methods of Chinese and American basketball players are quite different. The traditional training of basketball players in China is based on the training of professional sports teams under the national system. Although this kind of training mode has cultivated a group of outstanding basketball players in a short time, it has also caused a series of problems. In this way, the separation of the sports system from the education system, excessive emphasis on sports training, and neglect of cultural courses have prevented athletes from all-around development. In recent years, although new training methods such as combining sports and education, socialization, and professionalism have begun to emerge in China, their development is not mature enough. Generally speaking, traditional professional sports teams still dominate the training model of basketball players in China. The basic training method of American basketball players is to combine sports with sports. In the United States, a mature and systematic training model combining sports and education has been formed.

(2) There are large differences in the management systems of the basketball leagues between the two countries. The management system of the American Basketball Club is self-management, self-restraint, and self-motivation. The management system of Chinese basketball clubs is "common ownership of sports enterprises" and "personal ownership," but there is no independent management.

(3) There are some differences between the two countries in terms of basketball player training, basketball team, and basketball team coaching. The United States has a systematic basketball player training model, which has a good foundation in terms of cultural quality. However, the training of basketball players in China is relatively singular, and the cultural quality is relatively weak. Basketball players and coaches are mainly managed in the United States through laws, and in China, they are mainly managed through administrative means. The management of the American basketball team is mainly loose, and the management of the Chinese basketball team is highly unified.

However, due to the limitation of time and technology, we have not conducted in-depth research on the application of wireless sensor networks in basketball culture, and we will conduct more in-depth research and discussion in the future.

Data Availability

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

Conflicts of Interest

The authors declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

[1] M. Mary Cappelli, "Innovative strategies of indigenous resistance among the wounaan people of Colombia," *Native American and Indigenous Studies*, vol. 4, no. 1, pp. 89–95, 2017.

[2] I. Loturco, C. C. Cal Abad, D. Jeleilate et al., "Differences in fitness characteristics between brazilian world championship

and south-american championship national basketball teams," *The Journal of Sports Medicine and Physical Fitness*, vol. 56, no. 11, pp. 1428-1429, 2016.

[3] M. S. Wong, P. Worthy, J. Fung, and E. C.-H. Chen, "A qualitative analysis of the experience of female Chinese american church leaders: associations with gender role, culture, and work-family balance," *Pastoral Psychology*, vol. 66, no. 5, pp. 657–674, 2017.

[4] S. Lemez, N. Wattie, T. Lawler, and J. Baker, "Vital statistics and early death predictors of north american professional basketball players: a historical examination," *Journal of Sports Sciences*, vol. 36, no. 14, pp. 1–8, 2017.

[5] M. R. Klapper, J. lambert, *Unclean Lips: Obscenity, Jews, and American Culture*, New York University Press, NewYork, NY, USA, pp. 97-98, 2016.

[6] Y. Chen, "Study on neural network model-based senior high school men's basketball training strategy and approach," *Journal of Computational and Theoretical Nanoscience*, vol. 13, no. 12, pp. 10059–10063, 2016.

[7] C. E. Armstrong, "Running lean startup in the classroom: from idea to experiment in 1 week," *Management Teaching Review*, vol. 2, no. 2, pp. 132–140, 2017.

[8] N. B. Dohn, A. Fago, J. Overgaard, P. T. Madsen, and H. Malte, "Students' motivation toward laboratory work in physiology teaching," *Advances in Physiology Education*, vol. 40, no. 3, pp. 313–318, 2016.

[9] F. F. Xie, "Teaching reform and innovation ability training for undergraduate in closed-range photogrammetry course," *Journal of Geomatics*, vol. 42, no. 1, pp. 119–122, 2017.

[10] V. K. Iyer, "A dynamic intranet-based online-portal support for computer science teaching," *Education and Information Technologies*, vol. 22, no. 3, pp. 1–14, 2016.

[11] C. Laville, "Teaching machines: learning from the intersection of education and technology by bill ferster," *Configurations*, vol. 24, no. 1, pp. 109–111, 2016.

[12] A. Jonas, "In the heart of teaching: a two-dimensional conception of teachers' relational competence," *Educational Practice and Theory*, vol. 39, no. 2, pp. 39–56, 2017.

[13] S. Liu, S. Yu, X. Wang, and X. Han, "Spoc curriculum construction and teaching design of engineering surveying," *Journal of Geomatics*, vol. 42, no. 4, pp. 123–125, 2017.

[14] E. Goldblatt, "Every person is a philosopher: lessons in educational emancipation from the radical teaching life of hal adams," *Community Literacy Journal*, vol. 12, no. 1, pp. 97–99, 2017.

[15] I. Butun, P. Osterberg, and H. Song, "Security of the internet of things: vulnerabilities, attacks, and countermeasures," *IEEE Communications Surveys & Tutorials*, vol. 22, no. 1, pp. 616–644, 2020.

[16] R. S. Bhadoria and N. S. Chaudhari, "Pragmatic sensory data semantics with service-oriented computing," *Journal of Organizational and End User Computing*, vol. 31, no. 2, pp. 22–36, 2019.

[17] O. I. Khalaf and G. M. Abdulsahib, "Optimized dynamic storage of data (ODSD) in IoT based on blockchain for wireless sensor networks," *Peer-to-Peer Networking and Applications*, vol. 14, no. 5, pp. 2858–2873, 2021.

[18] O. I. Khalaf and G. M. Abdulsahib, "Energy efficient routing and reliable data transmission protocol in WSN," *International Journal of Advances in Soft Computing and Its Applications*, vol. 12, no. 3, pp. 45–53, 2020.

[19] D. Crockett, "Long-form science: teaching with extended texts," *The Science Teacher*, vol. 84, no. 1, pp. 27–32, 2017.

[20] W. Joyce, "Beyond pacifism: teaching world war i literature from left to right," *Philosophy and Literature*, vol. 17, no. 3, pp. 541–547, 2017.

[21] J. Jamaluddin, M. Mahali, N. M. Din, and M. A. N. Ahmad, F. A. Jabar, N. S. M. Fadzillah, and M. A. A. Malek, "A comparison of students' performance in gamification approach versus conventional approach of accounting teaching and learning," *Advanced Science Letters*, vol. 23, no. 8, pp. 7733–7736, 2017.

[22] W. Liu, "The changing pedagogical discourses in China," *English Teaching: Practice and Critique*, vol. 15, no. 1, pp. 74–90, 2016.

[23] S. L. Sangster, K. L. Loy, S. D. Mills, and K. L. Lawson, "Engaging first-year university students in research: promise, potentials, and pitfalls," *Canadian Journal for the Scholarship of Teaching & Learning*, vol. 7, no. 1, pp. 1–36, 2016.

[24] M. W. Cole, P. J. Dunston, and T. Butler, "Engaging English language learners through interactive read-alouds: a literature review," *English Teaching: Practice and Critique*, vol. 16, no. 1, pp. 97–109, 2017.

[25] P. Garcias and V. I. Marín, "Enhancement process of didactic strategies in a degree course for pre-service teachers," *International Journal of Web-Based Learning and Teaching Technologies*, vol. 12, no. 4, pp. 14–24, 2017.

[26] T. West, R. S. Nam, and A. W. Benckhuysen, "Kinesthetic language learning: how an accident led to a revelation," *Teaching Theology and Religion*, vol. 19, no. 4, pp. 378–384, 2016.

[27] L. Buckley, "Su-f-e-08: medical physics as a teaching tool for high school science curriculum," *Medical Physics*, vol. 43, no. 6, p. 3354, 2016.

[28] C. A. Hodes, *Feminist Pedagogy in Higher Education: Critical Theory and Practice Ed. By Renee Bondy, Tracey Penny Light, and Jane Nicholas (Review)*, pp. 180–182,University of Toronto Quarterly, Toronto, ON, Canada, 2017.

[29] L. Aronson, "Joanne bubolz eicher: trailblazer in the field of african textiles, dress, and fashion," *African Arts*, vol. 50, no. 3, pp. 38–47, 2017.

[30] S. Wan, L. Qi, X. Xu, C. Tong, and Z. Gu, "Deep learning models for real-time human activity recognition with smartphones," *Mobile Networks and Applications*, pp. 1–13, 2019.

[31] H. Song and M. Brandt-Pearce, "A 2-D discrete-time model of physical impairments in wavelength-division multiplexing systems," *Journal of Lightwave Technology*, vol. 30, no. 5, pp. 713–726, 2012.

Hindawi
Scientific Programming
Volume 2022, Article ID 9111509, 11 pages
https://doi.org/10.1155/2022/9111509

Research Article

Bocce Training Based on Computer Technology Has an Effect on Physical Education in Colleges and Universities

Heqi Yuan [1] and Mengze Li [2]

[1]*Graduate School, St. Paul University Philippines, Tuguegarao 3500, Cagayan, Philippines*
[2]*Graduate School, University of Perpetual Help System DALTA, Alabang-Zapote Avenue, Pamplona 3, Las Piñas 1740, Philippines*

Correspondence should be addressed to Heqi Yuan; yuanheqi@xin.edu.pl

Received 14 February 2022; Revised 9 April 2022; Accepted 3 May 2022; Published 31 May 2022

Academic Editor: Ahmed Farouk

Computer technology refers to the technical methods and technical means used in the computer field, which have the function of data storage, modification, and calculation of related logic and data. Physical education in colleges and universities has various levels and complex contents. From the perspective of bocce training in college physical education, this paper proposes a research direction for bocce training based on computer technology for the development of college physical education. First, a brief introduction to bocce is given, and then the traditional training methods of bocce are explained. It mainly includes technical training, physical fitness training, and psychological quality training. Then, the computer-assisted teaching is explained. Finally, the computer-assisted teaching and the traditional mode of teaching are contrasted. The experimental results show that the overall performance of students' technical training, physical fitness training, and psychological training assisted by computer technology is 3.53% higher than that of students under traditional teaching. This shows that bocce training based on computer technology is more conducive to improving the level of sports training of students, thereby improving the quality of physical education.

1. Introduction

With the development and progress of the times, the continuous maturity and perfection of computer technology has allowed it to penetrate into the development of various fields. For example, medicine, finance, and communication industries have all integrated with each other and achieved further development. It also affects the development of the current teaching field and the reform of teaching methods subtly. Nowadays, computer technology has begun to be used in many teaching practices, which to some extent also means that education and teaching have begun to develop in the direction of intelligence. The rapid update and real-time communication of scientific knowledge related to education and teaching are also inseparable from the support and guarantee of computer technology. Computer technology will also promote the rapid development of education and teaching informatization. The integration of computer technology and education and teaching has become the general trend of current education and teaching development. And, how to use advanced computer technology to improve teaching efficiency, increase teaching methods, reduce teaching costs, improve the current management of college education and teaching, and cultivate modern high-quality talents for the society, so as to achieve the sustainable development of teaching, has become the focus of many educators.

In the context of the rapid development of science and technology, the study of the integration and development of computer and education will enable people to have a deeper understanding of educational activities in the new era of intelligence [1]. Under the traditional model, the main channel for students to acquire knowledge is through teachers' teaching methods. However, in the computer age, students will inevitably need to re-examine the ways of acquiring knowledge in order to adapt to social changes, so as to optimize the educational process [2]. This helps to change the phenomena of mechanization and nondifferentiation in the traditional classroom so that the development of teaching will shift to the direction of intelligence, precision, and individualization. Bocce has always been agile, fast, skilled, and fierce. This requires strict daily training. Therefore, we need to use diversified methods and combine the characteristics of the times to continuously cultivate and improve students' training thinking and improve their training level.

Based on computer technology, this article puts forward a new research direction of bocce sports teaching auxiliary training in colleges and universities and discusses the new generation of teaching concepts in the new era. This provides new ideas for the research in the field of bocce teaching and has practical and practical significance in terms of physical education teaching methods and techniques.

2. Related Work

In recent years, many scholars have carried out research on the combination of computer technology and teaching. Zhang S. integrates computer technology into college English teaching. Based on the concept of ecological teaching, the article re-evaluates the adaptability and teaching effect of various teaching units such as MOOC, microcourse, multimedia, and network platform and analyzes the parameters of computer technology in the theoretical model. He uses computer-assisted technology as a theoretical evaluation model of the college English teaching ecological framework and ecological teaching effect and uses the ecological teaching concept to create a good learning environment for students and cultivate students' intercultural communication skills and professional English ability [3]. Tan et al. analyzed the dance information teaching model framework based on Kinect somatosensory computer technology. He believes that the problem with dance teaching is not only the difficulty of the movements but also the limited training environment and the lack of on-site guidance from teachers. So he used computer technology to design a dance auxiliary training system, input dance movements into the system, and analyze, evaluate, and correct the trainer's movements. Finally, it is verified through experiments that the trainer can effectively improve the dance level according to the simulation system, and the system meets the requirements of auxiliary training [4]. Lv J. has carried out research on the Japanese multimedia teaching model based on the computer platform. He introduced the connotation and function of Japanese teaching under computer technology by analyzing the multimedia teaching model of the Japanese classroom. Finally, the teaching results are analyzed and discussed, and the results show that the teaching mode based on computer technology has more advantages than the traditional Japanese teaching mode [5]. Jing C. believes that today's basic music teaching methods are too simple and relatively backward, unable to attract students' attention. He took music teaching as the research object, put computer-assisted technology into practical teaching work, and carried out comparative experiments. Finally, the experimental results show that the computer-assisted music teaching model makes up for the single teaching model of exam-oriented education and makes the music teaching classroom more vigorous and vigorous. At the same time, it also greatly stimulated the enthusiasm and interest of students in learning music and improved the enthusiasm of students in learning music and the teaching level of the school [6]. Weiwei Z. proposed an interactive model for the design process of the ideological and political course teaching system based on the computer network. He participated in all stages of the teaching system design and finally completed the system development together with the project team members. It uses advanced information system development technology and information network platforms to explore the informatization pattern of ideological and political work. And, through the use of computer technology to achieve online learning and communication, it breaks the limitations of time and region and finally verified the effectiveness of computer technology in improving ideological and political education through experiments [7]. Ran M. analyzed the construction and optimization of a multi-English teaching model based on computer cloud technology. After logging in to the interactive English teaching platform, students can browse course content, watch videos, and complete interactive exercises. With the help of modern information equipment, students can complete their own learning tasks independently. English teaching is no longer confined to traditional classroom teaching. The multiple interactive education model has fully stimulated students' interest in learning and provided a good teaching platform for teachers and students. This makes up for the shortcomings of traditional classroom education to a large extent and provides a three-dimensional teaching platform for college English teaching [8]. In summary, after recent years of exploration, the integration of computer technology and teaching has been deeply studied by many scholars, but there are not many studies on bocce training on college physical education. Therefore, in order to promote the in-depth development of teaching, it is urgent to study the practice of bocce training based on computer technology on college physical education.

3. Bocce Training Based on Computer Technology

3.1. Introduction to Bocce. Bocce is a sport in which athletes from both sides throw the ball with their hands on a prescribed field for confrontation. According to research, the earliest birthplace of bocce is ancient Egypt. Five thousand years ago, it was only regarded as a simple and entertaining casual game, which was extremely popular among ordinary people. Until the ancient Greek period, it was used as a sport for many farmers to strengthen their bodies. Following the changes in society and the progress of the times, this sport was widely circulated and once became a popular entertainment method [9]. In the second half of the nineteenth century, accompanied by a large number of immigrants from Europe, the sport of bocce got a deeper development, and the sport began to be accepted by people all over the world. The earliest bocce was just a stone ball that was ground into a smooth shape. Because the shape and quality

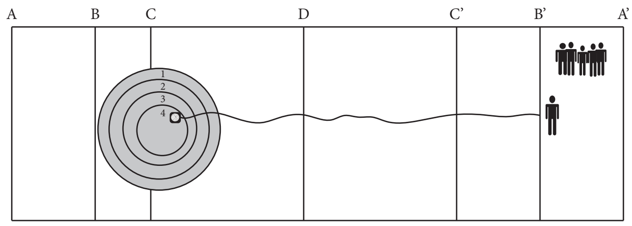


Figure 1: Bocce training chart.

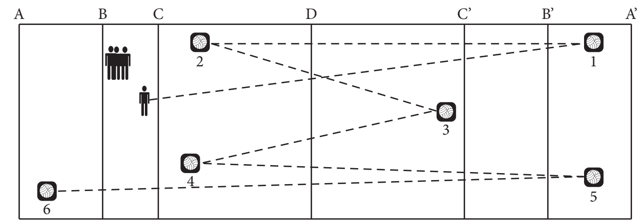


Figure 2: Bocce training chart.

of this stone ball are difficult to be unified, people later used olive wood as the raw material to make it into a wooden ball with a better feel. But now many countries have stricter specifications for bocce. They replaced the wood with metal or synthetic plastics, and as a result, the size and quality of the throwing balls had a more uniform standard. At the same time, the training methods of this sport have also undergone great changes, and various styles of play have begun to appear, and corresponding rules have been set for the evaluation of different items.

3.2. The Traditional Training Method of Bocce. All training methods and tactics serve the training mission [10]. The selection and use of bocce skills and tactical training methods must be combined with reality, that is to say, certain training methods must be selected or created to complete certain training tasks. These methods have a clear purpose and are scientific in order to achieve good results. Common bocce training methods generally include technical training, physical fitness training, and psychological training [11].

3.2.1. Technical Training. The three techniques of bocce mainly include relying on the ball, rolling, and throwing. For single technique training, one training is divided into three stages, and training is carried out one technique by technique. The order is by ball, rolling, and tossing and distribute training according to a certain proportion of the time. Ball training refers to drawing concentric circles with unequal radii in the effective area of the field and marking the number of points scored in each range [12]. Place the small ball at the center of the circle, and the athletes roll the same number of balls in turn and calculate the scores, as shown in Figure 1.

The ball is first placed at a certain point in the effective area of the court, and the ball's position is continuously changed. The athletes each roll to four consecutive balls in turn, and the ball farthest from the ball is the effective ball, the effective ball needs to be as close as possible to the small ball. Then, the athletes each roll two balls in turn, one ball closer to the small ball is the effective ball, and the effective ball should be as close to the small ball as possible [13].

Then, draw a number of circles with a diameter of 50 cm and a distance of 5 to 20 meters on the field and mark the sequence number. Athletes roll the ball into each lap in turn according to the sequence number. After a lap, the ball can be rolled continuously. It is required to roll the ball into the last lap in the least number of times, as shown in Figure 2.

After the athletes are ready to roll against the ball, close their eyes, and roll the ball to the range delineated near the *D* line, the far end C line, the B line, and the A line according to the coach's command. The error is required to be minimized. When performing the above exercises, athletes' movements are required to be coordinated and natural. Through these exercises, it can become familiar with the ball to enhance the feel and improve the adjustment ability of rolling at different distances [14].

Rolling training refers to athletes imitating hitting movements with their bare hands. The entire batting practice includes run-up, support, arm swing, and full action practice. The athlete needs to roll the targets at different points in the effective area in turn until they hit all the targets, as shown in Figure 3, and from this to calculate the hit rate of the entire shot.

Tossing training requires athletes to have coordinated movements, which are natural and reasonable and are the same as the practice methods of rolling techniques. For throwing training and throwing the ball after the *C* line, first, draw a straight line from a certain point on the field line to the far end line along the swing direction of the athlete, and then the athlete throws the ball in turn. The thrown ball needs to fall on the drawn line as much as possible, as shown in Figure 4.

For the practice of tossing a fixed target from several different points on the field line, if it wants to increase or decrease the athlete's angle of the shot, it needs the coach to stand in a proper position on the field with a bamboo pole in hand. This requires the athlete to throw the ball over or under the pole to hit a fixed target [15]. Place the two balls at a distance of 12 cm between the front and rear in the effective area. Use the method of increasing the angle of shot to hit the ball in front, and use the method of lowering the angle of shot to hit the two balls at the same time.

3.2.2. Physical Fitness Training. With the increasing level of bocce ball, physical fitness training becomes more and more important. Physical fitness training must be carried out in each training session, and each time accounts for about half of the training time. Generally, it focuses on the development of upper and lower limb strength, waist, abdominal, and back muscle strength, and wrist and finger strength. The main methods to develop strength quality are bench press, weight-bearing jump, weight-bearing half-squat jump, sit-ups, reverse grip ball throw, finger-ups, arm weights, and forearm forward lifts.

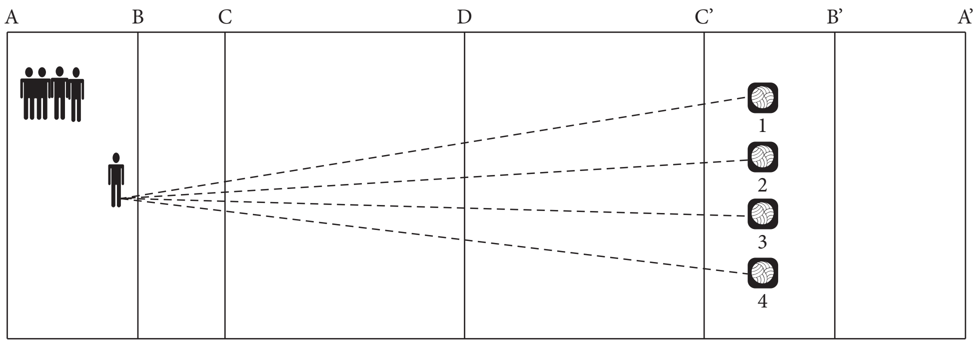


Figure 3: Rolling training chart.

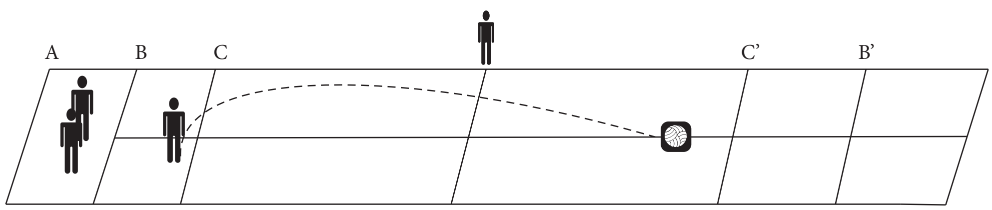


Figure 4: Tossing training chart.

Table 1: Common mental training methods.

Appellation	Main content
Representation training	Through multiple action representations, improve the athlete's representation and memory abilities
Blind training	No specific goals are set, athletes train on their own
Forecast practice	Set specific goals and athletes train according to the goals
Psychological adjustment training method	Improve athletes' ability to concentrate by adjusting their mentality

3.2.3. Mental Quality Training. Although the bocce game is not as intense as other ball games, there is no physical contact between the players, and the pace is not so fast. But for the throwing of every technical action, the requirements are very subtle, strict, and precise [16]. This requires athletes to have good psychological qualities (spatiotemporal sensation, muscle control, attention control, elimination of interference, etc.). Therefore, psychological training is an indispensable training method for bocce. The psychological training often used in bocce sports includes representation training, blind training, forecasting training, and psychological adjustment training, as shown in Table 1.

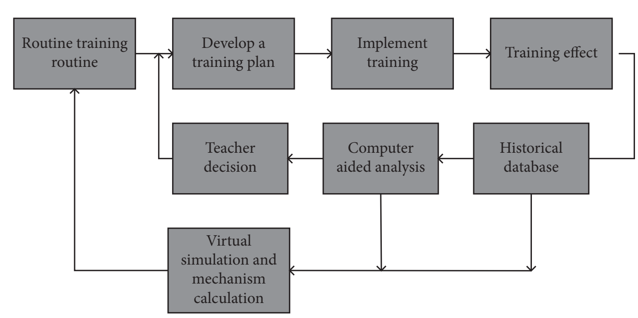


Figure 5: Computer-aided training process.

3.3. Bocce Computer-Assisted Training. Computer technology has powerful data storage capabilities. If computer technology is applied to the management of students' daily training bowls, it will inevitably affect the flow of sports training [17]. This paper proposes a computer-aided training process based on the traditional training process, as shown in Figure 5.

In physical education, it can store different types and meanings of data information and flexibly add new data items according to the individual differences (character traits, training style, strengths, etc.) of each student and the training methods of the teacher. And, it analyzes these data and develops training plans for different student groups. It summarizes the laws of sports training and verifies the experience [18]. As a software platform to assist teaching and training, it can integrate the methods of physiological and biochemical indicator analysis and training content in the books into the software, helping teachers learn professional knowledge in daily training management [19, 20]. It can also rely on its powerful computing capabilities to simulate complex events in reality through calculations based on some basic laws of physics. This surpasses the constraints of hardware conditions in previous training and also surpasses the difficulty of theoretical derivation. With its support, events that are difficult to achieve in

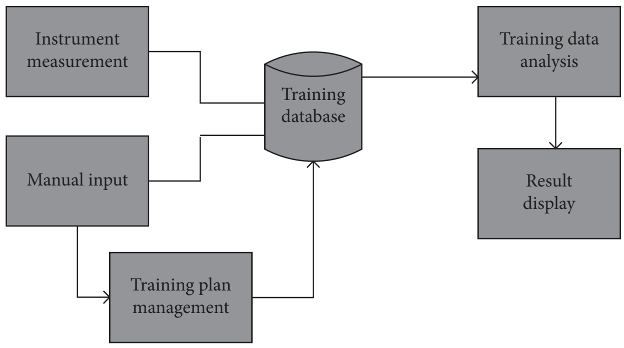


Figure 6: Computer-aided training structure diagram.

reality can be simulated in the computer to obtain results, thereby greatly reducing teaching costs, shortening training time, and quickly breaking through training bottlenecks, so that students' training results can jump out of the local maximum limit [21].

3.4. Computer Technology-Assisted Training System Structure. The structure of the computer-aided training system is composed of storage, analysis, display, and simulation. Its structure is shown in Figure 6.

The data input by the system includes training scores, data recorded by the instrument, and biochemical indicators. The input method is multichannel, which can be manually entered or automatically entered into the database through the network. The system output is mainly based on charts. In addition, the system can be divided into three parts structurally: the first part is the training management subsystem with the database as the core, including data entry and display, training plan management, and is mainly responsible for daily training information management. The second part is an auxiliary decision-making subsystem with the analysis of physiological and biochemical indicators as the core, helping teachers to supervise students' status and decision-making training content. The third part is a subsystem with simulation as the core to help teachers improve training elements [22]. The training management subsystem is the core of the whole system, which mainly corresponds to the historical database, the auxiliary decision-making subsystem corresponds to the inner loop feedback loop, and the simulation subsystem corresponds to the outer loop.

It can be seen from Figure 5 that the inner loop of the computer-aided training process retains the negative feedback loop of the traditional training mode. It uses the BP intelligent algorithm to ensure that it still has the robustness and anti-interference advantages of the traditional training mode.

BP algorithm is one of the most commonly used and effective learning methods. The input is divided into n layers, and the n layers correspond to the dimensions of the sample vector. The specific content of each layer in the input is opposite to the sample vector, which N_j represents the first data in the hidden layer. In this way, the output of the first hidden layer can be expressed as follows [23]:

$$Y_j^1 = \frac{1}{1-\left(\sum_{j=1}^{n} X_i \cdot \omega_{ji}^1\right)}, \quad j = 1, L, N_1. \tag{1}$$

The outputs of the other hidden layers are

$$Y_j^k = \frac{1}{1-\left(\sum_{j=1}^{N_{k-1}} Y_i^{k-1} \cdot \omega_{ji}^k\right)}, \quad k = 2, \Lambda, k; \, j = 1, \Lambda, N_k. \tag{2}$$

If the problem has m desired outputs, the output layer should have m nodes, and the outputs are as follows [24]:

$$Z_j^1 = \frac{1}{1-\left(\sum_{i=1}^{N_k} Y_i^k \cdot \omega_{ji}^0\right)}, \quad j = 1, L, m, \tag{3}$$

where ω_{ij} represents the weight relationship between the jth node in a layer and the ith node in the previous layer. This weight value is obtained through prior training, and this training method is called the BP training method. Initialize the weights(ω_{ij}^h, ω_{ki}^o) and bias(θ_j^h, θ_k^o), add the input variable $X_p = [x_{p1}, x_{p2}, \ldots\ldots x_{pq}]$ to the input unit, and calculate the net input to the hidden layer.

$$\mathrm{net}_{pj}^h = \sum_{i=1}^{q} \omega_{ji}^h x_{pi} + \theta_j^h. \tag{4}$$

The output value is calculated from the sigmoid function defined by the hidden layer [25].

$$f_j^h\left(\mathrm{net}_{pj}^h\right) = \left(1 + e^{-\mathrm{net}_{pj}^h}\right)^{-1}. \tag{5}$$

The output value is as follows [26]:

$$c_{pj} = f_j^h\left(\mathrm{net}_{pj}^h\right). \tag{6}$$

Then, go to the output layer and calculate the net input value of each unit of the output layer.

$$\mathrm{net}_{pk}^o = \sum_{j=1}^{K} \omega_{kj}^o c_{pj} + \theta_k^o. \tag{7}$$

Computing the output, using the same S-function as above, gives the output:

$$O_{pk} = f_k^o\left(\mathrm{net}_{pk}^o\right). \tag{8}$$

Compute the error term for the output cell.

$$\delta_{pk}^o = \left(d_{pk} - o_{pk}\right) \frac{\partial f_k^o\left(\mathrm{net}_{pk}^o\right)}{\partial\left(\mathrm{net}_{pk}^o\right)}. \tag{9}$$

Compute the error term for the hidden unit.

$$\delta_{pj}^h = \frac{\partial f_j^h\left(\mathrm{net}_{pj}^h\right)}{\partial\left(\mathrm{net}_{pj}^h\right)} \sum_k \delta_{pk}^o \omega_{kj}^o. \tag{10}$$

Update the weights of the $(n+1)$ th iteration of the output layer; Ω is a bias value.

$$\omega_{kj}^o(n+1) = \omega_{kj}^o(n) + \alpha \cdot \omega_{kj}^o(n-1) + \eta \delta_{pk}^o c_{pj} + \Omega. \tag{11}$$

Update the weights of the $(n+1)$ th iteration of the hidden layer.

$$\omega_{ji}^{h}(n+1) = \omega_{ji}^{h}(n) + \alpha \cdot \omega_{ji}^{h}(n-1) + \eta\delta_{pj}^{h}x_i + \Omega. \tag{12}$$

The system performs fuzzy reasoning according to the extracted rules. In a given rule, there will be multiple preconditions. The evaluation of fuzzy rules in this paper is expressed as the following formulas:

$$u_{A \bigcup B}(x) = \max\left[u_A(x), u_B(x)\right], \tag{13}$$

$$u_{A\cap B}(x) = \min\left[u_A(x), u_B(x)\right]. \tag{14}$$

In formulas (13) and (14), $u_{A \bigcup B}(x)$ represents a rule, $u_A(x)$ and $u_B(x)$ are "OR" operations, and $u_{A\cap B}(x)$ represents an "AND" operation between the two.

According to the fuzzy judgment, in order to reduce the computational complexity of the system and improve the execution speed of the system, the system adopts the defuzzification operation.

$$F(x) = \frac{\sum_{x=a}^{b} k_i x}{\sum_{x=a}^{b} k_i}. \tag{15}$$

In the actual process of the system operation, a large amount of operating data and many new faults will be generated, which requires the system itself to have a strong learning ability and rule sorting ability. It is difficult to improve the accuracy and learning ability of diagnosis by simply relying on neural network for diagnosis. In this paper, the neural network expert system is used for diagnosis, and the knowledge base of the fault diagnosis system is supplemented to increase the learning ability of the system and the accuracy of diagnosis.

The rules of the neural network expert system are based on the traditional neural network rules, and a certain factor is added, that is, the value of CF, which is represented by cf in the formula. Its determination formula is expressed as follows:

$$\begin{gathered}
cf = \frac{MB(H,E) - M\Delta(H,E)}{1 - \min\left[MB(H,E), M\Delta(H,E)\right]}, \\
MB(H,E) = \begin{cases} 1, & \text{if } P(H) = 1, \\ \dfrac{\max\left[P(H|E), P(H)\right] - P(H)}{\max[1,0] - P(H)}, & \text{otherwise}, \end{cases} \\
MB(H,E) = \begin{cases} 1, & \text{if } P(H) = 0, \\ \dfrac{\min\left[P(H|E), P(H)\right] - P(H)}{\min[1,0] - P(H)}, & \text{otherwise}. \end{cases}
\end{gathered} \tag{16}$$

where $P(E)$ is the prior probability. In neural network expert systems, $P(E)$ is usually 1, and $P(H)$ is the expert probability when hypothesis H is true.

The system uses the optimization theory to select the most effective solution among the various solutions, discusses the characteristics of the best choice for decision-making problems, and constructs a calculation method to find the best solution.

The general form of the optimization problem is as follows [27]:

$$\begin{cases} \min & f(x), \\ \text{s.t.} & x \in X. \end{cases} \tag{17}$$

Here, $X \in R^n$ is the decision variable, $f(x)$ is the objective function, and $X \in R^n$ is the constraint set of the feasible region. If the set is reduced to $X = R^n$, the optimization problem is called an unconstrained optimization problem [28].

$$\min_{\infty \in R^n} f(x). \tag{18}$$

Constrained optimization problems are usually written as follows [29]:

$$\begin{cases} \min & f(x), \\ & c_i(x) = 0, \quad i \in E, \\ \text{s.t.} & \\ & c_i(x) \geq 0, \quad i \in I. \end{cases} \tag{19}$$

Here, E and I are the index sets of equality constraints, respectively. Inequality constraint $c_i(x)$ is the constraint function. When there is at least one nonlinear function in the objective function and constraint function, the problem is called nonlinear programming [30].

If the system optimization enters the local maximum value, it will change the initial value with a certain probability to reoptimize. In simulation training based on optimization theory, local maxima is a metaphor for the stagnant training level of students. Simulation technology can help students to simulate motion results under a new training element. It solves the problem of local maxima at a small cost. Computer-aided training integrates sports scientific research projects scattered in various fields in the past and comprehensively applies it to sports training. This not only promotes the original research in various directions but also improves the training level.

4. Comparative Experiment between Computer Technology-Assisted Training and Traditional Training Mode

In this experiment, students from one or two classes of freshmen are used as the experimental objects. The sample size is 90 people, including 45 in class A and 45 in class B. A uses computer technology to assist training, B uses traditional training mode, and all students have never formally learned bocce.

4.1. Pre-Experimental Student Situation Test. In order to improve the accuracy of this experiment and reduce the error, a statistical survey was carried out on the physical shape and physical quality of the students in the control class and the experimental class who participated in the experiment before the start of the experiment. The statistical results are shown in Tables 2 to 5.

It can be seen from Tables 2 and 3 that Class A and Class B each have 27 boys and 18 girls. In terms of age, the age P

Table 2: Statistical table of differences in the basic physical condition of boys.

Inspection index	Boys in experimental class (27)	Control class boys (27)	T value	P value
Age	18 ± 0.574	18.33 ± 0.379	−0.277	0.749
Height (cm)	171.74 ± 7.324	172.11 ± 6.443	0.531	0.51
Weight (kg)	67 ± 5.639	65.3 ± 5.796	1.656	0.096

Table 3: Statistical table of differences in the basic physical condition of girls.

Inspection index	Boys in experimental class (18)	Control class boys (18)	T value	P value
Age	18.56 ± 0.412	18.71 ± 0.715	0.79	0.404
Height (cm)	158.64 ± 5.419	159.13 ± 5.116	−0.576	0.514
Weight (kg)	52 ± 3.144	52.773.613	−0.254	0.847

Table 4: Statistical table of differences in physical fitness of boys.

Inspection index	Boys in experimental class (27)	Control class boys (27)	T value	P value
Bench press (kg)	30 ± 0.166	29 ± 0.275	−0.277	0.362
Weight-bearing jump (kg)	15 ± 1.347	15 ± 2.396	0.71	0.097
Weight-bearing half-squat jump (kg)	13 ± 0.639	15 ± 0.712	1.33	0.831
Sit-ups	80.163 ± 6.515	76.55 ± 7.21	0.514	0.691
Reverse grip ball throw	30.22 ± 1.77	34.17 ± 3.214	2.357	0.112
Finger ups	11 ± 3.11	9 ± 1.474	1.672	0.34
Arm weights (kg)	20 ± 0.146	22.144 ± 0.551	0.556	0.527
Forearm forward lift (cm)	30 ± 6.44	33.247 ± 5.211	0.814	0.974

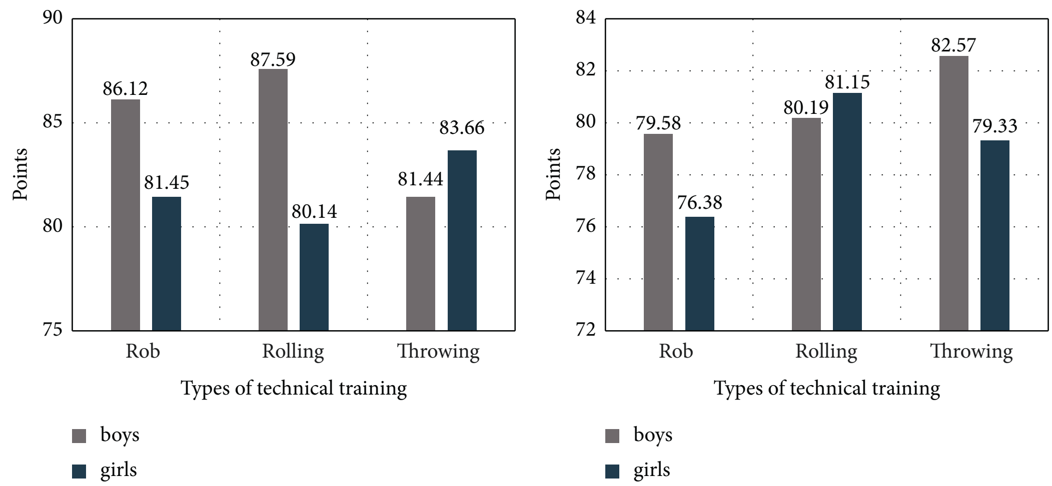
Table 5: Statistical table of differences in physical fitness of girls.

Inspection index	Boys in experimental class (27)	Control class boys (27)	T value	P value
Bench press (kg)	17 ± 0.327	15 ± 1.56	−0.91	0.774
Weight-bearing jump (kg)	5 ± 0.217	5.22 ± 0.612	0.191	0.312
Weight-bearing half-squat jump (kg)	7 ± 0.155	7 ± 0.349	0.146	0.923
Sit-ups	49.741 ± 5.37	52.165 ± 4.221	0.736	0.148
Reverse grip ball throw	17.19 ± 2.14	16.32 ± 1.442	0.227	0.387
Finger ups	1 ± 0.214	0 ± 1.054	1.322	0.961
Arm weights (kg)	9.21 ± 1.411	11 ± 1.244	−0.224	0.741
Forearm forward lift (cm)	37.31 ± 7.14	35.32 ± 3.647	0.822	0.943

value of boys in classes A and B is 0.749, which is greater than 0.05, and the difference is not significant. Therefore, there is no significant difference in the age of boys in the two classes. The age P value of girls in classes A and B is 0.404, which is also greater than 0.05, and the difference is not significant. Therefore, it is considered that there is no significant difference in the age of girls in the two classes. In terms of height, the height P value of boys in classes A and B is 0.51, which is greater than 0.05, and the difference is not significant. Therefore, it is considered that there is no significant difference in the height of boys in the two classes. The height P value of girls in classes A and B is 0.514, which is greater than 0.05, and the difference is not significant. Therefore, it is considered that there is no significant difference in the height of girls in the two classes. In terms of body weight, the weight P value of the boys in classes A and B is 0.096, which is greater than 0.05, and the difference is not significant. Therefore, it is considered that there is no significant difference in the weight of the two boys. The weight P value of girls in classes A and B is 0.847, which is greater than 0.05, and the difference is not significant. Therefore, it is considered that there is no significant difference in the weight of girls in the two classes. Through the above data analysis, it is believed that there is no significant difference in the basic physical conditions of the students in classes A and B.

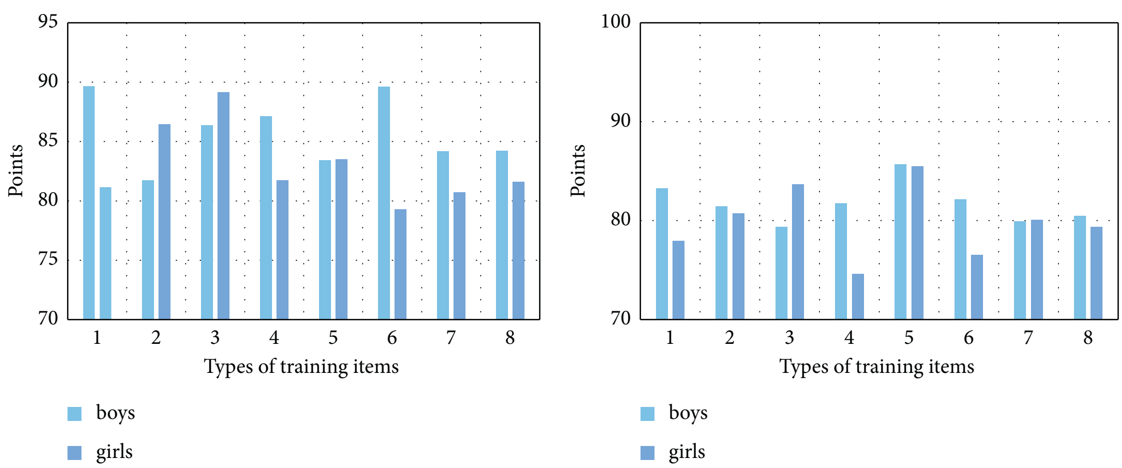
As shown in Tables 4 and 5, in the bench press, weight-bearing take-off, weight-bearing half-squat jump, sit-up, reverse grip ball throwing, finger push-up, arm weight bearing, and forearm forward lift, these 8 physical fitness items test, the P values of the test data for boys in classes A and B were both greater than 0.05. This shows that the physical quality of boys in the two classes is not significantly different. Similarly, the P values of the eight physical fitness items of the girls in classes A and B are all greater than 0.05, indicating that the physical quality of the girls in the two classes is not significantly different.

4.2. Comparative Experiment after Teaching. This paper uses computer technology-assisted teaching and traditional teaching mode to carry out bocce teaching training for



(a) (b)

Figure 7: Statistics of bocce technical training results.



(a) (b)

Figure 8: Statistics of physical fitness training for bocce.

students in classes A and B. The training content includes technical training, physical fitness training, and psychological training.

4.2.1. Technical Training. The technical training assesses students' proficiency in bocce skills. The assessment content mainly includes training on ball skills, rolling skills, and throwing skills. The statistical results of the assessment are shown in Figure 7.

Figure 7(a) shows the technical training results of male and female students under computer technology-assisted teaching.

Figure 7(b) shows the technical training results of male and female students under the traditional teaching mode.

As can be seen from Figure 7, the overall average of boys' technical training scores under computer technology-assisted teaching is 85.05 points, and the overall average of girls' technical training scores is 81.75 points; under the traditional teaching mode, the overall average of boys' technical training scores is 80.78 points, and the overall average of girls' technical training scores is 78.95 points.

4.2.2. Physical Fitness Training. The physical fitness assessment mainly includes 8 major items: bench press, weight-bearing take-off, weight-bearing half-squat jump, sit-up, reverse grip ball throw, finger push-up, arm weight bearing, and forearm forward lift. The statistical results of the assessment results and the comparison before and after the experiment are shown in Figures 8 and 9.

Figure 8(a) shows the physical fitness training results of male and female students under computer technology-assisted teaching.

Figure 8(b) shows the physical fitness training results of male and female students under the traditional teaching mode.

As can be seen from Figure 8, the overall average of boys' physical fitness training scores under computer technology-

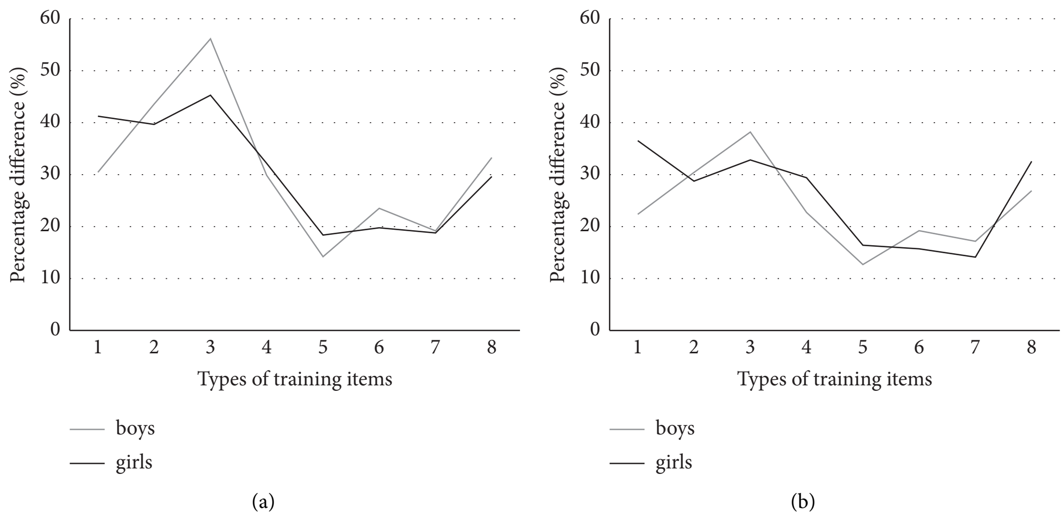


Figure 9: Comparison of physical fitness after the experiment.

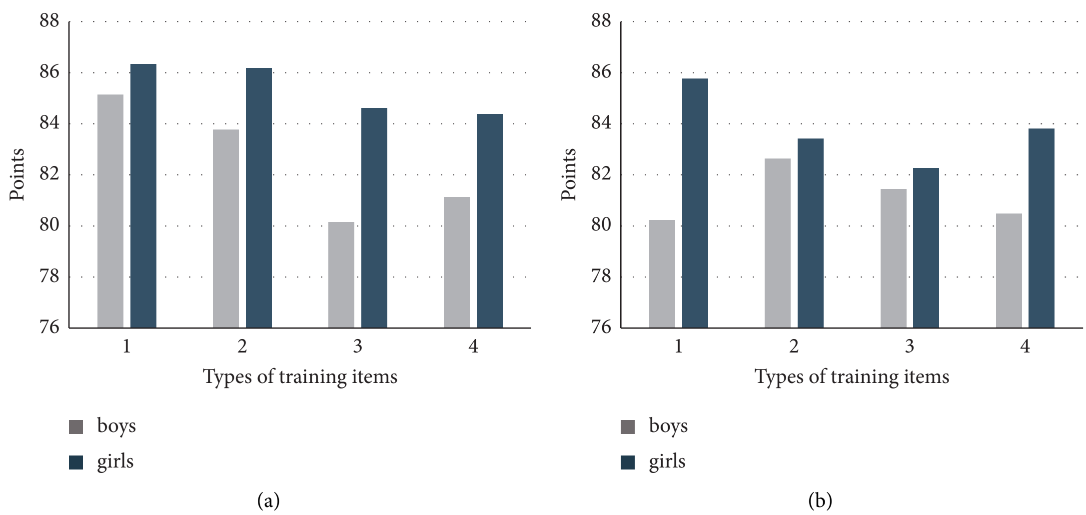


Figure 10: Statistic results of psychological training for bocce.

assisted teaching is 85.80 points, and the overall average of girls' physical fitness training scores is 82.96 points; under the traditional teaching mode, the overall average of boys' physical fitness training scores is 81.77 points, and the overall average of girls' physical fitness training scores is 79.81 points.

Figure 9(a) is a comparison of physical fitness training performance differences between male and female students before and after training under computer-assisted teaching.

Figure 9(b) is a comparison of physical fitness training performance differences between male and female students before and after training under the traditional teaching mode.

It can be seen from Figure 9 that the physical fitness assessment performance of the boys in class A after the computer technology-assisted teaching training was improved by 31.27% compared with that before the training, and the physical fitness assessment performance of the girls in class A was overall increased by 30.60% compared with before the training; the physical fitness test scores of the boys in class B after the traditional teaching training were improved by 23.71% compared with those before the training, and the physical fitness test scores of the girls in class B were increased by 25.78% compared with those before the training.

4.2.3. Mental Quality Training. The assessment contents of psychological quality training are spatial and temporal perception ability, muscle control ability, attention control ability, and interference elimination ability. The statistical results of the assessment results are shown in Figure 10.

Figure 10(a) shows the psychological quality training results of male and female students under computer technology-assisted teaching.

Figure 10(b) shows the psychological quality training results of male and female students under the traditional teaching mode.

It can be seen from Figure 10 that the overall average score of boys' psychological quality training under computer technology-assisted teaching is 82.55 points, and the overall mean of girls' psychological quality training scores is 85.38 points; under the traditional teaching mode, the overall average score of boys' psychological quality training is 81.19 points, and the overall mean of girls' psychological quality training scores is 83.82 points.

5. Discussion

Through the comparative experimental data between computer technology-assisted teaching and traditional teaching, the following conclusions can be drawn:

(1) At the level of technical training, the overall mean of boys' training performance under computer technology-assisted teaching is 4.27 points higher than the overall mean of boys' training results under the traditional teaching mode. The overall mean of girls' training performance is 2.80 points higher than the overall mean of girls' training results under the traditional teaching mode.

(2) In terms of physical quality training, the overall average of boys' training performance under computer-assisted teaching is 4.03 points higher than that of boys under traditional teaching mode. The overall mean of girls' training performance is 3.15 points higher than the overall mean of girls' training results under the traditional teaching mode. And in terms of the difference between the scores before and after training, the students of Class A who have undergone computer technology-assisted training have made more progress.

(3) In terms of psychological quality training, the overall mean of boys' training performance under computer-assisted teaching is 1.36 points higher than that of boys under traditional teaching mode. The overall mean of girls' training performance is 2.06 points higher than the overall mean of girls' training results under the traditional teaching mode.

The whole comparative experimental data shows that under the condition of keeping the same experimental conditions for students in classes A and B, after different modes of teaching and training, both in the mastery of bocce skills and in the physical and mental quality of students, they are all A. Class students performed better. It shows that bocce training based on computer technology can effectively improve the training level of students, thereby promoting the further development of efficient physical education.

6. Conclusion

The continuous update and development of information technology has promoted the process of education modernization, and a new round of reform has begun to appear in education and teaching. Computer technology is widely used in all walks of life and exerts its greatest value. Combining it with the education industry is not only conducive to its own diversified development, but also to the education industry to improve the level of intelligent teaching and enrich teaching methods and means. Bocce training is flexible and strict, and if it only relies on the traditional model for teaching, then the teaching workload of teachers will be relatively large, and the teaching burden will be relatively heavy. The training and teaching of bocce sports based on computer technology can not only improve students' sports training level but also improve their physical and mental health. For teachers, the personalized teaching developed by computer technology for students can effectively reduce the teaching burden of teachers, improve teaching efficiency, and realize the development of physical education informatization. It is believed that with the continuous maturity and improvement of computer technology, physical education teaching in colleges and universities can be further optimized.

Although this paper uses computer technology to carry out a profound study on bocce training in college physical education, there are still many deficiencies. The depth and breadth of this research is not enough. In the process of this research, the selection and acquisition of experimental data were carried out under absolutely ideal conditions, the completeness and validity were not enough, and some interference factors involved in the teaching process were not considered. The actual daily training of students is also restricted by many factors. My academic level research is also limited, and the research on physical education teaching in colleges and universities is still in the preliminary stage. In future work, we will study appropriate teaching methods and means from more perspectives based on the existing technology and level and continuously improve the teaching quality.

Data Availability

The data used to support this study are included in the paper.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] Z. Lv, Y. Han, and A. K. Singh, "Trustworthiness in industrial IoT systems based on artificial intelligence," *IEEE Transactions on Industrial Informatics*, vol. 17, no. 2, pp. 1496–1504, 2020.

[2] J. Y. Hong, H. Ko, L. Mesicek, and M. B. Song, "Cultural intelligence as education contents: exploring the pedagogical aspects of effective functioning in higher education," *Concurrency and Computation: Practice and Experience*, vol. 41, 2019.

[3] S. Zhang, "A research on the construction of computer aided college English teaching system based on ecological teaching," *Revista de la Facultad de Ingenieria*, vol. 32, no. 11, pp. 359–364, 2017.

[4] J. Tan, X. Peng, and L. Yang, "Research on the framework of dance information teaching model based on kinect somatosensory technology," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 15, pp. 84–90, 2017.

[5] J. Lv, "Research on the multimedia teaching mode of the Japanese language teaching based on a computer platform," *Agro Food Industry Hi-Tech*, vol. 28, no. 1, pp. 415–419, 2017.

[6] C. Jing, "Application and research on computer aided technology in the new music teaching method," *IPPTA: Quarterly Journal of Indian Pulp and Paper Technical - A*, vol. 30, no. 7, pp. 301–306, 2018.

[7] Z. Weiwei, "Research on the design of interactive ideological and political teaching system based on computer network," *Revista de la Facultad de Ingenieria*, vol. 32, no. 16, pp. 365–371, 2017.

[8] M. Ran, "Research on the construction and optimization of multi English teaching model based on computer cloud technology," *International Journal for Engineering Modelling*, vol. 31, no. 1, pp. 228–235, 2018.

[9] H. Li, S. Zhang, and J. Shi, "Research and design of intelligent learning system based on recommendation technology," *Control and Intelligent Systems*, vol. 47, no. 1, pp. 43–49, 2019.

[10] S. Wan, L. Qi, X. Xu, C. Tong, and Z. Gu, "Deep learning models for real-time human activity recognition with smartphones," *Mobile Networks and Applications*, vol. 33, pp. 1–13, 2019.

[11] S. Yang, "Experimental data analysis of college English teaching based on computer multimedia technology," *Computer-Aided Design and Applications*, vol. 17, no. S2, pp. 46–56, 2020.

[12] X. Guo and L. Liu, "Research on the teaching method of a public computer course based on constructivism," *Agro Food Industry Hi-Tech*, vol. 28, no. 1, pp. 386–390, 2017.

[13] K. Sasikumar, A. M. Shashidhar, and R. Krithika, "A review on computer and virtual based interventions for autistic children," *Research Journal of Pharmacy and Technology*, vol. 10, no. 8, pp. 2777–2783, 2017.

[14] H. Wu, C. Guang, W. Zhang, and W. Mu, "Multimedia interaction-based computer-aided translation technology in applied English teaching," *Mobile Information Systems*, vol. 2021, no. 5, pp. 1–10, Article ID 5578476, 2021.

[15] M. Hamada and M. Hassan, "An enhanced learning style index: implementation and integration into an intelligent and adaptive e-learning system," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 13, no. 8, p. 4449, 2017.

[16] "Design and preliminary application of regional control and prevention auxiliary information system under the attack of COVID-19 infectious disease," *Chinese Journal of Medical Science Research Management*, vol. 33, no. 00, p. E013, 2020.

[17] M. E. Hankla, C. S. Kohn, and M. P. Normand, "Teaching college students to pour accurately using behavioral skills training: evaluation of the effects of peer modeling," *Behavioral Interventions*, vol. 33, no. 2, pp. 136–149, 2017.

[18] J. Li, "Application of mobile information system based on internet in college physical education classroom teaching," *Mobile Information Systems*, vol. 2021, no. 9, pp. 1–10, Article ID 1481070, 2021.

[19] H. Song and M. Brandt-Pearce, "A 2-D discrete-time model of physical impairments in wavelength-division multiplexing systems," *Journal of Lightwave Technology*, vol. 30, no. 5, pp. 713–726, 2012.

[20] F. Meng, W. Cheng, and J. Wang, "Semi-supervised software defect prediction model based on tri-training," *KSII TRANSACTIONS ON INTERNET AND INFORMATION SYSTEMS*, vol. 15, no. 11, pp. 4028–4042, 2021.

[21] S.-y. Deng and X. Que, "Research on the teaching assessment of students of science and engineering teachers in a university," *Computer Applications in Engineering Education*, vol. 27, no. 1, pp. 5–12, 2019.

[22] N. Zaranis and E. Synodi, "A comparative study on the effectiveness of the computer assisted method and the interactionist approach to teaching geometry shapes to young children," *Education and Information Technologies*, vol. 22, no. 4, pp. 1–17, 2017.

[23] J. Tao, "Research on university education reform and teaching mode innovation based on multimedia technology," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 6, pp. 595–602, 2017.

[24] Z. Wang, "Research on university sports management based on computer data management system," *Revista de la Facultad de Ingenieria*, vol. 32, no. 5, pp. 355–362, 2017.

[25] C. Xu, "Thoughts on the implementation of online and offline hybrid teaching of university computer courses," *Region - Educational Research and Reviews*, vol. 3, no. 2, pp. 1–4, 2021.

[26] J. Tian, "Optimization of embedded mobile teaching model based on network streaming media technology," *Complexity*, vol. 2021, no. 4, pp. 1–10, Article ID 3449338, 2021.

[27] F. Ikechukwunwaosa and T. I. Eze, "The effect of information and communication technology on students' cognitive achievement and interest in metal work technology in technical colleges," *IOSR Journal of Research & Method in Education*, vol. 10, no. 6, pp. 3–10, 2021.

[28] N. Zhao, "Study on ecological teaching method of college English based on computer network environment," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 19, pp. 697–701, 2017.

[29] Z. Zhong, "Design and application of university physical education system based on computer aided system," *IPPTA: Quarterly Journal of Indian Pulp and Paper Technical - A*, vol. 30, no. 8, pp. 681–686, 2018.

[30] Y. Zhang, "An Empirical study on computer network flipped classroom teaching model in college English learning," *Clinica Chimica Acta*, vol. 42, no. 5, pp. 2227–2231, 2017.

Hindawi
Scientific Programming
Volume 2022, Article ID 7219080, 13 pages
https://doi.org/10.1155/2022/7219080

Research Article

Countermeasure of Telecom Network Fraud Investigation Based on Big Data

Tianyu Wang [1] and Bo Yang [2]

[1] *College of Criminal Justice, China University of Political Science and Law, Beijing 100088, China*
[2] *School of Sociology and Political Science, China University of Political Science and Law, Beijing 100088, China*

Correspondence should be addressed to Tianyu Wang; cu204025@cupl.edu.cn

Received 8 January 2022; Revised 23 March 2022; Accepted 1 April 2022; Published 26 May 2022

Academic Editor: Ahmed Farouk

With the diversification of information data in the information age of big data and the integration of network technology and the development of different industries, criminals who carry out telecommunication fraud are also using the technical loopholes existing in the process of integration of big data with different industries as an opportunity to commit crimes. This paper studies the investigation process and countermeasures of telecom network fraud through big data technology. This paper first introduces the characteristics of big data, analyzes the challenge of personal information security under the background of big data, warns people to protect their personal information in the era of big data, puts forward the clustering algorithm based on big data, introduces the concrete steps based on big data clustering algorithm, and then puts forward the specific steps of big data clustering algorithm. The current situation of telecom network fraud is analyzed, and the telecommunication network fraud is clustered based on big data. The experimental results show that, based on the clustering analysis of telecommunication network fraud based on big data, it is found that through the information age of big data, as long as big data are used rationally, it can effectively suppress telecommunications fraud and reduce it by 80%.

1. Introduction

With the advent of the "Internet+" era, the integration of information network technology and traditional industries is deepening, as well as the effective use of information network space and information data resources is profoundly changing the way of human existence. The intersection and integration of network and traditional industries, on the one hand, promotes the overall promotion of society in various fields; this is beneficial for the development of society, and can promote common progress in all fields of society and develop competition. In addition, due to the infringement of computer technology and the diversity and dispersion in the development of big data analysis, the emerging telecommunication fraud crime cases have shown a growing trend; its modus operandi is diverse and complex, seriously threatening the people's sense of wealth and security. Therefore, it is necessary for us to study the basic legal characteristics and investigation measures of telecom fraud crimes under the background of the Internet and the times, and to carry out precision strikes by strengthening the joint, focusing on the police force, forming a joint force, and looking for weaknesses, starting from the change of reconnaissance concept and the promotion of reconnaissance skills. The increasing development of Internet globalization has made the problem of personal information leakage more and more prominent. Protecting personal information is an important basis for safeguarding property rights. On the one hand, we should strengthen the performance of the legal obligations of Internet information service providers to protect information security; on the other hand, we should try our best to protect personal information.

Telecom fraud is a new high-intelligence, contactless crime with a rising crime rate in recent years; its organizational structure is tight and gradually developed into a corporatized business management model, and the modus operandi has reached intelligence and diversification by using high-tech means. Telecommunications fraud has the following characteristics: outstanding noncontact; wide scope of criminal violations; various tricks and quick renovations; the use of electronic high-tech achievements to carry out remote crimes; industrialization development; enterprise operation; and other characteristics. The research on the problem of network fraud and preventive measures can play an effective preventive effect, which is of great practical significance to ensure the development of the network information industry, to ensure the steady growth of the national economy, to maintain the security of personal property, to ensure the social order of the network, and to promote the stability and development of the network society.

According to the research progress at home and abroad, different researchers have also studied the countermeasures of telecom network fraud investigation: In order to solve the information security problem in the process of large-scale data aggregation on the Internet, Zou et al. proposed a privacy protection algorithm (PPA) based on large-scale network data aggregation in view of the deficiencies of existing standard large-scale network data aggregation. Experiments have shown that this algorithm increases time utilization and has excellent reversibility and security in increasing false positive rates, making it more useful [1]. Sliwczynski et al. show the results of time transfer using optical fiber. The results show that operators of telecommunications networks can use this stable fiber link as a reliable source of synchronous signals with better accuracy than those using the most advanced GNSS time receivers [2]. Bouhamida et al. is designed to power remote telecommunications networks (RTNs) with appropriate photovoltaic-based energy generation systems by evaluating their performance and monitoring the associated Smart Microgrid (SMG) to provide safe and energy-efficient energy RTN management [3]. Cerroni et al. focuses on telecommunications software, network virtualization, and software-defined networks. Software and virtualization are increasingly important and transformative in today's telecommunications world, bringing the level of abstraction, decomposition, distribution, scalability, and programmability in network infrastructure and services to unprecedented levels [4]. Chen et al. have developed a fraud analysis and detection system based on real-time message communication, which constitutes one of the most common human-computer interaction services in online social networks, and proposes an integrated platform consisting of various text mining techniques, such as natural language processing, matrix processing, and content analysis through potential semantic models. Then, build an Android-based application to alert you to suspicious log and fraud events. The application is designed to facilitate the emergence of new self-configured integrated computing communication platforms to uninstall and process big data streams from mobile/wireless devices with limited resources in real time [5]. Baccarelli et al. outline the key challenges of managing real-time energy savings from distributed resources available in mobile devices and Internet-connected data centers [6]. The purpose of Mauro et al. is to identify and describe the most prominent areas of research related to "big data" and to propose a comprehensive definition of the term. Mauro et al. analyze a large number of industry and academia papers related to big data and discovers the commonalities between the topics they deal with, and give a new concept for the term, including that big data is an information asset characterized by such high capacity, rate, and complexity that specialized processing techniques and analytical methods are needed to translate it into real value [7]. Zheng et al. have developed ways to combine big data analytics with Internet optimization technologies to improve the quality of the user experience. First, mobile network optimization architecture for big data drivers (BDDs) is provided. Then, it introduces the characteristics of big data collected not only from ordinary user devices but also from the mobile Internet, and discusses some techniques in the process of big data acquisition and analysis from the perspective of network optimization [8]. However, these scholars do not combine big data to analyze the prevention of telecommunication network fraud countermeasures.

The innovation points of this paper are mainly reflected in: (1) introduces the characteristics of big data, and challenges the security of personal information in the context of big data, (2) puts forward the algorithm based on clustering analysis in the context of big data, and analyzes telecom network fraud by using clustering algorithm.

2. Methods on the Investigation of Telecommunication Network Fraud Based on Big Data

2.1. Features of Big Data. Big data analysis involves a large amount of data processing, a lot of kinds, so it is necessary to use the software system within the time limit prescribed by law to process the data of the corresponding data set, and analyze the basis for providing decision-making reference, in order to truly highlight the useful value of big data analysis [9]. It is generally believed that big data mainly has the following four typical characteristics: scale, diversity, high speed, and value. Big data have some characteristics:

(1) The amount of data is large and complex. The amount of information is huge, but the general database system does not have the ability to collect and store information; the kind of big data is rich, the data come from all aspects of society; the sources of information are complex, present in different structures and in different media forms, far beyond the management and analysis that can be accomplished by conventional database systems, which requires a database system with powerful functions to discover the potential value of big data, in order to achieve the effect of big data technology to promote economic development [10]. Big data include structured, semi-structured, and unstructured data, and unstructured data are increasingly becoming a major part of the data.

(2) The processing of data is fast. The demand for computer technology in the era of big data analysis is also getting higher and higher, and because of the

diversity of data analysis, the data analysis path of Figure 1 is particularly important for the timely processing of data analysis; people not only obtain data but also require data information classification, data mining, and also need to analyze the preferences and behavior models of information subjects, so that data information can be quickly and continuously classified and processed. This enables the important reference requirements for real-timeness to be met [11].

(3) Use big data analytics to get valuable economic information. The core of big data analysis is mathematical modeling, the foundation is the actual business, and the result is an automated procedure. The core of big data analysis is not to save or simply manage a large amount of data but to classify these data in a specific way and then obtain some key information. For example, after analyzing the shopping lists of a large number of consumers in a large supermarket, it was found that beer products often appeared on the same shopping list with diapers, and the large supermarkets quickly came to the conclusion that consumers who bought beer products tended to choose diapers more, so when the goods were placed, the beer products and diapers were placed together, which not only made it easier for consumers to pick up goods but also increased the price of these two products [12]. In these cases, supermarkets use the analysis of financial data to obtain important information of real value to their operations, and big data analysis technology is also the same, but its information is larger, and data processing, data analysis methods are more complex.

2.2. Challenges to the Security of Personal Information in the Context of Big Data. The increasing awareness of the protection of personal information of the public is also increasing with the vigorous development of the Internet. This is because with the advent of the information age, it is more and more obvious that many criminals use network technology to infringe on citizens' information [13]. But the background of big data analysis also brings convenience to the transmission and acquisition of bad information and the transmission and acquisition of information that has not been approved by the information subject, and adds great risks to the information security and protection of citizens. The exploration of big data and the development of data analysis technology foundation are changing rapidly; different institutions and individuals are also beginning to compete to seize the information resources, and the background of big data analysis also makes information more and more easy to become a "commodity." Driven by commercial interests will inevitably produce all kinds of enterprises to infringe information for profit phenomenon, so there is a huge security risk of information [14]. Figure 2 shows a few ways for information to be compromised. What are the ways of leaking personal information? Currently, the main ways of leaking personal information are to use Internet search engines to search for personal information, compile it into a book, and sell it to those who need to buy it at a certain price. The development of the information age also has advantages and disadvantages. The era of information sharing can make the society develop more rapidly, but at the same time, information is easily stolen.

In the context of large data, human society is more and more dependent on information; because of the rapid development of science and technology, economic and social development tend to humanize, and the important value of information is more prominent; in the market economy, there is a need for a market, and information will become a "commodity" because in the information age, whoever masters the advanced information technology first will be called the leader of this era. Therefore, under the conditions of a market economy, information is equivalent to commodities. In recent years, CCTV's annual 315th party will report on the time of information leakage caused by different reasons, initially for banks, China Telecom, and other large companies to leak user information, and then slowly developed into mobile phone applications, free WIFI leakage information [15]. Under the background of big data, the collection of personal information is mostly carried out by software, but with the wide application of smartphones, tablet computers, etc., the danger of big data to the security of personal information is even more perennial. However, due to the difference in knowledge level between information holders and fraudsters, in order to reduce the cost of crime, more crimes will occur, making personal information also in trouble.

2.3. Big Data Clustering Algorithms. Because the complex network system formed by computer network information has a large number of nodes and a large scale, and the network system information aggregation method has high time-consuming requirements, the research on the overall discovery algorithm is not suitable for the cluster analysis of network system information. We will start from the perspective of local whole research and provide an information clustering algorithm based on local whole key nodes [16].

In complex networks, the identification of major network nodes not only has practical theoretical research meaning, but also has great practical research value. This theoretical method can also be applied in various fields such as bioinformatics, social, and systems science. Starting with local critical nodes, the entire community structure can be discovered quickly and efficiently [17].

Community evolution tracking is a major part of biological evolution analysis. How do societies where needles appear at different times connect them (i.e., find the successors and successors of the society at a given moment) and how do you determine whether a society is new, dead, or separated or incorporated? These issues are crucial to social networking sites [18]. For societies that appeared at different times, they all have their own meanings. There are two ways of traditional association evolution analysis: point overlap,

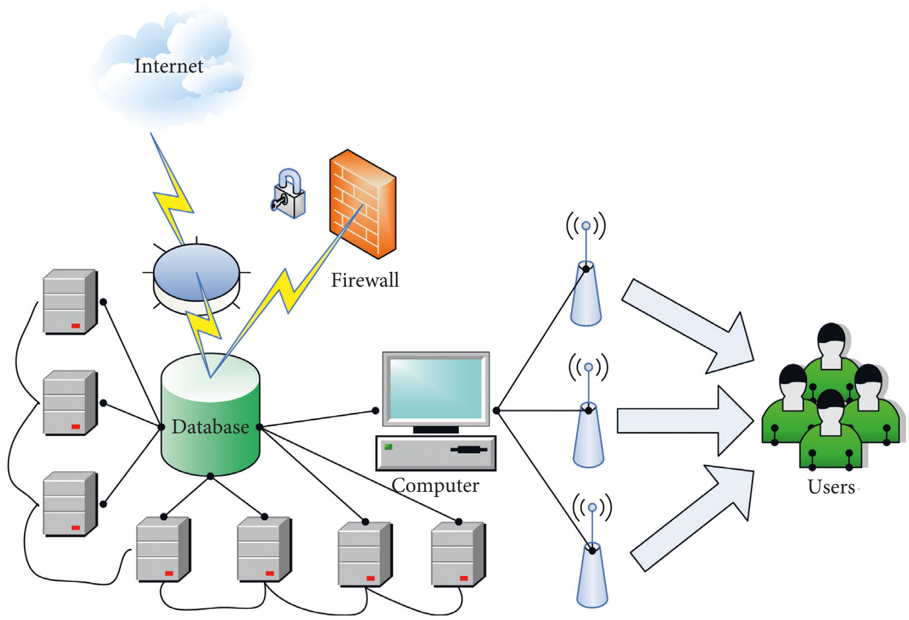


FIGURE 1: Data transmission path.

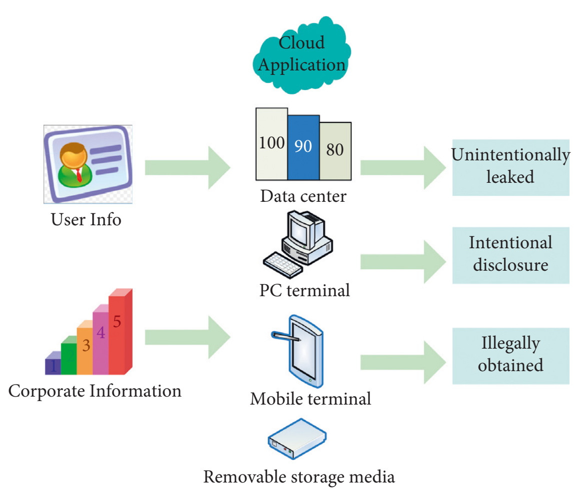


FIGURE 2: Information leakage path.

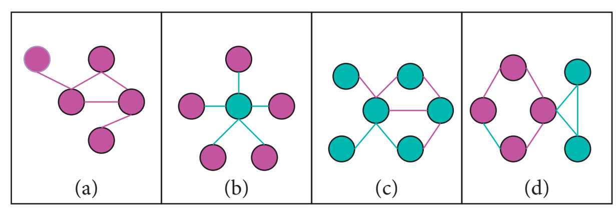


FIGURE 3: Correlation of structures and nodes.

refers to the degree of overlap between points at two moments before and after (generally using the Jaccard coefficient), when a threshold is exceeded, and there is a correlation between two associated points; the structure is similar (i.e. the topology of the edges), but both approaches have drawbacks. Figure 3 (a) and (b) although the node size is the same, their structure is completely different, (a) and (c) although the structure is exactly the same, its nodes have many differences, so it is difficult to say that their relationship is related [19]. Taken together, we feel that (a) and (d) are closer.

2.3.1. Improvements to the Fitness Function. Complex Internet community research methods based on adaptability, such as LFK algorithms, define adaptability functions as

$$j_Q = \frac{l_{\text{in}}^{Q}}{\left(l_{\text{in}}^{Q} + l_{\text{out}}^{Q}\right)^{\varphi}}. \tag{1}$$

At the same time, Q is a divided community that l_{in}^{Q} represents the sum of the number of interconnected edges between each node within social Q, i.e., twice the number of internal edges of the allocated social Q, wherein l_{out}^{Q} is the society Q between nodes connected to the number of edges outside the social Q, φ is a social control parameter, control adjusts the size of the social scale, but according to the experience, the φ value of 1.0–1.6 is more reasonable, the value selected in this article is 1.4. For any node φ D in the network, its adaptability to Community Q is defined as a change in Community Q join and without node D, the amount of change is

$$j_Q^D = j_{Q+D} - j_Q, \tag{2}$$

Among them, j_{Q+D} and j_Q, respectively, represent the adaptability of community $j_{D/Q}$ to node D, not the adaptability of node D to the original community Q. If $j_Q^D > 0$ means that the D node has increased adaptability after joining Community Q, and if so, the $j_Q^D < 0$ D node has joined Community Q the post-adaptation is reduced.

However, according to the adaptability $l_{\text{out}}^{Q} l_{\text{in}}^{Q} l_{\text{out}}^{Q}$ formula, determining whether a node can become a community requires calculations of the original community and the community after joining the node, greatly increasing the computing time [20].

Make the following improvements to the adaptability formula.

Community Q by joining node D is available by (2):

$$j_{Q+D} = \frac{l_{\text{in}}^{Q+D}}{\left(l_{\text{in}}^{Q+D} + l_{\text{out}}^{Q+D}\right)^{\varphi}}. \tag{3}$$

When node D is joined, the edge of the original community Q connection node D becomes the inner edge, l_D^Q and the edge of the node connection node Q is also the inner edge l_{in}^D the edge of node D connected to the original community Q external node becomes the outer edge, l_{out}^D so you get

$$l_{\text{in}}^{Q+D} = l_{\text{in}}^{Q} + l_{\text{in}}^{D} + l_{D}^{Q}, \tag{4}$$

$$l_{\text{out}}^{Q+D} = l_{\text{out}}^{Q} + l_{\text{out}}^{D} - l_{\text{in}}^{D}. \tag{5}$$

You l_D^Q can see that the equivalent of is equal to l_{in}^D, and the equation (4) is

$$l_{\text{in}}^{Q+D} = l_{\text{in}}^{Q} + 2l_{\text{in}}^{D}. \tag{6}$$

The equivalent of the bring-in (5) and (6) bring-in (3) is

$$j_{Q+D} = \frac{l_{\text{in}}^{Q+D} + 2l_{\text{in}}^{D}}{\left(l_{\text{in}}^{Q} + l_{\text{in}}^{D} + l_{\text{out}}^{Q} + l_{\text{out}}^{D}\right)^{\varphi}}. \tag{7}$$

You only need to calculate the sum of the initial community Q once, $l_{\text{in}}^Q l_{\text{out}}^Q$ and each time you add a new node later, you only need to calculate and meet the requirements, $l_{\text{in}}^D l_{\text{out}}^D$ which greatly reduces the computational time consumption [21].

When nodes D, E, and F are added at the same time, you get

$$j_{Q+D+E+F} = \frac{l_{\text{in}}^{Q} + 2l_{\text{in}}^{D} + 2l_{\text{in}}^{E} + 2l_{\text{in}}^{F} + 2l_{E}^{D} + 2l_{F}^{D} + 2l_{E}^{F}}{\left(l_{\text{in}}^{Q} + l_{\text{in}}^{D} + l_{E}^{D} + l_{D}^{F} + l_{\text{in}}^{E} + l_{E}^{D} + l_{E}^{F} + l_{\text{in}}^{F} + l_{D}^{F} + l_{E}^{F} + l_{\text{out}}^{Q} + l_{\text{out}}^{D} + l_{\text{out}}^{E} + l_{\text{out}}^{F} - 2l_{E}^{D} - 2l_{F}^{D} - 2l_{E}^{F}\right)^{\varphi}}. \tag{8}$$

Among them, l_{in}^D is the edge connecting community Q to node D, l_{out}^D is the edge connecting node D to the edge, l_{in}^E is the edge connecting community Q and node E, l_{out}^E is the edge connecting node E to external nodes, l_{in}^F is the edge connecting community Q to node F, l_{out}^F is the edge connecting node F to external nodes, and the l_E^D is the edge connecting node D to node E. Is the edge connected to l_F^D F for D. Is an edge connected to l_E^F E by F. Think of D, E, and F as a community. Q_1 is available.

$$l_{\text{in}}^{Q_1} = l_{E}^{D} + l_{D}^{E} + l_{F}^{D} + l_{D}^{F} + l_{E}^{F} + l_{F}^{E} = 2l_{E}^{D} + 2l_{F}^{E} + 2l_{E}^{F}, \tag{9}$$

$$l_{Q}^{Q_1} = l_{Q}^{D} + l_{Q}^{E} + l_{Q}^{F}, \tag{10}$$

$$\begin{aligned} l_{\text{out}}^{Q_1} &= l_{\text{out}}^{D} + l_{\text{out}}^{E} + l_{\text{out}}^{F} - l_{E}^{D} - l_{D}^{E} - l_{F}^{D} - l_{D}^{F} - l_{E}^{F} - l_{F}^{E} \\ &= l_{\text{out}}^{D} + l_{\text{out}}^{E} + l_{\text{out}}^{F} - 2l_{E}^{D} - 2l_{F}^{D} - 2l_{E}^{F}, \end{aligned} \tag{11}$$

where *is the* $l_{\text{in}}^{Q_1}$ inner edge of Community Q_1, $l_Q^{Q_1}$ the edge connected to Q_1 for Community Q, $l_{\text{out}}^{Q_1}$ and Q_1 Edge connected to outside. Bring-in (9)–(11) bring-in (8) to

$$j_{Q} = \frac{l_{\text{in}}^{Q} + 2l_{Q}^{Q_1} + l_{\text{in}}^{Q_1}}{\left(l_{\text{in}}^{Q} + l_{Q}^{Q_1} + l_{\text{in}}^{Q_1} + l_{\text{out}}^{Q} + l_{\text{out}}^{Q_1}\right)^{\varphi}}. \tag{12}$$

Therefore, the adaptation of Community Q_1 to Community Q can be calculated by using type (12) [22].

2.3.2. Complexity Analysis. The space and time consumption of the algorithm is mainly in the community expansion section, taking the clustered data with size a and the number of categories v as examples. Space complexity is a measure of the amount of storage space temporarily occupied by an algorithm during its execution. Time complexity is a function that qualitatively describes the running time of the algorithm.

(1) Spatial Complexity. The expansion process of spatial structure of each society always follows the serial implementation method, so that the occupied storage space found between societies can be reused, so the total spatial structure complexity is b, of which b is the largest social reserve space structure, the total space cost of the allocation process is v, so the allocation of the last maximum social reserve space structure is $a - i$, where $a - i$ is the number of nodes repeated between societies, the total data storage space is a. So, the spatial complexity is

$$C(a) = b + v + 2a + i. \tag{13}$$

The spatial complexity available by formula (13) is linear P (a).

(2) Time Complexity. Expansion within all communities scales out from within a key community, with data divided into $a - i_2$ and i_2 as nodes where communities overlap. Because a multithreaded strategy is used, assuming the number of threads is b, the time complexity is

$$R(a) = \frac{a + i_2}{b}. \tag{14}$$

In sparse networks, (14) can be equivalent to

$$R(a) = \frac{a}{b}. \tag{15}$$

Available by (15) Time Complexity is linear P (a).

Therefore, the overall spatial complexity of the parallel algorithm is

$$C(a) = b_1 + v_1 + 4a + b + v + i. \tag{16}$$

The overall spatial complexity of the parallel algorithm available by (16) is linear P (a).

Therefore, the overall spatial complexity can be

$$R(a) = \frac{a}{b} + i_1 + \frac{a + i_2}{b}. \tag{17}$$

In sparse networks (17) it can be equivalent to

$$R(a) = 2\frac{a}{b}. \tag{18}$$

Available by formula (18), the overall time complexity of the parallel algorithm is linear P (a).

(3) Evaluation Function Based on Big Data. Nicosia et al. proposed functions to evaluate community structure in the evaluation of post-divided communities.

$$\begin{cases} Z_{ol} = \dfrac{1}{b} \displaystyle\sum_{f=1}^{a_f} \sum_{i,k} \left[J\left(\varphi_{i,f}, \varphi_{k,f}\right) D_{ik} - \dfrac{\gamma_{i\longrightarrow,f}^{\text{out}} x_{i,f}^{\text{out}} \gamma_{k\leftarrow,f}^{\text{in}} x_{k,f}^{\text{in}}}{a}, \right. \\[2em] \gamma_{i\longrightarrow,f}^{\text{out}} = \dfrac{\sum_k J\left(\varphi_{i,f}, \varphi_{k,f}\right)}{a}, \\[2em] \gamma_{k\leftarrow,f}^{\text{in}} = \dfrac{\sum_k J\left(\varphi_{k,f}, \varphi_{i,f}\right)}{a}, \end{cases}$$

$$J\left(\varphi_{i,f}, \varphi_{k,f}\right) = \frac{\sum_k J\left(\varphi_{i,f}, \varphi_{k,f}\right)}{\left(1 + e^{-j\left(\varphi_{i,f}\right)}\right)\left(1 + e^{-j\left(\varphi_{k,f}\right)}\right)},$$
$$j(m) = 2pm - p,\ p \in R, \tag{19}$$

Among them, D is the adjacency matrix of the network. When there are $x_{i,f}^{\text{out}}$ network nodes i, the progress of $x_{k,f}^{\text{in}}$ network nodes k is $\varphi_{i,f}$ and $\varphi_{i,f}$ represents i-to-f, that is, i is the membership factor of f, which is represented by $i\epsilon f$. $\sum_{f=1}^{af} \varphi_{i,f} = 1$ Nicosia et al. defined a more reasonable function through experimental testing, $J(\varphi_{i,f}, \varphi_{k,f})$ to calculate, gave the empirical value of p.30. And, in research papers by Nicosia et al., it has been shown that higher values represent overlapping community structures with a higher degree of modularity.

(4) Specific Steps Based on Big Data Clustering Algorithms. The first step is to randomly select network node D.

The second step is to get the neighbor node for D and calculate the degree of D and D's neighbor node.

In the third step, select the node with the greatest degree, and if D is the node with the greatest degree, then D is the local critical node, otherwise repeat the second step with the node with the highest degree as the initial node, until the initial node is the node with the highest degree [23].

The fourth step is to obtain the local important community by obtaining the large cluster where the local important nodes are located through the parallel strategy discovered by the large cluster.

Step 5, repeat Step 1 until you have acquired the existing local critical community, and include all the data including the normal nodes and the local area critical section community consisting of a large cluster [24].

Step 6, select the largest local key community as the initial community Q1, and expand according to the adaptation formula. If it encounters all points in other local key communities Q2 plus all points in Q1, it observes how their adaptation changes. If the fitness becomes larger, add Q2 to Q1, if the fitness decreases, Q2 will not be added to Q1 until no neighbor nodes belong to Q1.

Step 7, select the larger locally important neighborhoods in the remaining locally important neighborhoods as the starting block, and then repeat step six until you have traversed all the area points [25]. The process is shown in Figure 4.

3. Experimental Results of Telecommunication Network Fraud Investigation Strategy Based on Big Data Analysis

At present, the research on the crime of telecommunication network fraud is based on the most achievements of public security investigation and judicial investigation, and the research focuses mainly on the detection bottleneck and measures of telecommunication network fraud crime, the current situation and the results obtained, the regulation system, the analysis of classic cases, and so on. This article is based on the era of big data Internet, investigating telecommunications network fraud, and gives the corresponding countermeasures; it is expected to make a certain contribution to network security.

3.1. Current Situation of Telecommunications Network Fraud. After research, it is concluded that fraud suspects most often pass through the five types of communication channels to transmit illegal information. As can be seen from Table 1, fraudsters transmit illegal information containing fraudulent content through the use of communication tools or services provided by Internet companies. The most commonly used means of information dissemination for fraud suspects is that 24.01% of fraud information is disseminated using QQ; use classified information websites for dissemination; 5.21% use WeChat for dissemination. QQ and WeChat are both instant messaging services provided by Tencent, and the proportion of services provided is 29.32%.

It can be found that the most commonly impersonated specific groups of suspected fraudsters are, in turn, human resources personnel, public prosecution law, financial practitioners, the closest family members, and shopping network customer service. Other groups that wantonly counterfeit often deceive victims because of the very low cost of identity counterfeiting on the Internet, which makes it impossible to easily identify authenticity. Although most

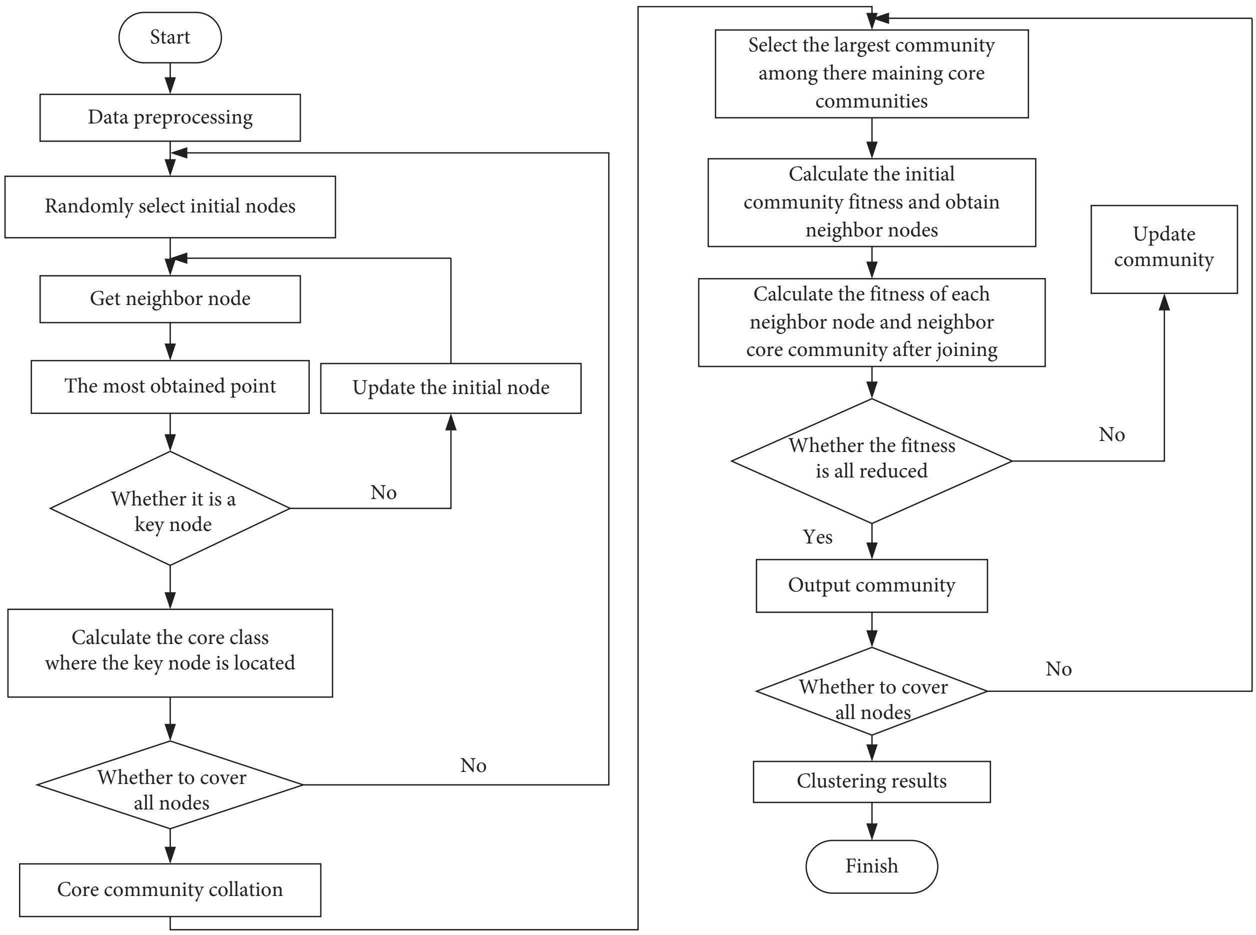


Figure 4: Flow chart of big data clustering algorithm for key communities.

Table 1: Statistics of communication channels and the most frequently impersonated people.

Channel	Count	Percentage	Impersonated group	Count	Percentage
Telephone	469	40.12	Impersonating human resources	219	17.99
QQ	291	24.01	Impersonation of public security law	171	14.01
Classified information website	147	12.49	Impersonating a financial practitioner	156	12.39
SMS	153	11.98	Impersonating someone close	139	11.98
WeChat	59	5.21	Pretend to be a customer service on a shopping site	112	8.89

people can identify the disguise of a fraud suspect, if the fraud suspect keeps sending messages in exchange for trust so as to pass false news to many people; this can successfully deceive some people.

By analyzing the data of the victims of the case filed by the public security organs, it can be found that most of the masses are more vulnerable to the impact of telecommunication network fraud, such as statistics on the sex and age of the victims, as shown in Figure 5.

It can be found from the figure that men aged 21 to 25 and women aged 26 to 30 are the most frequently victims of telecommunications network fraud.

At the same time, the research on banking and telecommunications network fraud also found that due to the manual inspection to complete the risk audit work, the workload and intensity of the bank office supervisors have increased. In recent years, the warning and write-off messages with high operational risk have gradually increased the trend. Since 2016, the main business data information generated is shown in Figure 6.

At present, the business operation risk problem extracted from the commercial bank's massive operation business still depends on manual, random, and sampling methods. In 2019, for example, of the 171.258 million underlying business data generated, only 362,000 were manually sampled and 2310 pieces of risk information were detected. It is not possible to strengthen risk prevention and management through data analysis, and there are many difficulties in the process of risk prevention. Since 2019, four types of operational risk write-off information have been randomly listed as shown in Table 2:

Since 2019, the number of write-offs per month has been irregular, such as the customer information governance check conducted in April 2019, when 107 write-off issues

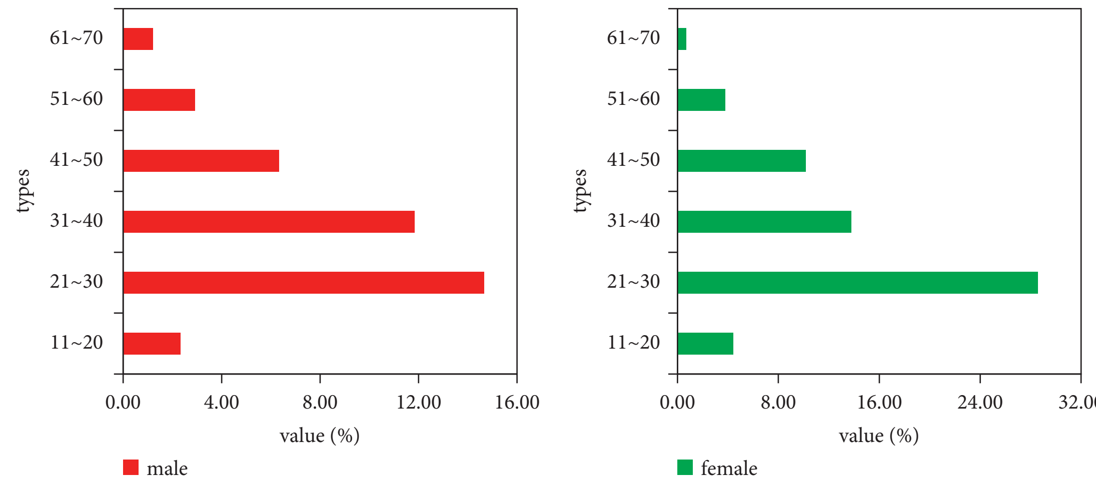


Figure 5: Age-sex ratio of victims.

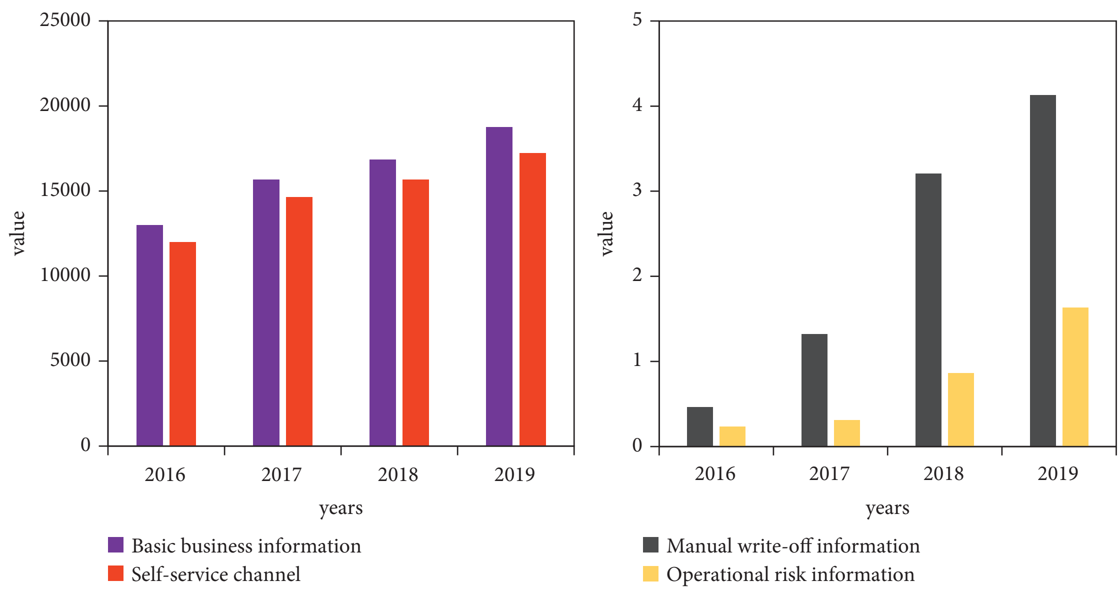


Figure 6: Banking business information in the past four years.

Table 2: Bank operational risk information table.

month	Write-off information	Operational risk information			
		Customer information protection	Real-name account system	Self-service equipment	Online merchants
January	2801	9	16	2	4
February	3298	16	9	5	2
March	3286	41	3	15	6
April	2995	111	10	10	8
May	3001	36	15	129	11
June	2869	9	47	18	5
July	3098	5	129	15	3
August	3168	21	31	10	8
September	3203	19	21	6	5

were identified. Not proportional to other monthly check write-off issues, 131 questions on the real-name system of accounts were verified during the account information rectification work carried out in July 2019; self-service equipment inspections were conducted throughout the city in 2017, with an average of no more than 10 write-offs per month, the number of write-offs reached 130 in May, while online merchants carried out special inspections in June because of a single operating process There has been no increase in write-off issues.

In view of the characteristics of investment risk of banking business data, through clustering analysis technology, the company's operating data are divided into investment market operation risk, business operation risk, and credit risk, and then used to extract the control risk type data in a full sample of business data; the specific analysis process is as follows: Cluster analysis is an exploratory analysis method. Different from discriminant analysis, cluster analysis does not know the classification standards in advance, or even how many categories should be divided into, but will automatically classify according to the characteristics of the sample data.

(1) The initial cluster center is specified. The objects of the business class are used as clustering centers and are recorded as c1, c2, c3 in three categories.
(2) Clustering. For all sample ai of the data set, calculate the largest gap between it and the first three clusters. The main approach is to measure risk characteristics by the type of business that the data contains, and to attribute the risk types closest to the gap to the same class of values.
(3) Update the cluster center. When calculating the sample average, if it is not significantly reflected in the calculation results, re-cluster to arrive at the sample average.
(4) Judgment. If the center of the calculation to each class no longer changes, the iteration ends with a clustering result.
(5) Export the clustering diagram, as shown in Figure 7.

By using clustering analysis, all samples of commercial bank operating financial data can be clustered to obtain the correct risk assessment and analysis information, and provide data support for the next stage of research and analysis management.

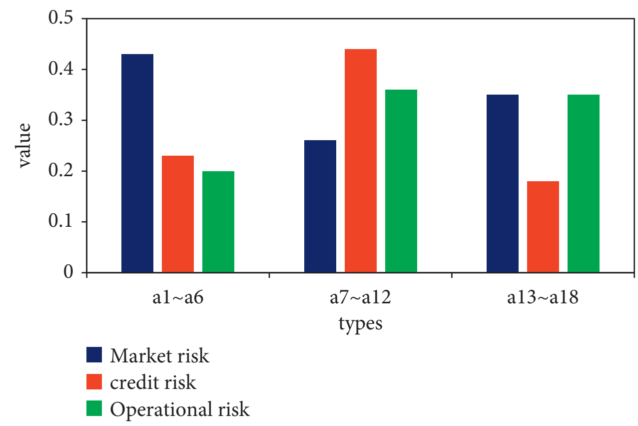


Figure 7: Cluster analysis diagram divided by risk type.

3.2. Clustered Analysis of Telecommunications Network Fraud Based on Big Data. From the experimental results, we can see, as shown in Figure 8, that in the karate data set test, the Q values obtained by the LFK algorithm, the big data clustering algorithm based on local key nodes and the big data clustering algorithm based on local key communities are 0.661 and 0.692 and 0.689, the information clustering algorithm based on the important network nodes of the local region and the information clustering algorithm based on the important community of the local region are higher than the Q value obtained by the LFK algorithm. The time spent is 0.449 s, 0.319 s, and 0.371 s, respectively, and the difference between the first three can be found to be small in time frame. In the process of football data collection testing, the Q values obtained by the three algorithms are 0.631 and 0.701 and 0.698; however, it can also be found that the information clustering algorithm based on local key nodes is more modular than the clustering results obtained according to the information clustering algorithm of local important communities, and the average time limit used by the three is 8.364 s, 7.214 s, and 7.954 s, and the difference between the three average time is much worse than during the karate data set testing process, but still not obvious.

As can be seen from Figure 9, for smaller real network karate and football, the calculations we give are not very different from the original computational time, while the Q values are higher based on the information clustering algorithm of locally important nodes and the information clustering algorithm based on locally important communities. In the CA-HepPH data set test, the Q values obtained by the three algorithms were 0.561 and 0.701 and 0.709, using 639.185 s, 467.832 s, and 502.636 s. It can be found that the large data clustering algorithm using local whole important nodes is more modular than the large data clustering algorithm using local whole important community, and the reduction effect of time consumption is more significant. In the Enron data set, the Q values obtained by the three algorithms are 0.291, 0.509, and 0.569, using 863.205 s, 698.386 s, and 789.306 s, so we can find that the large data clustering algorithm that originally used local area important nodes was more modular than the clustering algorithm obtained by using the local whole important community big data clustering algorithm, and the average time consumption was more significant. In addition, it can be found in the conclusion that for smaller information aggregation, the use of local area important network nodes of big data clustering algorithm and the use of local important society of big data clustering algorithm is not very different, and because of the small data information gathering of important social area is relatively small, the time consumption found in important society is relatively small, occupied by a larger proportion of resources.

The Q values are not much different, as are the smaller data sets and the resulting clustering results are fixed, so the Q values are also relatively fixed. In larger data sets, the time-consuming gap between the two is much larger than in smaller data sets, but it is also within the acceptable range. This is because there are more communities divided in larger data sets and more key communities within the community, so there is more time spent on finding key communities. The Q values of the two are also different, as there are more critical communities per community in larger data sets, so

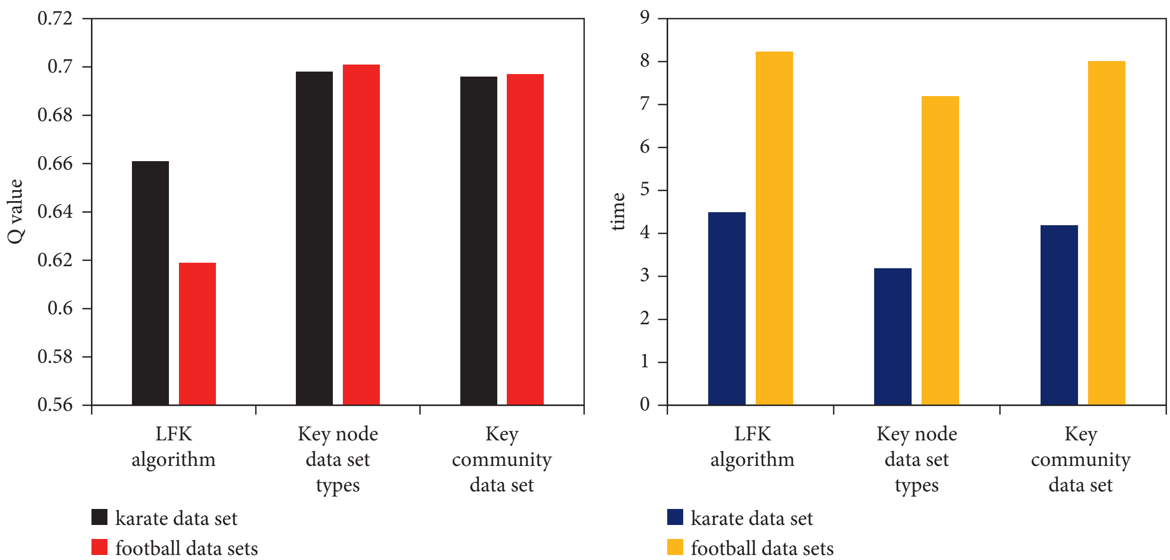


Figure 8: Test results of the three algorithms in the karate and football data sets.

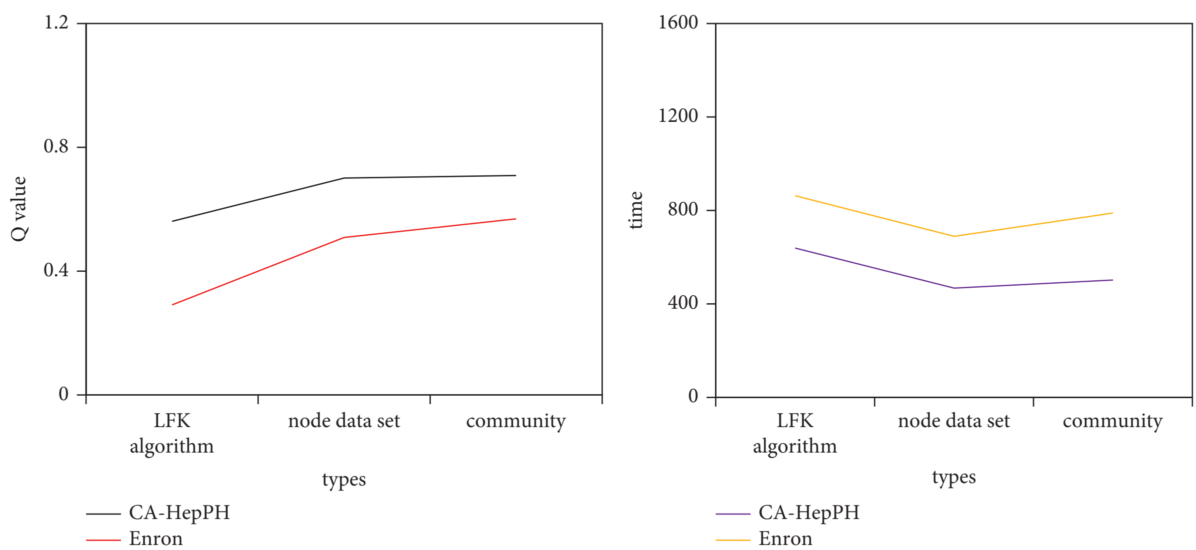


Figure 9: The test results of the three algorithms in the Enron and CA-HepPH data sets.

big data clustering algorithms based on local critical nodes may exclude key communities within some communities, resulting in a decrease in clustering results. Thus, it can be found that for large areas of real network data sets, through the information clustering algorithm based on local important nodes, and through the information clustering algorithm based on local important communities, the results of clustering analysis can enhance the clustering effect and effectively reduce time consumption. At the same time, the time consumrd to adopt the information clustering algorithm of the important nodes of the local whole region is relatively small, while the information clustering algorithm of the important community of the whole local area is higher.

As you can see from Table 3, in the karate data set test, the Q values of single-threaded, two-threaded parallel, and three-thread parallel are 0.692, 0.689 and 0.679, because the data set is small and the classification is fixed, single-thread, two-thread parallel, and three-thread parallel clustering have the same effect. The time spent of 0.398 s, 0.387 s, and 0.491 s shows that the time consumption of the three is not much different. In the football data set test, the Q values of single-threaded, two-threaded parallel, and three-threaded were 0.692 and 0.701, and 0.716, respectively, and you can also see that the clustering effect is not much different, the time used for the three is 8.002 s, 7.501 s, and 6.098 s, the time difference between the three is larger than in the karate data set test, but it is still not obvious.

As you can see from Table 4**,** in smaller real networks, the parallel time consumption of single-threaded, parallel with two threads, and three-threaded is not much different, and the Q values obtained by the three are not much different. In the CA-HepPH data set test, single-threaded, two-threaded parallel, and three-thread parallel Q values were 0.709, 0.753,

Table 3: Test results of parallel strategies in karate and football data sets.

	Karate data set			Football data set		
	Single thread	Two threads in parallel	Three threads in parallel	Single thread	Two threads in parallel	Three threads in parallel
Q value	0.692	0.689	0.679	0.692	0.701	0.716
My T	0.398	0.387	0.491	8.002	7.501	6.098

Table 4: Test results of parallel strategies in CA-HepPH and Enron data sets.

	CA-HepPH data set			Enron data set		
	Single thread	Two threads in parallel	Three threads in parallel	Single thread	Two threads in parallel	Three threads in parallel
Q value	0.709	0.753	0.712	0.569	0.562	0.571
My T	235.561	125.673	101.623	987.382	839.212	789.322

and 0.712, respectively, using a time of 235.561 s, 125.673 s, and 101.623 s; from then on, you can see that the clustering quality of the three is not much different, but the time consumption of multithreaded parallel operations is significantly reduced. In enron data sets, single-threaded, two-thread parallel, and three-thread parallel operations result in Q values of 0.571, 0.559, and 0.567, respectively, using 987.382 s, 8.39.212 s and 789.322 s; the clustering quality of the three is not much different, but the reduction in multithreaded time consumption is more obvious and proportional to the number of threads.

So, Figure 10 is a parallel strategy run efficiency graph, as can be seen from the experiment. For smaller data information integration, the time-consuming difference between multiple threads and single threads is not significant. This is mainly because the data set is small, so the time consumption for clustering is less. Although multithreaded can reduce the loss of information clustering and also improve the time loss of hardware, multithreaded and single-threaded time loss and smaller data sets are not very different.

For larger data sets, however, the reduction in time consumption for multiple threads is even more significant, as the amount of time spent on clustering will account for the bulk of the total time consumed in larger data sets, and the overall time consumption is more significant than the negligible hardware loss caused by the following multithreads. For smaller and larger data sets, however, the Q values derived by double multithreads are not much different from those obtained by single threads, indicating that single multithreads do not degrade the quality of clustered results. Thus, it can be found that in multithreaded technology for large real network data set, it can reduce the time consumption without reducing the quality of clustering, while reducing the time consumption is proportional to the number of threads. Based on the clustering of telecommunication network fraud based on big data, it is found that through the information age of big data, the rational use of big data can effectively curb telecommunications fraud and reduce the occurrence of similar fraud incidents by 80%.

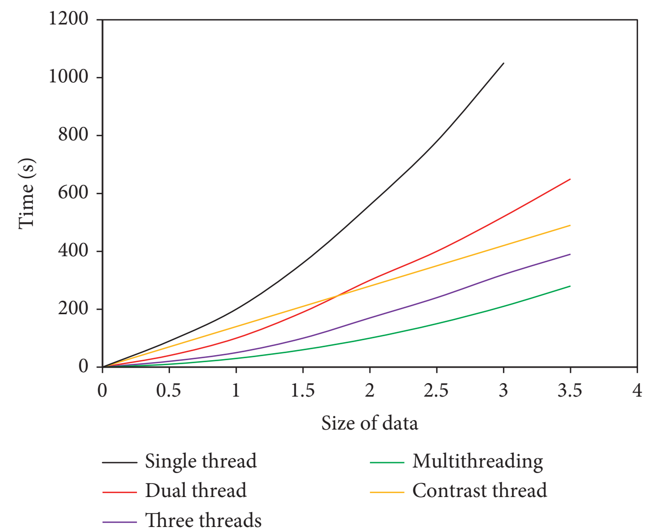


Figure 10: Operational efficiency graph of parallel strategy.

4. Discussion

With the rapid development of Internet society, the problem of network fraud is becoming more and more serious, and it has a great impact on individuals and families, which has seriously damaged the whole network society. At present, the general preventive measures of online fraud are not perfect, and the problem of online fraud is still serious, so it is particularly important to improve the prevention measures of online fraud. Under the background of big data analysis, the important value of information has also begun to be gradually highlighted, which has a positive impact on economic development, scientific and technological progress, and the construction of a harmonious society. If the civil law protection of personal information is still strictly protected, it cannot meet the requirements of the development of the times, nor can the social value of personal information be well found and used. Therefore, the government must adopt unified legislation to recognize people's legitimate use of personal information resources and policy guidance to avoid the risk of personal information rights being infringed, and thus prompt the government to use big data technology to use information resources legally, and thus create a convenient life and a more humane working environment. At the same time, we also need to pay attention to the improvement of the legal assistance channels for victims whose personal information rights and interests have been violated, so as to balance the rational use of information and ensure the proper balance between the interests of both sides. In the case of information leakage, government departments should also take corresponding measures to reduce the leakage of public private information and protect the public from all aspects.

5. Conclusions

In order to achieve the rational use of information, it is necessary to build on the broad trust of human beings in the system, and implementing special legislation on information protection will help human beings realize that they enjoy the right to information and understand their own information, so that they can understand the rational use of information, and can adopt a more open mind to accept and use information brought about by the convenience. It is true that the development of law has the characteristics of lag, especially in today's network, and information light speed developed; no matter how sound the establishment of personal information protection law, it is also possible to completely deviate from the intended direction of development. In this way, information needs to adapt its connotation to the adjustment of the times according to the social development requirements of each era, in order to realize the good relationship between the rational use of information and civil law guarantee, and provide people with a good social atmosphere with a sense of security, so as to achieve a better future of information.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by National Key Research and Development Program of China (2018YFC0831002).

References

[1] Y. Zou, W. He, L. Zhang, J. Ni, and Q. Chen, "Research on privacy protection of large-scale network data aggregation process," *International Journal of Wireless Information Networks*, vol. 26, no. 3, pp. 193–200, 2019.

[2] L. Sliwczynski, P. Krehlik, J. Kolodziej et al., "Fiber-optic time transfer for UTC-traceable synchronization for telecom networks," *IEEE Communications Standards Magazine*, vol. 1, no. 1, pp. 66–73, 2017.

[3] H. A. Bouhamida, S. Ghouali, M. Feham, B. Merabet, and S. Motahhir, "PV energy generation and IoT power consumption for telecom networks in remote areas," *Technology and Economics of Smart Grids and Sustainable Energy*, vol. 6, no. 1, pp. 1–11, 2021.

[4] W. Cerroni, A. Galis, K. Shiomoto, and M. F. Zhani, "Telecom software, network virtualization, and software defined networks," *IEEE Communications Magazine*, vol. 57, no. 10, pp. 40-41, 2019.

[5] L.-C. Chen, C.-L. Hsu, N.-W. Lo, K.-H. Yeh, and P.-H. Lin, "Fraud analysis and detection for real-time messaging communications on social networks," *IEICE Transactions on Information and Systems*, vol. 100, no. 10, pp. 2267–2274, 2017.

[6] E. Baccarelli, N. Cordeschi, A. Mei, M. Panella, M. Shojafar, and J. Stefa, "Energy-efficient dynamic traffic offloading and reconfiguration of networked data centers for big data stream mobile computing: review, challenges, and a case study," *Computers & Chemical Engineering*, vol. 91, no. 2, pp. 182–194, 2016.

[7] A. De Mauro, M. Greco, and M. Grimaldi, "A formal definition of big data based on its essential features," *Library Review*, vol. 65, no. 3, pp. 122–135, 2016.

[8] K. Zheng, Z. Yang, K. Zhang, P. Chatzimisios, K. Yang, and W. Xiang, "Big data-driven optimization for mobile networks toward 5G," *IEEE Network*, vol. 30, no. 1, pp. 44–51, 2016.

[9] M. Zaharia, R. S. Xin, P. Wendell et al., "Apache Spark: a unified engine for big data processing," *Communications of the ACM*, vol. 59, no. 11, pp. 56–65, 2016.

[10] E. Zeydan, E. Bastug, M. Bennis et al., "Big data caching for networking: moving from cloud to edge," *IEEE Communications Magazine*, vol. 54, no. 9, pp. 36–42, 2016.

[11] N.-H. Bao, M. Tornatore, C. U. Martel, and B. Mukherjee, "Fairness-aware degradation based multipath re-provisioning strategy for post-disaster telecom mesh networks," *Journal of Optical Communications and Networking*, vol. 8, no. 6, pp. 441–450, 2016.

[12] J. Wang, Y. Guo, X. Wen, Z. Wang, Z. Li, and M. Tang, "Improving graph-based label propagation algorithm with group partition for fraud detection," *Applied Intelligence*, vol. 50, no. 10, pp. 3291–3300, 2020.

[13] N. K. Bhattacharya, "Telecom services industry -technological evolution and future opportunities," *Gigabit Newsletter*, vol. 25, no. 10, p. 71, 2018.

[14] Y. Zhang, "GroRec: a group-centric intelligent recommender system integrating social, mobile and big data technologies," *IEEE Transactions on Services Computing*, vol. 9, no. 5, pp. 786–795, 2016.

[15] S. J. Leistedt and P. Linkowski, "Fraud, individuals, and networks: a biopsychosocial model of scientific frauds," *Science & Justice*, vol. 56, no. 2, pp. 109–112, 2016.

[16] I. Ahmad, "Revenue assurance & fraud management is a constant journey of discovery and action," *Gigabit Newsletter*, vol. 24, no. 1, pp. 66-67, 2017.

[17] J. Melvin, "Energy infrastructure investments must extend to utilities' telecom networks," *Platts Megawatt Daily*, vol. 23, no. 50, pp. 6-7, 2018.

[18] A. Gent, "Fighting fraud on mobile networks," *Computer Fraud & Security*, vol. 2017, no. 2, pp. 10–13, 2017.

[19] J. Longworth, "VPN: From an obscure network to a widespread solution," *Computer Fraud & Security*, vol. 2018, no. 4, pp. 14-15, 2018.

[20] S. Galzarano, R. Giannantonio, A. Liotta, and G. Fortino, "A task-oriented framework for networked wearable computing," *IEEE Transactions on Automation Science and Engineering*, vol. 13, no. 2, pp. 621–638, 2016.

[21] D. Specht, "The data revolution: big data, open data, data infrastructures and their consequences," *Media, Culture & Society*, vol. 37, no. 7, pp. 1110-1111, 2016.

[22] J. Wang, W. Liu, S. Kumar, and S.-F. Chang, "Learning to hash for indexing big data-a survey," *Proceedings of the IEEE*, vol. 104, no. 1, pp. 34–57, 2016.

[23] E. D. Siew, R. K. Basu, H. Wunsch et al., "Optimizing administrative datasets to examine acute kidney injury in the era of big data: workgroup statement from the 15th ADQI consensus conference," *Canadian Journal of Kidney Health and Disease*, vol. 3, no. 1, pp. 1–12, 2016.

[24] H. Stevens, "Big data, little data, no data: scholarship in the networked world," *Journal of the Association for Information Science & Technology*, vol. 67, no. 3, pp. 751–753, 2016.

[25] Y. Zhang, M. Qiu, C. W. Tsai, M. M. Hassan, and A. Alamri, "Health-CPS: healthcare cyber-physical system assisted by cloud and big data," *IEEE Systems Journal*, vol. 11, no. 1, pp. 88–95, 2017.

Hindawi
Scientific Programming
Volume 2022, Article ID 3603238, 10 pages
https://doi.org/10.1155/2022/3603238

Research Article

Data Fusion Approach for Managing Clinical Data in an Industrial Environment using IoT

Mrunalini Harish Kulkarni,[1] **Chaitanya Kulkarni**,[2] **K. Suresh Babu**,[3] **Saima Ahmed Rahin**,[4] **Shweta Singh**,[5] **and D. Dinesh Kumar**[6]

[1]*Department of Pharmaceutical Chemistry, School of Pharmacy, Vishwakarma University, Pune, India*
[2]*Computer Engineering, VPKBIET, Baramati, India*
[3]*Department of Biochemistry, Symbiosis Medical College for Women, Symbiosis International (Deemed University), Pune, India*
[4]*United International University, Dhaka, Bangladesh*
[5]*Electronics and Communication Department, IES College of Technology, Bhopal, India*
[6]*Department of Electronics and Instrumentation Engineering, St. Joseph's College of Engineering, OMR Road, Chennai 600119, Tamilnadu, India*

Correspondence should be addressed to Mrunalini Harish Kulkarni; mrunalini.kulkarni@vupune.ac.in and Saima Ahmed Rahin; srahin213012@mscse.uiu.ac.bd

Received 22 March 2022; Revised 18 April 2022; Accepted 30 April 2022; Published 23 May 2022

Academic Editor: Ahmed Farouk

As health issues continue to become more prevalent as the population grows, building a public health network is critical for enhancing the overall health quality of the community. This study offers an Internet of Things (IoT) based health care system that can be employed in the context of community medical care industrial areas. The main focus of this research is to develop a disease prediction strategy that could be applied to community health services using theoretical modelling. Using principal component analysis (PCA) and cluster analysis, an artificial bee colony (ABC) creates a nonlinear support vector machine (SVM) classifier pair. Feature-level fusion analysis was performed to detect probable abnormalities. The results of the experiments reveal that the SVM model offers significant benefits in disease prediction. In the SVM illness prediction model, the ABC algorithm has the best parameter optimization effect in terms of accuracy, time, and other factors. The suggested method outperformed the traditional SVM and BP neural network methods by 17.24 percent and 72.41 percent, respectively. It can lower the RMSE and improve assessment indicators like the precision recall rate and the F-measure, demonstrating the method's validity and accuracy. As a result, it is frequently used in community health management, geriatric community monitoring, and clinical medical therapy in an industrial environment.

1. Introduction

With the rapid development of the global economy and the acceleration of life, increasingly, people have been in a subhealth state for a long time and are prone to chronic diseases. Some fatal diseases are hidden, and the early pathological characteristics are not apparent [1]. Obvious symptoms appear in the late stage, and the best treatment period has been missed at this time. With the acceleration of population ageing, health problems are becoming increasingly prominent, so improving community health infrastructure is very effective practical significance to enhance the overall health quality of the whole people. Based on known published research on the key features of data procurement and management in the IoT in conjunction with data fusion and mining technology, this proposed research aims to investigate support vector machine (SVM) for the projection and diagnosis of public health management to address some underlying complications in this field.

To improve the disease prediction ability of the community, medical and health management system to improve people's lives and health is a very worthwhile research topic. Developments in digital health have permitted the acquisition of vast volumes of data in clinics, homes, and communities over the last few decades. Activity and metabolic data were collected using wearable sensors. Contextual information has been given by ambient detectors and wearable cameras. Electronic Patient-Reported Outcomes (ePROs) have been collected using smartphones and tablets. Concurrent with this, improvements in machine learning have created an opportunity to extract therapeutically relevant information from vast datasets. The discipline of rehabilitation medicine is changing as a result of these advancements [2]. In recent years, many scholars at home and abroad have carried out in-depth research in this field and achieved rich results. Wallace et al. [3] realized automatic a-trial for fibrillation and coronary heart disease by analyzing the pulse signal. The authors of [4], based on the Internet of Things technology, builds a health management system, uses a variety of machine learning techniques to analyze a variety of disease data sets, and finds that the random forest has a good prediction effect on a variety of diseases, with reasonable accuracy, but the algorithm has poor robustness. Random forests (RF) are multidecision tree ensemble classifiers that train numerous decision trees randomly. The random forest approach is made up of two steps: a training step that creates numerous decision trees and a testing step that categorizes or estimates an outcome variable depending on an input vector. Theoretically, RF is immune to overfitting and is unaffected by noise or anomalies. Furthermore, by lowering generalization defects, it can produce high-accuracy outcomes. However, on the other hand, RF is more inclined to have an elbow point, implying a steeper gradient with more trees. Furthermore, choosing an insignificant explanatory variable increases the likelihood of each tree being more intricate [5].

The Internet of Things (IoT) healthcare system allows for more efficient monitoring and tracking, which aids in better resource management. IoT can effectively track patients from afar as well as provide emergency assistance, which is incredibly beneficial for cardiac patients. The following are some of the primary benefits of IoT in healthcare:

Cost savings: IoT allows for real-time patient tracking, reducing the number of unwanted medical appointments, hospitalizations, and readmissions.

Treatment that is more effective: it allows doctors to make educated decisions supported by facts and ensures greater transparency.

Quicker disease prognosis: using continuous patient monitoring and actual information, doctors can diagnose disease at an earlier phase, well before symptoms appear.

Providing proactive medical care: continuous health monitoring allows for the provision of proactive medical interventions.

Control over drugs and equipment: in the medical industry, managing pharmaceuticals and hospital instruments is a large concern. These are effectively handled and used by connected devices, leading to lesser expenses.

Reduced error: data provided by IoT devices not only aids in a better judgement call but also guarantees that medical operations run smoothly with minimal errors, loss, and system expenses.

Various healthcare sensors generate a plethora of information in healthcare applications. These disparate devices generate information in a wide range of formats. In most clinical decisions, a single source of data might not even be sufficient to reach an appropriate conclusion. These different types of data can be merged for thorough assessment, which aids in the development of a better knowledge of the condition. For both patients and healthcare practitioners, combining information from multiple sources such as clinical databases, sensory equipment, historical, or textual data is critical [6, 7]. Sensor data acquired, merged, and analyzed are critical for diagnosing and treating patients with severe conditions (such as hypertension and diabetes) as well as tracking and assisting the elderly [8]. Dautov et al. suggested a distributed hierarchical data fusion architecture that combines information from multiple sources at every stage of the IoT taxonomy to generate timely and reliable outcomes [9]. Several diverse and complex data sources can be combined, and the measured data can be processed and transported to a superordinated data-science-oriented cloud solution, according to Neubert et al. on a mobile data collection system; their unique concept emphasizes on the incorporation and fusion of several mobile data sources (mDCS) [10]. The authors of [11] established a similar unified management platform, using the back propagation neural network (BP-NN) to analyze the prevalence of chronic diseases (such as heart disease and diabetes) based on the physiological health data of the elderly, with high accuracy to achieve early detection and early treatment of diseases. An input layer, an implicit layer, and an output layer make up a BP neural network. It is a pedagogical approach based on signal transmission, where the signal is carried in two phases: forward and backward propagation, and it is adept at approximating nonlinear mappings with arbitrary precision. If the output value is near the required value, after the reiterating the cycle, the training is completed [12]. Although the functions of the above health management systems are relatively complete, the models involved in data processing and disease prediction are relatively simple. A single type of disease cannot predict potential conditions based on multiple physiological indicators comprehensively. It needs to be improved in practical applications. A single disease cannot comprehensively forecast potential circumstances based on several physiological signs. It requires improvement in practical applications because most diseases follow their own evolutionary principles, which are frequently accompanied by changes in many physiological markers of the human body. To accurately anticipate disease, this necessitates a large volume of patient data. Authors of [13] used machine learning methods (nearest neighbor method, SVM) to predict chronic obstructive disease staging with high accuracy and specific clinical significance. However, this study did not. The theory is integrated into the

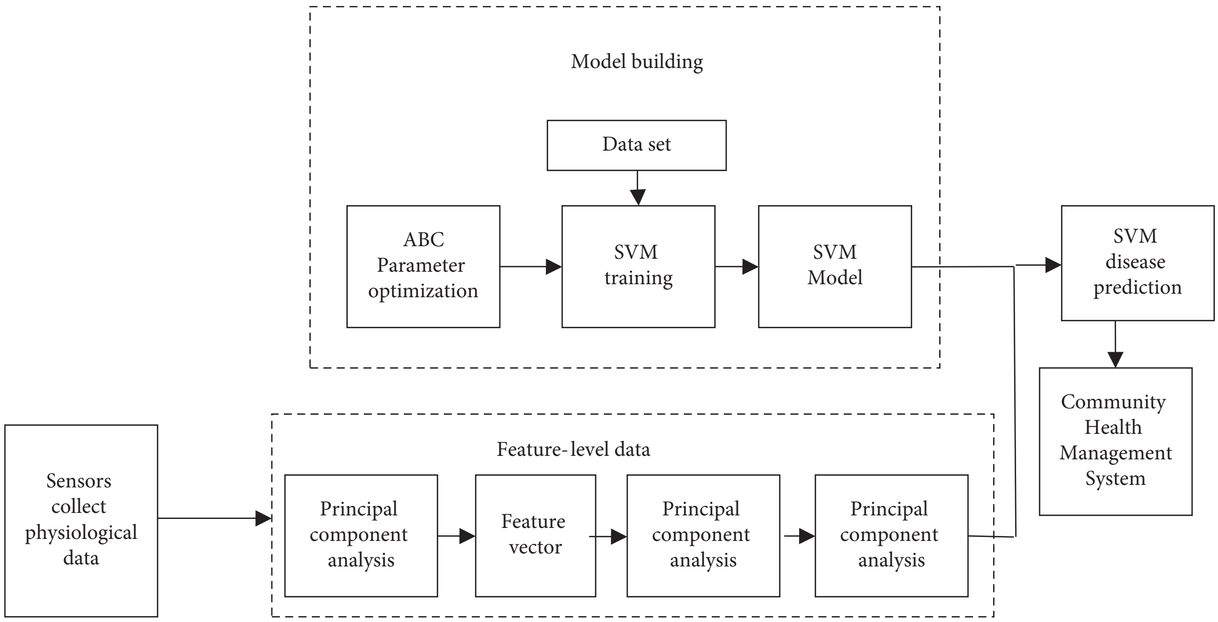


Figure 1: Community disease prediction model.

existing health infrastructure, and the application scenarios are relatively narrow. Author of [14] applied the hybrid machine learning algorithm combined with the Internet of Things technology to predict heart disease, which improved the prediction accuracy to 100%, and the prediction effect was remarkable. Authors of [15] applying machine learning and big data technology to the health care community improve the prediction accuracy. It can be seen that the full use of extensive data analysis technology can analyze the potential disease development law from massive data and then make accurate predictions of the disease [16].

Aiming at some existing problems in this field, based on existing research results, through the research on key technologies of data acquisition [17] and management in the Internet of Things environment, combined with data fusion and mining technology, support vector machine (SVM) is introduced into the disease prediction of community health management. After parameter optimization by the artificial bee colony (ABC) algorithm, the prediction accuracy can be effectively improved. Furthermore, thanks to the self-learning ability of SVM, with the increase of the knowledge base, the disease prediction ability will also be enhanced, which is conducive to promoting the grid construction of community medical care and residents' health management and giving full play to the advantages of community medical care.

The contribution of this paper is in the following features:

(1) An artificial bee colony (ABC) constructs a nonlinear support vector machine (SVM) classifier pair using principal component analysis (PCA) and cluster analysis

(2) To detect potential irregularities, feature-level fusion analysis is used

The rest of the paper follows the following organization: in Section 2, the theoretical aspects of the disease prediction model are being investigated along with parameter optimization; Section 3 is focused on the analysis of the experiments performed, and finally Section 4 concludes the paper.

2. Theoretical Analysis of Disease Prediction

2.1. Community Disease Prediction Model. As shown in Figure 1, the physiological data collected by the sensor extract critical information through the feature-level data fusion method and input the optimized SVM model for disease analysis and prediction, and the final processing results can be fed back to the community health management system.

2.2. Data Feature Extraction. Due to the large amount of data collected by the community IoT terminal, high dimension, and possible unfavorable factors such as accidental errors and noise interference, it is necessary to reduce the size and compress the physiological data before data analysis and remove redundant information and minimize interference to enhance the system efficiency. Principal component analysis (PCA) is a dimensionality reduction algorithm commonly used in data mining [18]. It can use a few linearly independent main components to reflect the most original variables through dimensionality reduction techniques—part of the information [19].

The detection samples with group dimension of nm collected:

$$Y = (y1, y2, y3, \ldots.., yn). \tag{1}$$

In the formula, it is the row and column vector. To uniformly represent different feature dimensions in the sample, it is necessary first to centre the piece.

$$Y^{\sim} = (y_1 - \mu_1, y_2 - \mu_2, \ldots, y_n - \mu_n),$$
$$\mu_i = \frac{1}{m} \sum_{j=1}^{m} y_i^j \left[1, 1, 1, \ldots 1^{U]}\right]; i = 1, 2, ..n. \quad (2)$$

In the formula: μ_i is the mean vector of the physiological data of dimension, and in any size, the sample variance is

$$\mathrm{var}(y_i) = \frac{1}{m} \sum_{i=1}^{m} \left(y_a^{\sim i}\right)^2. \quad (3)$$

When the number of sensors $n \geqslant 2b$, the covariance of dimension and dimension is

$$\mathrm{Cov}(y_a, y_b) = \frac{1}{m} \sum_{i=1}^{m} y_a^{\sim i} y_b^{\sim i}. \quad (4)$$

Let the matrix $D = 1/m\, Y^{\sim U} Y^{\sim}$ $C = 1m\tilde{\ }XT\tilde{\ }X$ be

$$D = \begin{vmatrix} \frac{1}{m} \sum_{i=1}^{m} y_1^{\sim i} y_1^{\sim i} & \ldots.. & \frac{1}{m} \sum_{i=1}^{m} y_1^{\sim i} y_n^{\sim i} \\ \cdots & \cdots & \cdots \\ \frac{1}{m} \sum_{i=1}^{m} y_n^{\sim i} y_1^{\sim i} & \cdots & \frac{1}{m} \sum_{i=1}^{m} y_n^{\sim i} y_n^{\sim i} \end{vmatrix}. \quad (5)$$

C diagonal elements are the sample variances, and the off-diagonal elements are the covariances. The goal of dimensionality reduction optimization is to reduce the dimensional data. For dimension, the method is to select an ortho-normal unit basis. The pairwise covariance of the data under the linear representation of this set of unit orthonormal basis is the variance with the maximum value. That is, it is a symmetric matrix. The matrix's transition matrix after the basis transformation is also diagonal; such a front row is the selected ortho-normal basis. Since it is a real symmetric matrix, the eigenvectors corresponding to its different Eigen values are orthogonal to each other.

$$Q^U DQ = Q^U \frac{1}{m} Y^{\sim U} Y^{\sim} Q = \frac{1}{m}\left(X^U X\right) = \Delta = \begin{bmatrix} \lambda_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \lambda_n \end{bmatrix}. \quad (6)$$

In summary, the ortho-normal basis sought is Q, and the data obtained after dimensionality reduction is X.

PCA problem can be attributed to the similar diagonalization problem of real symmetric matrices, convenient for computer implementation. PCA (principal component analysis) is a dimensionality reduction approach applied frequently in data mining. Through dimensionality reduction techniques—part of the information—it can employ some linearly independent critical components to describe the most original variables. This statistical method condenses a group of interrelated variables into a few dimensions that capture a significant portion of the original variables' variability. These dimensions are known as components, and they have the property of gathering strongly correlated variables inside each component while remaining uncorrelated [20]. After PCA dimensionality reduction, the data dimension is reduced, and the redundant horizontal data is removed from the above. The redundant longitudinal information is reflected in the redundant samples. Removing the redundant samples is also a direction that needs to be optimized. The cluster analysis method [21] is used to find the centre of gravity of the sample data, and the representative samples are extracted. The specific steps are as follows.

(1) Randomly select a sample as the cluster centric.

$$h_1, h_2, \ldots, h_j \in Y. \quad (7)$$

(2) For each example, the calculation criterion of the cluster centre $d(i)$ is

$$d^i = \mathrm{argmin}\left\|y^i - h_j\right\|^2. \quad (8)$$

(3) Recalculate the centric

$$h_j = \frac{\sum_{i=1}^{n} \left\{d^i = j\right\} y^i}{\sum_{i=1}^{n} \left\{d^i = j\right\}}. \quad (9)$$

Repeat the above three steps to divide the samples into clusters with different interclass distances L according to the distribution characteristics of the data, then select the pieces closer to the cluster centre according to specific criteria, and discard some redundant sample points on the edge of the cluster. After the data is preprocessed above, the dimensions and the number of samples are reduced, the system overhead and computational complexity are reduced, and the processing efficiency of subsequent work is improved.

2.3. SVM Disease Classification Model. SVM is a collection of related supervised learning methods for classification and regression in diagnosing diseases. SVM maximizes the geometric margin while decreasing the empirical classification error. As a result, SVM stands for maximum margin classifier. SVM is a fundamental approach based on statistical learning theory's ensured risk boundaries, often known as the structural risk minimization principle. The kernel approach allows SVMs to do nonlinear classification effectively by projecting their inputs into feature spaces. The kernel trick enables the classifier to be built sans defining the feature space directly [22]. SVM is a generalized classifier that performs multivariate sensor data classification according to supervised learning, supporting linear and nonlinear types. Its decision boundary is to solve the maximum margin hyperplane for the learning samples [23]. The main idea is to use the maximum margin hyperplane. Correctly classify the physiological data containing different disease information according to the characteristics of the disease type to achieve the effect of disease prediction [24, 25]. Assuming that there are only two different disease types in the sample space, the sensor feature data can be expressed as

$$U = \{(x1, y1), (x2, y2), \ldots, (xn, yn)\}; xn \in X. \tag{10}$$

In the formula, $yn \in \{+1, -1\}$ is the disease type label. Let z^U be the average vector and c is the intercept, then these two types of samples with different disease information can be obtained from the hyperplane.

$$Z^U x + c. \tag{11}$$

Divide it into two and find the distance from any sample point to the hyperplane:

$$e = \frac{Z^U x + c}{\|Z\|}. \tag{12}$$

Let the point above the hyperplane correspond to the disease label as $y_n = 1$, and the point below corresponds to $y_n = 1$. Define the function interval as

$$\hat{s} = \frac{y_i Z^U x + c}{\|Z\|} = \frac{s}{\|Z\|}; i = 1, 2, \ldots, n. \tag{13}$$

SVM optimization problem: it is necessary to find the hyperplane determined by Z, c so that the distance between the nearest support vector and this hyper plane is as considerable as possible, that is,

$$\begin{gathered} \min_{Z,c}; \text{s.t}\, \hat{s}\} = \min_{Z,c}\left(\frac{s}{\|Z\|}\right), \\ \text{s.t}\, y_i \left(Z_0 x_i + c_o\right) \geq s; i = 1, 2, \ldots, n. \end{gathered} \tag{14}$$

To maximize the interval, it is only necessary to maximize $\|Z\|^{-1}$, which is equivalent to

To minimize $\|W\|^{-1}$, let $Z = Z_0 s$; $c = c_0$, (14) is equivalent to

$$\min_{Z,c}\left(\frac{1}{2}\|Z\|^2\right) \text{s.t}\, y_i \left(Z_0 x_i + c_o\right) \geq 1; i = 1, 2, \ldots, n. \tag{15}$$

According to the transformation of the Lagrange multiplier method, the dual problem of equation (15) is obtained. After solving αi, we can get the optimal hyperplane

$$f(x) = z_0^U x + c_0 = \sum_{i=1}^{m} \alpha_i y_i x_i^U x + c_0. \tag{16}$$

Equations (15) and (16) are established on the premise that the KKT (Karush–Kuhn–Tucker) condition is satisfied.

The above is the linear solution process of the SVM disease prediction model. However, in practice, the physiological data collected by multisensors are generally nonlinearly distributed, and there may be multiple disease types in the sample. For such nonlinear models, the kernel function (kernel function) maps the sample space to the kernel space for solving [24], that is, replace the part in equation (16) with $l(x_i; x_j)$.

2.4. Parameter Optimization of Disease Prediction Models. The key to affecting the prediction effect of the SVM classifier is to select an appropriate kernel function model and its corresponding parameters according to the characteristics of the physiological data. The Gaussian kernel function (RBF) is popular in machine learning, and its performance mainly depends on c,g parameter [26]. Among them is the penalty coefficient. If the value of this parameter is too high, overfitting may quickly occur; otherwise, underfitting will quickly occur, resulting in poor data generalization ability; the RBF form is

$$l_{RBF}\left(x_i, x_j\right) = \exp\left|-\frac{e\left(x_i, x_j\right)^2}{2\sigma^2}\right| = \exp\left[-\Upsilon c\left(x_i, x_j\right)^2\right]. \tag{17}$$

The h parameter determines the distribution of the original data mapped to the new feature space, which is negatively correlated with the number of support vectors, which directly affects the algorithm's speed. To find the optimal parameter d, h, you can use the ABC algorithm for parameter optimization [27]. This algorithm is a parameter optimization algorithm proposed by Karaboga in 2005 to solve the multivariable parameter optimization problem [28]. It has been widely used in many fields, including image processing and numerical optimization. [26, 29], and the algorithm performs better than other heuristic algorithms such as particle swarm optimization (PSO) algorithm and genetic algorithm (GA) in multidimensional data processing [26] ABCSVM is the disease prediction process. Ant colony optimization (ACO) is a probability-based optimization approach that is intended to solve computational problems and discover the ideal route using graphs. ACO is capable of working more proficiently and precisely than GA, attributed to the reason that determining the optimal path involves less calculation time and iterations. Furthermore, the accuracy of ACO is demonstrated by the optimal path discovered in each time run [30]. ACO has the ability to cluster and construct routes, and PSO is simple to implement. However, due to its poor exploration, PSO has issues with parameter selection [31]. First, according to the characteristics of physiological data d; the highest sum combination ensures that the model works with the optimized parameters to improve the accuracy of disease classification prediction.

3. Experimental Analyses

To verify the validity and accuracy of the method in this paper, the experimental data were used the physical examination monitoring data of 5 061 cases in a community in Shanghai in 2017, covering residents of all ages from 16 to 90 years old. Some experimental data are shown in Table 1. For the convenience of discussion, in the experiment, four common diseases, including renal function impairment, dyslipidemia, metabolic syndrome, and diabetic nephropathy, were selected as the research objects, and the validity of the diagnostic prediction model was verified.

Table 1: Physiological datasets used in the experiment (partial samples).

SN	G	AGE	CREA	UA	APOA	APOB	GLU	LDL	UREA	CH
1	F	65	66	261	1.34	0.79	4.9	2.92	5.7	4.81
2	M	61	45	282	1.25	0.76	4.7	3.18	5.4	4.86
3	F	59	63	419	1.37	0.97	4.6	3.04	4.9	3.92
4	M	63	60	274	1.46	1.04	10.7	2.21	4.8	4.79
5	F	76	89	294	1.38	0.9	4.7	1.05	6.5	4.3
6	M	65	69	401	1.57	0.66	4.7	2.47	5.8	4.79
...	...	...	...	...	...	...	...	...	...	...

3.1. Sample Encoding. The sample coding requirements can conveniently represent the type of disease and reasonably determine the kind of disease 24 = 16 and its severity in the sample according to the coding value. Considering that there may be many different diseases in the same model, to facilitate the computer for processing, we first use 4-bit binary code for the disease type (B1~B4, respectively, represent diabetic nephropathy, metabolic syndrome, dyslipidemia, and renal function damage). For standard samples, the code value is set to 0×0. The above code can indicate the possibility of disease (i.e., hexadecimal 0×0~0×F), and the sample codes of 5 representative disease combinations are shown in Table 2.

After removing outliers from the original data (missing critical data is considered outliers), we use the *t*-SNE dimensionality reduction toolbox to map the 8-dimensional raw data to the 2-dimensional space visualization. In the figure, there are a total of 10 types, colors represent ten different disease combinations *D*, respectively, blue represents a standard sample (i.e., the code value is 0×0), and red represents that the model suffers from the four diseases in Table 2 at the same time (i.e., the coded value is 0×0).

The coding value is 0×F. The gradient process of the color bar from blue to red from top to bottom corresponds to the gradual increase in the types of disease suffered by the sample. It can also be intuitively understood that the warmer the color, the worse the health status of the model.

3.2. Data Feature Extraction. Take the 8-dimensional data of CRE~CH in Table 1 and standardize it according to formula (2) and then carry out PCA processing according to procedures (3)~(6) to obtain the characteristic principal component N of the physiological index and its contribution rate as shown in Figure 2 with Table 3. The curve represents the cumulative contribution rate of the first *k* main components $R = \sum_{k=1}^{N} r_k\,(k = 1, 2, 3, \ldots, n)$ is the contribution rate of the first principal component. Current principal components when the cumulative contribution rate of the parts is greater than the set value, it can be considered that the information contained in the first *k* main components is sufficient to represent the entire set of data. The calculation shows that the contribution rate of the first six principal components reaches 97.2%. Central component 6 can contain most of the information about the sample.

After PCA processing, the data dimension is reduced to 6 sizes, and then crucial samples are screened out through cluster analysis, further improving the ant interference ability. The cluster analysis dendrogram of sample *S* is shown in Figure 3 with Table 4. To express the distribution law of sample data more intuitively, only 30 leaf nodes are shown here (one leaf node may correspond to multiple sample points). In the dendrogram, it can be observed that, according to the sample, the data distribution features can be subdivided into 5 clusters in total.

The clustering results are visualized by t-SNE dimensionality reduction. Different symbols in the figure represent

Table 2: Sample codes for 5 representative disease combinations.

Sample encoding	Disease type			
	B4	B3	B2	B1
0*0	N	N	N	N
0*1	N	N	N	Y
0*2	N	N	Y	Y
0*4	N	Y	N	N
0*8	Y	N	N	N

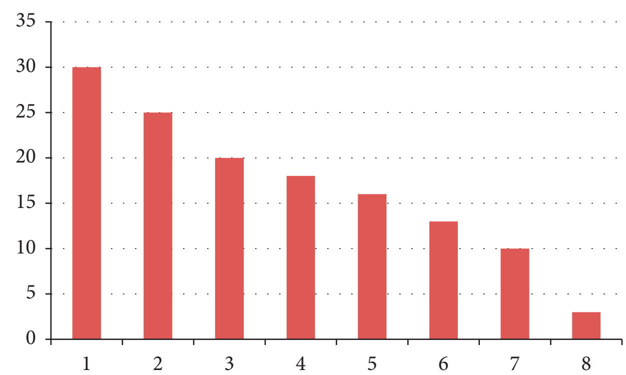


Figure 2: Principal components and contribution rates in physiological indicators.

Table 3: Principal components and their contribution rates in physiological indicators.

Serial	*R*
1	30
2	25
3	20
4	18
5	16
6	13
7	10
8	3

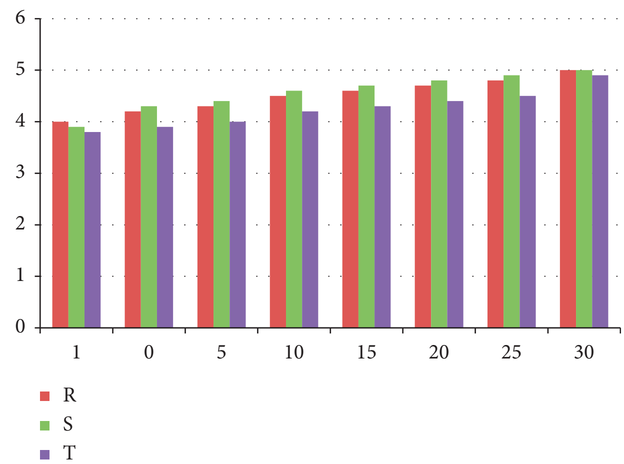


Figure 3: Cluster analysis dendrogram for samples.

Table 4: Cluster analysis dendrogram for samples.

Serial	R	S	T
1	4	3.9	3.8
0	4.2	4.3	3.9
5	4.3	4.4	4
10	4.5	4.6	4.2
15	4.6	4.7	4.3
20	4.7	4.8	4.4
25	4.8	4.9	4.5
30	5	5	4.9

clusters with other characteristics. The distance from the cluster centre d_i $(i = 1, 2,...,5)$ is the cluster radius of s_i $(i = 1, 2,...,5)$, and the sample points located within the radius are selected as the follow-up experimental data and will not be in the cluster. Points within the class radius are regarded as redundant and discarded, and 1 598 sets of physiological data are finally selected.

In the above five types of samples, 98% of the data of every kind of sample are randomly selected as the training sample $S1$, and the remaining 2% of the data are used as the test sample $S2$ to test the model, and finally, $S1 = 1\,569$ group and $S2 = 29$ groups.

3.3. Analysis of Disease Diagnosis Results. To more intuitively reflect the superiority of SVM in disease analysis, the BP-NN prediction is used as a comparison, and the results are shown in Figure 4 and Table 5. In Figure 4, the three curves represent the prediction effect of BP-NN and the prediction of the SVM model. It can be seen from the comparison that the prediction effect of the SVM model is the best, and the accuracy rate can reach 75 : 86% (22 = 29). In contrast, the disease prediction effect of BP-NN is poor, and the accuracy ratio is only 20 : 69% (6 = 29). Figure 5 and Table 6 shows the root mean square error (RMSE) of the top n predicted values for the two forecasting algorithms.

$$e_{\mathrm{RMSE}} = \left(\frac{1}{2}\left(\hat{x} - x\right)^2\right)^{1/2}. \tag{18}$$

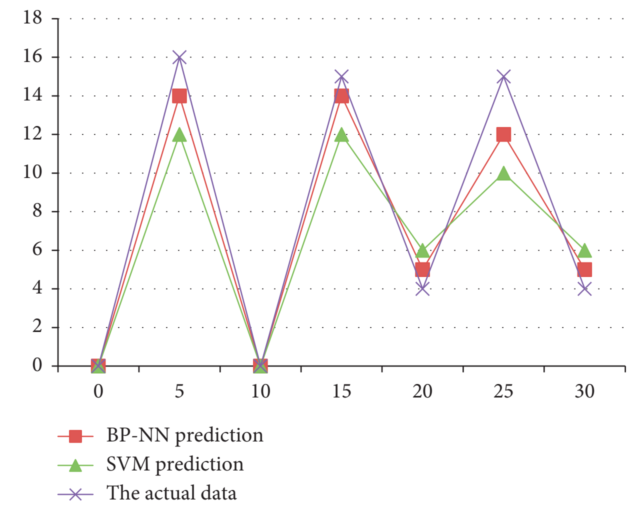


Figure 4: Comparison of the prediction effects.

Table 5: Comparison of the prediction effects of the three diagnostic models.

Serial	BP-NN prediction	SVM prediction	The actual data
0	0	0	0
5	14	12	16
10	0	0	0
15	14	12	15
20	5	6	4
25	12	10	15
30	5	6	4

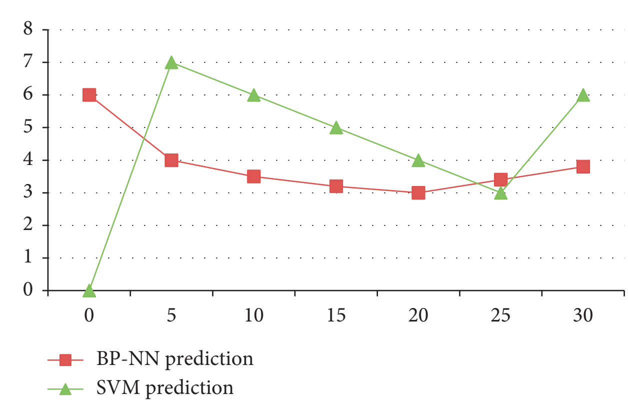


Figure 5: RMSE curves.

Here, $\hat{x}$ and x are the predicted and actual values, respectively. It can be seen from Figure 6 that, in the previous sample, the eRMSE of the SVM model is 0 because the disease type code output by the model in the subsequent false detection is different from the actual value the significant difference in disease type coding leads to a higher RMSE. Still, the performance of this situation in the latter samples is not much different from that of BPNN, which also reflects the importance of SVM parameter optimization from the side. Due to the fuzzy mapping of BP-NN, however, SVM can output discrete and definite value ranges and can accurately output specific sample codes.

Table 6: RMSE curves.

Serial	BP-NN prediction	SVM prediction
0	6	0
5	4	7
10	3.5	6
15	3.2	5
20	3	4
25	3.4	3
30	3.8	6

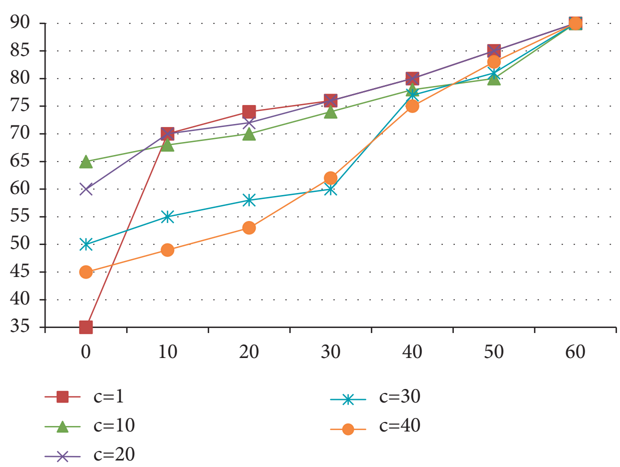


Figure 6: The influence of c,g parameters on the prediction accuracy of ABC-SVM.

Table 7: Accuracy of c,g parameters of ABC-SVM.

Serial	$c = 1$	$c = 10$	$c = 20$	$c = 30$	$c = 40$
0	35	65	60	50	45
10	70	68	70	55	49
20	74	70	72	58	53
30	76	74	76	60	62
40	80	78	80	77	75
50	85	80	85	81	83
60	90	90	90	90	90

The influence of different c,g parameters on the SVM disease prediction model is shown in Figure 6 and Table 7. It can be seen from the figure that, for the same g parameter, the accuracy rate η of the prediction result is almost unrelated to the value of the c parameter

From the perspective of the entire interval, for the same parameter, the accuracy rate tends to increase with the increase of the parameter, and there may be multiple extreme points in the curve, so how to find the globally optimal powerful moment is the key to model optimization.

The prediction effect of the SVM disease prediction model after optimization by different optimization algorithms is shown in Figure 7 and Table 8. It can be seen from the figure that the disease prediction effect of the PSO algorithm optimization model (PSO optimization, PSO-OPT) is the worst. The total accuracy rate is only 13 : 79%, the GA algorithm optimization model (GA optimization, GA-OPT) has a slightly better effect, the accuracy rate is 79 : 31%, the ABC algorithm (ABC optimization, ABC-OPT) has the best optimization effect, the accuracy rate can accurately predict the disease types of 93 : 10% of the samples, with the shortest time t and the highest efficiency. The final results are shown in Table 9.

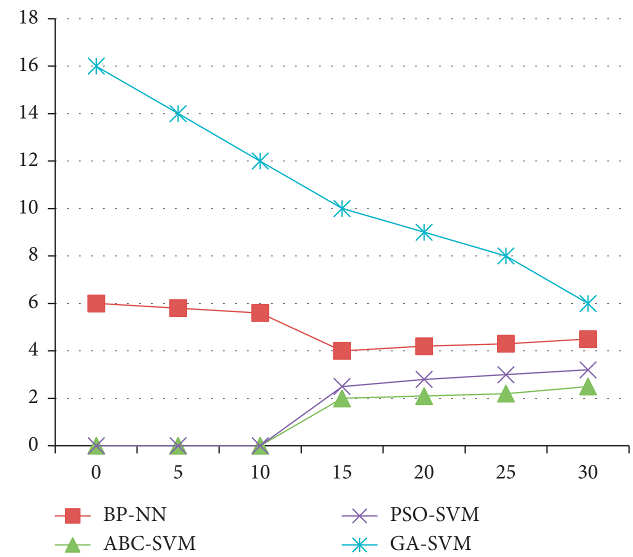


Figure 7: Comparison of the optimization effects of the three optimization algorithms.

Table 8: Comparison of the optimization effects of the three optimization algorithms.

Serial	BP-NN	ABC-SVM	PSO-SVM	GA-SVM
0	6	0	0	16
5	5.8	0	0	14
10	5.6	0	0	12
15	4	2	2.5	10
20	4.2	2.1	2.8	9
25	4.3	2.2	3	8
30	4.5	2.5	3.2	6

$$Q = \mathrm{Dr} = (\mathrm{Dr} + De),$$

$$S = \frac{Dr}{Dt}, \tag{19}$$

$$G = \frac{2QS}{(S+Q)}.$$

The RMSE comparison of different disease prediction methods is shown in Figure 7. It can be seen from the figure that the optimized SVM model has the lowest eRMSE and apparent advantages.

The prediction effects of different optimization algorithms for different disease combinations are compared in terms of the precision P of disease prediction, the recall rate R, and the F metric $F3$.

Let DP denote the set of disease prediction results in the test sample, DR indicates the actual disease condition in the test sample, Dr is the number of sample codes in DP\DR be

Table 9: Parameters for optimization algorithms.

Optimization algorithm	c	g	t/s	η
GA-OPT	89 : 72	12 : 36	555 : 70	79 : 31% (23 = 29)
PSO-OPT	40 : 69	0.720138889	872 : 06 : 00	13 : 79% (4 = 29)
ABC-OPT	89 : 76	91 : 77	138 : 10 : 00	93 : 10% (27 = 29)

the number of elements in DR and be the number of elements in the set A (and) number of sample codes.

This paper compares different forms of algorithms for data fusion in clinical data, out of which ABC-SVM shows better results compared to the traditional SVM model and BP-NN method. It can lower the RMSE and improve assessment indicators like the precision recall rate and the F-measure, demonstrating the method's precision and credibility.

4. Conclusions

As the population ages, health issues become more prevalent; hence, enhancing community health infrastructure is critical for improving the overall health quality of the populace. The occurrence and development of most diseases follow their unique evolutionary laws, which are often accompanied by changes in various physiological indicators of the human body. Through theoretical modelling, a disease prediction method that can be applied to community health services is proposed. Starting from the health index data of daily life, it can automatically analyze potential health problems, conducive to the timely understanding of human health status and taking corresponding measures. Support vector machine (support vector machine, SVM) is incorporated into the disease prediction of public health management, aiming at some current challenges in this field, based on established scientific data, through research on important features of data acquisition and management in the Internet of Things environment, combined with data fusion and mining technology. The prediction accuracy can be effectively increased after optimizing the process parameters using the artificial bee colony (ABC) technique. Furthermore, because of SVM's self-learning capacity, disease prediction ability will improve as the experience and knowledge grows, which is advantageous in encouraging grid construction of community healthcare and residents' health management, as well as fully exploiting the benefits of public medical care. The experimental results show that the SVM model has outstanding advantages in disease prediction. The ABC algorithm has the ideal parameter optimization effect in the SVM disease prediction model inaccuracy, time-consuming, etc. The recognition accuracy rate reaches 93.10%, 17.24%, and 72.41% higher than the traditional SVM model and BP-NN method, respectively. It can reduce the RMSE and improve the evaluation indicators such as precision, recall rate, and F-measure, which fully proves the method validity and accuracy. The method can be described by a rigorous mathematical model, with fast execution speed, high efficiency, and accessible computer implementation. It has broad application prospects and promotion in improving people's quality of life and health and disease prevention.

4.1. Future Scope. This study has a wide range of potential applications and promotional values in addition to enhancing people's quality of life, health, and illness prevention. However, limited by the current level of economic development, sensor objective factors such as technology, new materials, and their preparation processes, coupled with the variety of diseases and complex pathogenic mechanisms in practical applications, make it still challenging to popularize, and use this method. The planned research will focus on improving sensor technology, reducing production costs and making some medical testing instruments truly wearable and affordable, and improving the prediction accuracy and generalization ability of disease prediction models.

Data Availability

The data shall be made available upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] W. Huang, "Research on user satisfaction of older community care based on structure equation," in *Proceedings of the 2012 Fourth International Symposium on Information Science and Engineering*, pp. 489–492, Washington, DC, USA, December 2012.

[2] P. Bonato, "Keynote: digital health technologies and their role in the development of precision rehabilitation interventions," in *Proceedings of the 2021 IEEE International Conference on Pervasive Computing and Communications Workshops and other Affiliated Events (PerCom Workshops)*, p. 200, Kassel, Germany, March 2021.

[3] R. B. Wallace, F. Horsfall, R. Goubran, A. El-Haraki, and F. Knoefel, "The challenges of connecting smart home health sensors to cloud analytics," in *Proceedings of the 2019 IEEE Sensors Applications Symposium (SAS)*, pp. 1–5, Sophia Antipolis, France, March 2019.

[4] A. Jagatheesan, S. Maragathavel, M. Sivapurapu, and J. Lee, "Drops: a multi-producer and multi-consumer data sharing framework with human experience," in *Proceedings of the 2015 12th Annual IEEE Consumer Communications and Networking Conference (CCNC*, pp. 601-602, CCNC), Las Vegas, NV, USA, January 2015.

[5] H. Byeon, "Is the random forest algorithm suitable for predicting Parkinson's disease with mild cognitive impairment out of Parkinson's disease with normal cognition?"

International Journal of Environmental Research and Public Health, vol. 17, no. 7, p. 2594, 2020.

[6] M. G. Seneviratne, M. G. Kahn, and T. Hernandez-Boussard, "Merging heterogeneous clinical data to enable knowledge discovery," in *Proceedings of the BIOCOMPUTING 2019: Proceedings of the Pacific Symposium*, pp. 439–443, 2019.

[7] S. Kalamkar, "Clinical data fusion and machine learning techniques for smart healthcare," in *Proceedings of the 2020 International Conference on Industry 4.0 Technology (I4Tech)*, pp. 211–216, IEEE, Pune, India, February 2020.

[8] S. Vitabile, M. Marks, D. Stojanovic et al., "Medical data processing and analysis for remote health and activities monitoring," in *High-performance Modelling and Simulation for Big Data Applications*, pp. 186–220, Springer, Cham, Switzerland, 2019.

[9] R. Dautov, S. Distefano, and R. Buyya, "Hierarchical data fusion for smart healthcare," *Journal of Big Data*, vol. 6, no. 1, pp. 19–23, 2019.

[10] S. Neubert, A. Geißler, T. Roddelkopf et al., "Multi-sensor-fusion approach for a data-science-oriented preventive health management system: concept and development of a decentralized data collection approach for heterogeneous data sources," *International Journal of Telemedicine and Applications*, vol. 2019, Article ID 9864246, 18 pages, 2019.

[11] R. Gargees, J. Keller, and M. Popescu, "Early illness recognition in older adults using transfer learning," in *Proceedings of the 2017 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*, pp. 1012–1016, Kansas City, MO, USA, November 2017.

[12] N. Jiang, Z. Zhao, and P. Xu, "Predictive analysis and evaluation model of chronic liver disease based on BP neural network with improved ant colony algorithm," *Journal of Healthcare Engineering*, vol. 2021, Article ID 3927551, 7 pages, 2021.

[13] P. Gope, Y. Gheraibia, S. Kabir, and B. Sikdar, "A secure IoT-based modern healthcare system with fault-tolerant decision making process," *IEEE Journal of Biomedical and Health Informatics*, vol. 25, no. 3, pp. 862–873, 2021.

[14] Q. Chen, W. Wang, F. Wu et al., "A survey on an emerging area: deep learning for smart city data," *IEEE Transactions on Emerging Topics in Computational Intelligence*, vol. 3, no. 5, pp. 392–410, Oct. 2019.

[15] M. Song, Z. Yang, A. Baird et al., "Audiovisual analysis for recognising frustration during game-play: introducing the multimodal game frustration database," in *Proceedings of the 2019 8th International Conference on Affective Computing and Intelligent Interaction*, pp. 517–523, ACII), Cambridge, UK, September 2019.

[16] R. Williams and J. Leonard, "Surgery benefits from defense technology: dual use applications of wright laboratory avionics technologies to computer assisted minimally invasive surgery (CAMIS)," *IEEE Aerospace and Electronic Systems Magazine*, vol. 9, no. 10, pp. 3–6, 1994.

[17] M. Fahim and A. Sillitti, "Anomaly detection, analysis and prediction techniques in IoT environment: a systematic literature review," *IEEE Access*, vol. 7, pp. 81664–81681, 2019.

[18] L. Sevrin, N. Noury, N. Abouchi, F. Jumel, B. Massot, and J. Saraydaryan, "Characterization of a multi-user indoor positioning system based on low cost depth vision (Kinect) for monitoring human activity in a smart home," in *Proceedings of the 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pp. 5003–5007, EMBC), Milan, Italy, August 2015.

[19] M. Rosenberg and M. A. Williams, "10 bringing global health home," in *Howard Hiatt: How This Extraordinary Mentor Transformed Health with Science and Compassion*, pp. 153–164, MIT Press, Cambridge, MA, USA, 2018.

[20] Z. Zhang and A. Castelló, "Principal components analysis in clinical studies," *Annals of Translational Medicine*, vol. 5, no. 17, p. 351, 2017.

[21] I. Khlobystov and L. Horoshkova, "7 inequality in the distribution of income as at threat to the sustainable development of united territorial communities in Ukraine," in *Economic Inequality–Trends, Traps and Trade-Offs*, pp. 123–138, River Publishers, Denmark, 2021.

[22] V. A. Kumari and R. Chitra, "Classification of diabetes disease using support vector machine," *International Journal of Engineering Research in Africa*, vol. 3, no. 2, pp. 1797–1801, 2013.

[23] L. Lawrence, *Weed; Lincoln Weed, Ending Medicine's Chronic Dysfunction: Tools and Standards for Medical Decision Making*, Morgan & Claypool, San Rafael, CA, USA, 2021.

[24] A. Gupta and L. K. Awasthi, "P4P: ensuring fault-tolerance for cycle-stealing P2P applications," in *Proceedings of the 2007 International Conference on Grid Computing & Applications, GCA 2007*, pp. 151–158, Las Vegas, NV, USA, June 2007.

[25] A. Mehbodniya, J. L. Webber, M. Shabaz, H. Mohafez, and K. Yadav, "Machine learning technique to detect sybil attack on IoT based sensor network," *IETE Journal of Research*, pp. 1–9, 2021.

[26] A. Gupta and L. K. Awasthi, "Peer enterprises: possibilities, challenges and some ideas towards their realization," in *On the Move to Meaningful Internet Systems 2007: OTM 2007 Workshops*, pp. 1011–1020, Springer, Berlin Germany, 2007.

[27] S. Deshmukh, K. Thirupathi Rao, and M. Shabaz, "Collaborative learning based straggler prevention in large-scale distributed computing framework," in *Security and Communication Networks*, M. Kaur, Ed., vol. 2021, Article ID 8340925, 9 pages, 2021.

[28] B. Gulzar and A. Gupta, "DAM: a theoretical framework for SensorSecurity in IoT applications," *International Journal of Next-Generation Computing*, vol. 12, no. 3, 2021.

[29] M. P. Bhandari and S. Hanna, "12 social responsibility as a tool for the human resources policy development and reducing inequalities on tourism industry," in *Inequality–the Unbeatable Challenge*, pp. 293–306, River Publishers, Denmark, 2021.

[30] N. B. Sariff and N. Buniyamin, *Genetic Algorithm Versus Ant Colony Optimization Algorithm*, Scitepress, Setúbal, Portugal.

[31] S. Samsuddin, M. S. Othman, and L. M. Yusuf, "A review of single and population-based metaheuristic algorithms solving multi depot vehicle routing problem," *International Journal of Software Engineering and Computer Systems*, vol. 4, no. 2, pp. 80–93, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 1540263, 11 pages
https://doi.org/10.1155/2022/1540263

Research Article

The Architecture of an Intelligent Technical Support System for Electricity Spot Market

Shuhao Sun,[1] Huijie Gu,[1] Chaoyi Peng,[1] Huafeng Zhou,[1] and Dewen Seng[2]

[1]*China Southern Power Grid Company Limited, Guangzhou 510623, China*
[2]*School of Computer Science and Technology, Hangzhou Dianzi University, Hangzhou 310018, China*

Correspondence should be addressed to Dewen Seng; sengdw@hdu.edu.cn

Received 11 January 2022; Accepted 23 April 2022; Published 16 May 2022

Academic Editor: Ahmed Farouk

With the accelerating pace of China's electricity market reform, the construction of the electricity spot market has been put on the agenda. However, as the number and scope of market participants gradually expand, the market-oriented transaction power continues to rise, and the intraprovincial and interprovincial transaction varieties are increasingly abundant. How to design an intelligent and powerful system that can meet the performance requirements of high concurrency and high-frequency transactions in the future market is a major problem in power reform. Based on the research of theoretical research results, this paper builds the front-end interaction platform of the southern spot electricity system based on the regional center to provide a data declaration interface for market users, including market management, market declaration, market release, market evaluation, intelligent analysis, front-end data interface, security protection, and other functional modules, provide declaration information and some market evaluation results to the southern regional spot power system platform, and obtain clearance results and published information from this platform.

1. Introduction

Power market refers to a combination of electricity commodity, transaction period, and way of transaction and a market for electricity trade. The market trending is affected by energy policy, power net structure, demand and supply, market participants' management decisions, etc. [1]. In 2017, a notice on the implementation of the pilot construction of the electric power spot market [2] was published by the general office of the national development and reform commission and the National Energy Administration's general office, which chooses the southern region (starting from Guangdong), western Inner Mongolia, Zhejiang, Shanxi, Shandong, Fujian, Sichuan, Gansu, etc. and counts up to eight regions as the first pilot of the spot market, making sure that the mechanism of power fare should be formed. Based on the goal of optimization of the spot market, we establish the clearing mechanism and blocking management mechanism of the spot market under security constraints. So far, three of the first eight electric power spot market pilot projects have been launched. 2019 is the first year of China's electricity spot market, based on the pilot operation of the spot market in south China (starting from Guangdong) and Gansu and Shanxi in 2018, and the remaining five of the first eight pilot areas will start trial operation in mid-2019 as required. The pilot operation of the electric power spot market will elevate the reform of the electric power system centering on the construction of the electric power market to a new level, further activate the electric power market, and put forward higher requirements on the power trading ability and market risk control ability of power generation enterprises and power selling companies. On the other hand, the establishment of a fully functional and smoothly connected technical support system is also the support and important technical guarantee of spot trading pilot implementation.

Domestic scholars have carried out a series of studies on domestic and foreign electricity markets in recent years. Savelli et al. [3–5] studied and analyzed the actual cases of the construction of foreign electric power spot market;

Barazza and Strachan [6, 7] discussed the construction path of the power market from the perspectives of the construction mode of the spot market in the southern region and the mechanism design of the power market in Yunnan; Santos et al. [8, 9], respectively, designed the electric power spot market mechanism from the perspective of real-time price elasticity of user demand and marketization operation of incremental distribution network; López-Salamanca et al. [10], based on the similar network topology of blockchain and electric power spot market system, designed a brand new electric power spot real-time scheduling transaction and regulatory model for the intelligence and real-time and security requirements of electric power spot market transactions. The above literature provides valuable references for the construction of the spot market from multiple perspectives but lacks analysis on the construction of the complete technical support system of the spot market of electric power. As a matter of fact, the electricity market is a market with very strong technical characteristics, and economic problems are closely related to technical problems. With the growth of the number of users, the business volume of marketized electricity transactions increases at a geometric level. The existing technical support system is difficult to support the performance demand of high concurrency and high-frequency transactions in the future market. However, each upgrade is not a local software and hardware repair, but a change in the system architecture level. Thus, it is necessary to design an electric power spot system architecture with high connectivity, security, and scalability.

On the other hand, China's power market has gradually entered a new stage oriented by market demand, and the classification of power users is one of the necessary means to realize the optimal allocation of power resources [11]. The development of the electric power spot market is based on the premise of meeting the diversified demand of the market's main body, possessing the remarkable feature of bidirectional selection. In such an environment, the new generation of power trading platforms needs to adopt price measures and incentive policies based on user clustering and user portrait, support business decisions with data, and ultimately promote the smooth and efficient operation of the power system.

Aiming at the fact that the characteristics of domestic electricity spot market business are complicated, we put forward the southern regional power spot system front-end interactive platform construction principle and partition of hierarchical application deployment business framework, through the "loose coupling" business architecture that can be extended according to the actual needs of users of the many new features, thus providing more modular, humanization, and intelligent service.

At the same time, the system is developed based on the high performance and high availability middleware and the technology platform oriented to the Internet distributed system, which increases the security isolation and reliability isolation between the systems and provides a reference for the construction of the domestic electric power spot market technical support system.

It is not easy to open the spot electricity market. There are many problems that need to be solved. How do we find the price of electricity? What data are used as the basis for the price discovery process? What to do with all this data? How do we design corresponding rules? As an electricity selling company, after determining the spot price, how do we sign the medium- and long-term contract? In the wholesale market, how do we sell electricity and customers to sign a contract? How do we sign a contract with a power company? In the spot process, how do we distribute the quantity, how do we decompose, and so on?

Naturally, all models in the spot power market can be abstracted into a huge algorithmic model, and many methods in artificial intelligence have natural advantages for processing big data. By integrating computing and data into the electronic market, the power spot system based on artificial intelligence will be more competitive.

The data involved in the power market are diverse, including multidimensional data such as climate, environment, and fuel price; large sample data of grid side and whole network; cluster data of users on the selling side; user side depth behavior data; and a large amount of data generated by high-frequency trading in the spot scenario. At the same time, China's electricity market data is slightly different from other data in the world. China's data mainly involves some security issues, some of which can be made public (climate, environment, and other data), and some of which can be made semitransparent (grid-side data). Therefore, more attention needs to be paid to data security when using cloud services in the power market. For the electricity market, we want to use certain technical means, in the case of semitransparent calculation results.

In the wholesale market and big data environment, artificial intelligence has a profound future in the power market. In the spot power market, price forecasting is the key. In order to achieve this goal, it is necessary to start with simulation modeling, fundamental analysis, load forecasting, game behavior, strategy optimization, and other aspects. For different types of benchmarks, different treatment conditions are adopted to maximize the control cost. At the same time, for the market and declaration management subsystem, market evaluation subsystem, portal website, intelligent customer service four major business modules, the data analysis, and prediction can better clear the communication channel between the modules.

To solve the above problems, the paper proposes a new architecture based on an Intelligent Technical Support System for the Electricity Spot Market: (1) analysis of the construction of a complete power spot market technical support system; (2) user behavior analysis, intelligent customer service, and other key technologies; and (3) providing a reference for the construction of technical support system in the domestic power spot market.

2. Construction Principles

2.1. Design Principles. The system construction strictly follows the following design principles:

(1) *Openness.* The platform can be widely interfaced with a variety of external systems, which can be interface specifications for the platform or use existing

interface standards on the market. External systems include power grid dispatch control systems, power grid dispatch management systems, and mid-long-term trading systems.

(2) *Expandable*. The system adopts a modular design. When the business development needs to expand new business and new functional modules are needed, the original system architecture is not affected, and the risk of major modification of existing systems is reduced.

(3) *Configurable*. Different business models adopt the parametric design, which can be flexibly configured according to business needs.

(4) *High Availability*. The system uses clustering, fusing, backup, and other technical means to enhance the system's availability. When the system is abnormal, it has a self-recovery ability to prevent downtime.

(5) *High Security*. The system has a complete security mechanism, including a rights management system, a resource management system, and an operation management system to ensure that authorized business users and system users can use related functions, access related data, and implement operational function settings to effectively avoid operational risks. At the same time, the system has the function of data encryption protection, adopting the digital signature as the core digital signature, electronic seal, timestamp, and other means to encrypt the core data of the system business in the process of storage and transmission to prevent the leakage of transaction data. In addition, the system has a network attack prevention function on the Internet exportation and protects against network attacks such as Distributed Denial of Business (DDOS) attacks through various means such as flow cleaning to ensure that normal business is not affected by network attacks.

(6) *Manageable*. The system adopts the ACM platform to provide monitoring, management, control, and other functions for the business in operation. When abnormal transaction processing is found, it can provide multiple alarm paths and has a humanized monitoring and management interface.

According to the complex and changeable business characteristics of the domestic power spot market, this paper proposes a power architecture based on high connectivity, security, and scalability.

2.2. Technical Indexes. The front-end interactive platform needs to meet the following performance index, including the following:

(1) System availability is ≥ 99.99%. The system front-end interaction module can use the time/total time ≥99.99% for the core business in the statistical period (monthly).

(2) It should support concurrent online users of no less than 5,000 core business (e.g., price declaration) concurrent requests for users not less than 500.

(3) The message processing capability is not less than 6000 strips/second. Specifically, the number of messages processed per second by the system is not less than 6000 strips/second.

(4) It should support the permanent preservation of all historical data during the system life cycle.

2.3. Security Indexes. The front-end interactive platform needs to fully consider the requirements of security protection, including the following:

(1) The system architecture should consider the isolation of the network. In safety zone III and the demilitarized zone (DMZ), the internal and external network interaction platform should be used for isolation. The forward and reverse isolation devices should be used between safety zone III and safety zone II.

(2) Network security access must meet the security protection strategy of system access. The system should support security encryption of network communication, encrypted communication at the application layer, identity authentication, access control, and other measures.

(3) The system should have the identity authentication function, and the identity of the user should be verified by a digital certificate to establish a unified authentication system to prevent illegal access.

(4) The system should provide monitoring and security auditing interfaces, monitor the status of servers, workstations, and network devices in conjunction with the security situational perception system to achieve audits during and after the event, and trace responsibility for malicious actions and violation operations.

(5) The system should have the function of data encryption protection. It adopts a digital signature, electronic seal, and time stamp with a digital certificate as the core to encrypt the core data of the system business during storage and transmission to prevent the leakage of transaction data.

(6) The system should have the network attack prevention function in the Internet exportation and protect against network attacks such as DDOS attacks through various means such as flow cleaning to ensure that normal business is not affected by network attacks.

3. System Architecture Design

Based on the design principles and construction principles proposed in the previous section, we develop a technology platform based on high performance, high availability middleware for Internet distributed systems.

3.1. Business Architecture. In order to prevent the system from self-recovery and downtime in case of abnormality, the whole architecture is divided into four subsystems due to the principle of high availability middleware. The system consists of four business subsystems, namely, the market and declaration management subsystem, the market evaluation subsystem, the portal website, and the intelligent customer business, as shown in Figure 1.

(1) *Market and Declaration Management Subsystem.* It provides various businesses related to power trading required by the electricity market operation rules and provides technical support for constraint disclosure, price declaration, market release, and information release in the power market. As the core module of the whole system, after the module is implemented, it should be able to realize all kinds of transactions in the day-ahead, within-day, and real-time market according to the division of the trading cycle, to meet the development requirements of the power market; improve technical support for data reporting, market release, market analysis, and information release in the power market; provide market participants with convenient data declaring means, verify the validity of the declared data, and ensure the certainty and integrity of the data declaration; analyze statistics of market information, analysis, evaluation, and prediction of market operation; publish market information based on market planning; and ensure the validity, correctness, completeness, and security of the information.

(2) *Market Evaluation Subsystem.* In the electricity market environment, different types of market participants want to maximize economic returns in the market, and they also face different risk assessment and management issues. In order to control risks and ensure smooth operation of the regional power market, it is urgent to quantitatively study the market risks and price trends. At the same time, from the data point of view, combined with statistical analysis methods, we collect, process, and analyze a large number of market member bidding behavior information, tracking, analyzing, real-time forecasting, and early warning the characteristics of power supply and demand of various industries, regions, and people, and providing user classification and personalized services, which will help improve the level of meticulous operation management and demand-side management. The submodule provides quantitative analysis tools for power market operations and supervisors to analyze financial market financial risks, forecast electricity prices, and monitor electricity market bidding behaviors, including data modeling, user behavior analysis, user portraits, data statistics, risk monitoring, and other functions.

(3) *Market Member Management Subsystem.* For all kinds of market members, such as power grid enterprises, power generation enterprises, power sales enterprises, power users, and independent ancillary service providers, the functions of registration, alteration, exit, maintenance, and export of market management information are provided. At the same time, it provides unit and power generation matching and constraint condition parameter management functions, manages various configuration parameters of the spot market, and sets the basic running environment of the spot market. The parameter categories include but are not limited to basic parameters, security correction parameters, optimization calculation parameters, unit constraints, system balance constraints, network constraints, and other constraints set parameters.

(4) *Intelligent Customer Service.* It provides fast and efficient customer service for end-users of the spot system, effectively saves the human resource requirements of customer service, and provides unified customer service for different types of platforms through rich interfaces, specifically including Automatic Speech Recognition (ASR) service for user voice-to-text and Text to Speech (TTS) service for answer text-to-speech, through large-scale knowledge processing, natural semantic understanding, and other technologies. According to the application scenarios of different businesses at the same time, layering and grouping the structure of the knowledge base to realize a multipurpose "people" to improve work efficiency and completely automatic learning of unknown problems or unknown questions based on precise algorithms make the knowledge base constantly updated and optimized and reduces maintenance costs, use the crawler system to collect unstructured data, dock data centers or other data source information, and generate the basic market, information, and analytical data of knowledge base through the processing of the data.

3.2. Technical Architecture. The basic idea behind microservices is to think about creating applications around business domain components that can be independently developed, managed, and accelerated. An advocate will apply this model to a series of small services; each service focuses on a single business function, running in separate processes, which make the boundary between the services is clear, and can use lightweight communication mechanism (such as HTTP/REST) to communicate with each other, cooperate to achieve a complete application, and meet the needs of business and user [12]. Therefore, this system uses the microservice environment provided by cloud computing to build the development, deployment, and operation environment of the software. Meanwhile, according to different responsibilities, the whole system is divided into a terminal display, access network, background service, operation and maintenance monitoring, platform, and middleware layer, so as to meet the requirements of high availability of the business system. The overall technical architecture is shown in Figure 2.

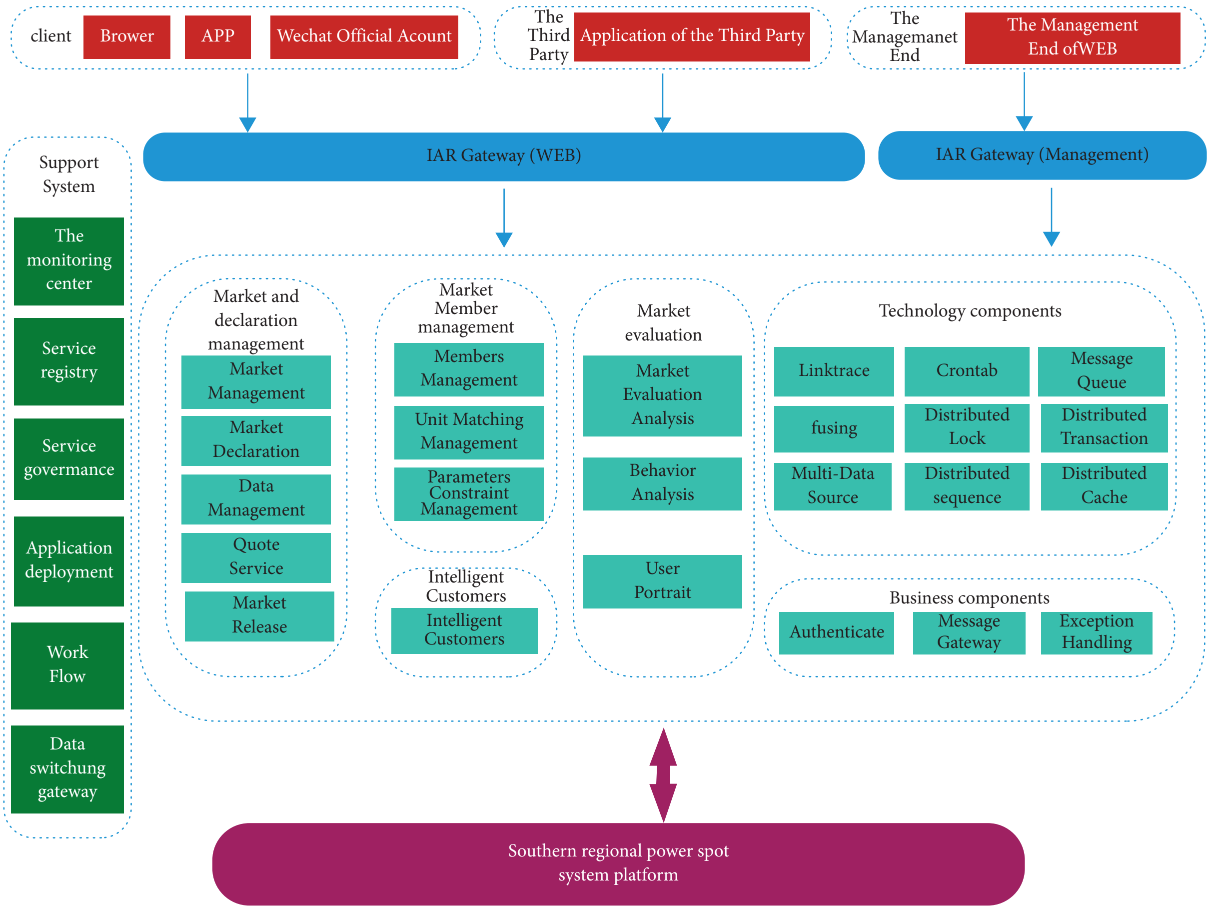


Figure 1: The business architecture of the front-end interactive platform of electric power spot system.

3.2.1. Terminal Presentation. The terminal is mainly divided into transaction clients, management clients, and third-party clients. The front gateway of the front-end interaction module of the spot trading system is accessed through HTTP/HTTPS protocol. The request/reply mode is the main message communication mode to realize the interaction with the server system and complete the business operation and system maintenance functions.

3.2.2. Access Gateway. The main task is to convert external HTTP/HTTPS protocol requests into internal microservice calls and implement access control. It mainly provides session management, channel management, and other functions, through service discovery and service routing to locate the request service address and complete the service call. In addition, the access gateway also has load balancing, flow control, and other functions to protect the back-end service and prevent it from being overwhelmed by the large flow.

3.2.3. Back-Office Services. It mainly provides various services and components on which the business functions of the front-end interactive platform of the spot trading system depend, including application services and basic services, to simplify the business development process and improve the reuse of applications.

3.2.4. Operational Monitoring. It mainly realizes the unified monitoring and management of all kinds of resources in the application system and provides up and down service, service degradation, and real-time warning. It can be convenient for troubleshooting and solving, for each application system provides the most convenient monitoring and management mode.

3.2.5. Platform and Middleware Layer. It mainly provides the basic services needed by the application in the development, testing, and running process.

3.3. System Deployment Plan. Figure 3 shows the network topology of the front-end interactive platform of the power spot system. DMZ is a buffer between nonsecure systems and a secure system to solve the problem that access users of the external network cannot access the internal network server after installing a firewall [13]. The system deploys application services in the DMZ area and the secure III area, respectively. Meanwhile, an internal and external network

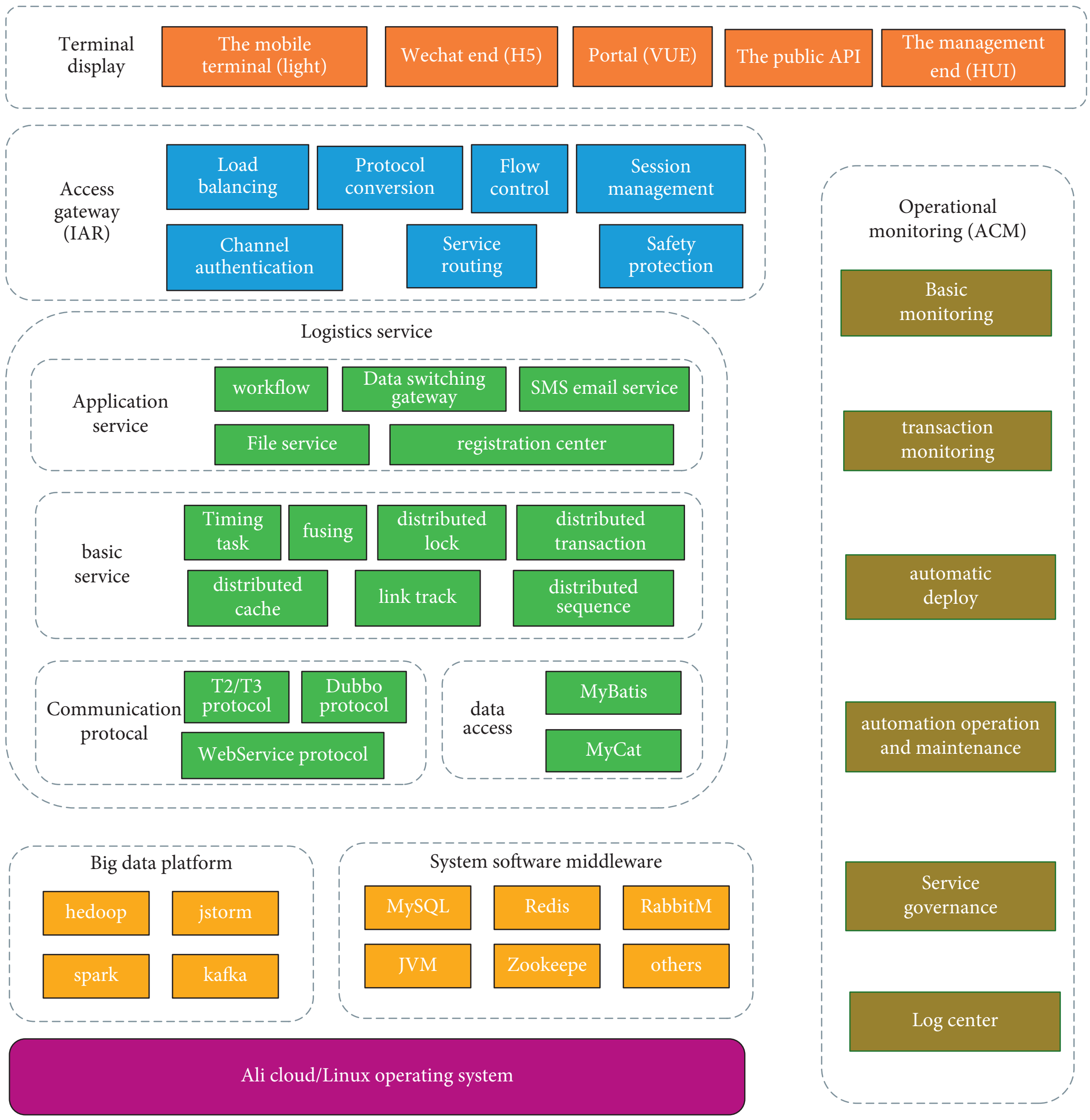


FIGURE 2: Technical framework of front-end interactive platform of electric power spot system.

interactive platform is built between the secure III area and the DMZ area to realize data transmission between the internal and external networks, as shown in Figure 4. For security III zone deployment firewall to strengthen the restriction on the security of the internal network, and through the security route to force the security settings of the network equipment inspection, we shield the network connection to nonsecurity equipment, to ensure the security of the internal network. Among them, the application deployed in the DMZ is targeted at market members and accessed through Internet exit, mainly providing various member interaction functions such as market information release, price declaration, and member information management. Safety III area is the production of administrative zones, mainly for market operation and maintenance personnel, and provides all kinds of process management, market management, application of price management, market information release management operations, etc.

3.4. Interface Docking. As the subsystem needs to be connected with the power spot system of the southern region, we interact through *E* file format and coordinate the interaction process by using the data exchange gateway to realize information sharing and integration between each business subsystem and the external business system, as shown in Figure 4. The southern regional power platform transmits data between each subsystem through the Aliyun cloud object storage service (OSS of Aliyun) and exchanges data with each gateway through the Aliyun cloud message service (MNS of Aliyun). In order to prevent the leakage of sensitive information during the transmission of *E* files, the system encrypts the contents of the files and adopts an asymmetric encryption algorithm. Among them, the encryption key is provided by the file receiver. The file sender encrypts the content of the file by using the encryption key, and the receiver decrypts the content by using the decryption key and then carries out subsequent business processing. During

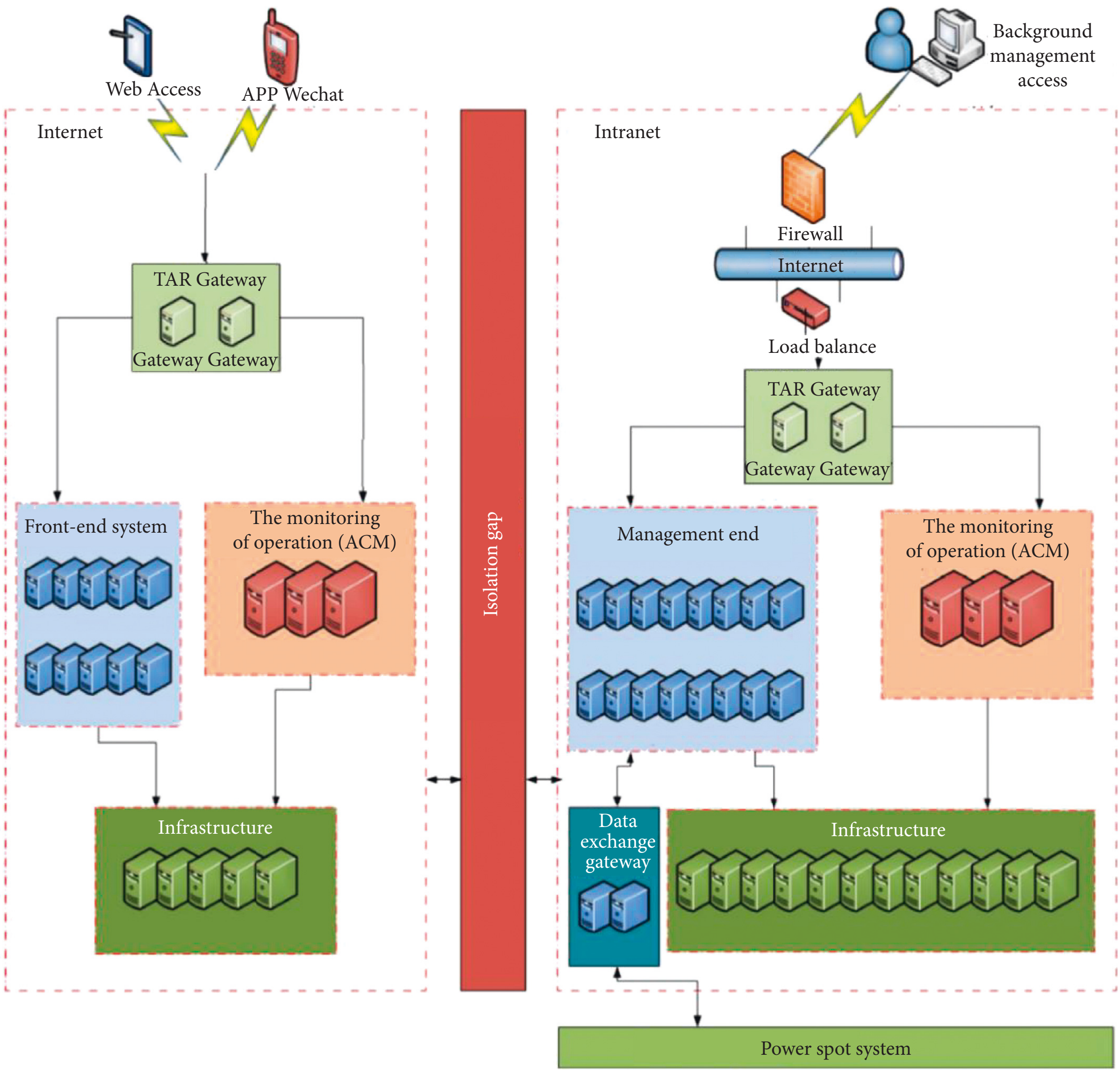


FIGURE 3: Topology of the network.

this period, the protocol transformation gateway will always monitor the call record and call status of the interface and alert the channel exception, data exception, and illegal access through the ACM platform.

4. The Core Modules

4.1. Market Declaration Module. The market declaration module is mainly used for various market members to declare data and verify and process the declaration data received. It includes the following functions.

It supports price declaration and provides grid constraint information to users for reference on the declaration page. Constraint information includes declaration period, declaration upper and lower limit price, equipment maintenance plan information, tie line plan information, grid safe operation index, and grid safety constraint information.

It supports the daily market declaration, including the declaration of electricity consumption, unit electric energy, unit expected grid-connection time, unit maximum generating capacity, unit heat supply flow, and unit emergency minimum output. At the same time, it supports the declaration of unit electric energy in the real-time market and the declaration of unit frequency modulation and peak regulation in the frequency modulation market.

It supports the monitoring and approval of market declaration information and informs the applicant via message reminder after approval.

It supports input and verification of declaration data and import and export of declaration data according to declaration data category.

Payment duplicate declaration, power users, and power selling companies can copy the data of historical declaration records through this function.

4.2. Market Release Module. According to the information disclosure principle in market rules, the market release module is mainly responsible for releasing current and

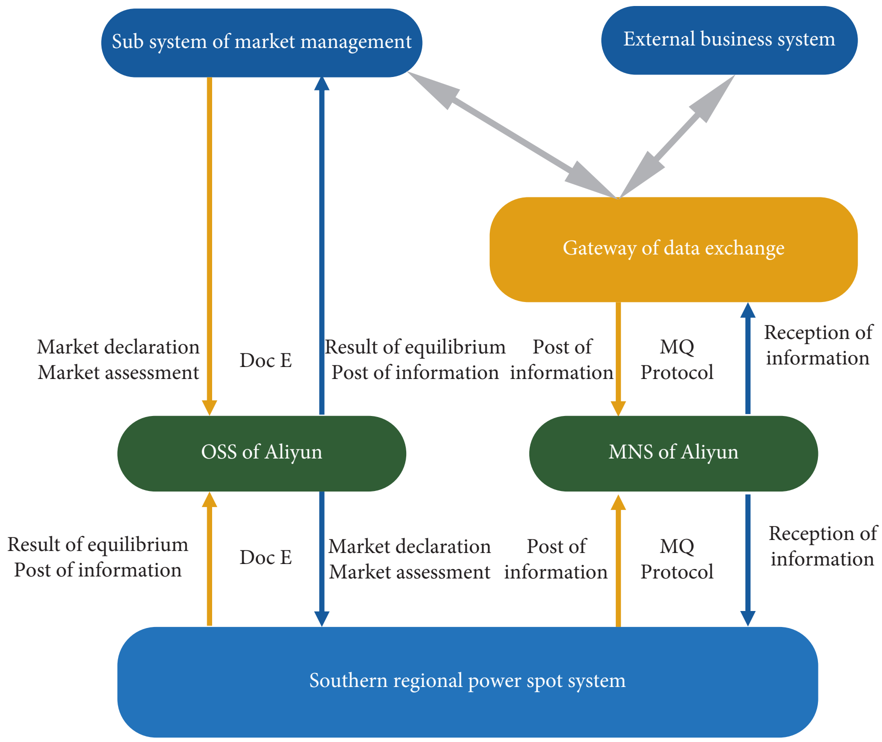


Figure 4: Interface of market management subsystem and electric power spot system.

future grid operation, market operation, market supervision, and other pieces of information to various market members, government authorities, and power regulatory authorities.

It releases maintenance plan information, such as maintenance shutdown and return of key equipment.

It releases plan information of the liaison line.

It releases network operation information, including the actual load of the system, the actual load of the bus, the actual output of the unit, the exchange power of the tie line, the load of important sections, and the safe operation index information of the network.

It releases grid security constraint information, including stable section quota and equipment operation quota.

It releases market operation information, including min long-term contract volume price data and transaction records, day-to-day market node electricity price, real-time market node electricity price, daily market safety check result, real-time market safety check result, day-to-market market node partition information, real-time market node partition information, crew frequency mileage information, real-time clearing results of the FM market, and real-time clearing results of the peaking market.

5. Key Technologies and Implementation

User behavior analysis systems and intelligent customer service are the focus and key of this paper. According to the regularity of user behavior and intelligent customer service, the artificial intelligence (AI) method is used to study and analyze it. AI is the technological science that studies and develops theorem, algorithms, technology, and application to imitate, inherit, succeed, expand, and even surpass the intelligence of human beings.

AI intends to be aware of the primary essence of intelligence of humans and create a new category of human beings to some extent. Research areas in artificial intelligence include computer vision, natural language processing, machine learning, expert systems, recommendation systems, and fuzzy logic. In addition, its research field is still expanding.

As the most significant method to implement and accomplish AI, machine learning is meanwhile the mainstream orientation for research of AI. Machine learning uses experience to improve the performance of the system itself. Machine learning can be classified into two parts: traditional methods and advanced methods. The former consists of supervised learning and unsupervised learning. And the latter is comprised of deep learning, transfer learning, and reinforcement learning.

One application of machine learning, as an example, is to explain and predict the phenomenon of the rising and falling of the spot market prices, which attracted enough interest from many researchers and other relevant institutions. A lot of previous research works have been done, where the researchers used various techniques of regression to solve the question of the changing market prices.

One of the sections of this paper proposes the case of changing prices as a classifying question and utilizes machine learning technology to predict the rising or falling market price [14]. This work uses varieties of feature engineering technologies such as PCA (principal component analysis). Another critical technology applied is the data transformation techniques, which process missing data, outlier data, and change the distribution of data such as box-cox transformation technology. The performance of one machine learning method is usually measured by the following 4 metrics: accuracy, precision, recall (sensitivity), and specificity. In this work, the two values 0 and 1 represent the two classes, respectively, where the class value 0 represents that the price of the market decreases. And the class value 1 represents that the price of the market increases to the contrary. Generally, a lost function can be defined as

$$J(\theta) = \frac{1}{2m}\left(\sum_{i=1}^{m}\left(h_\theta\left(x^{(i)}\right) - y^{(i)}\right)^2\right) + \frac{\lambda}{2m}\left(\sum_{j=1}^{n}\theta_j^2\right), \tag{1}$$

where the linear relationship between h and x is given as

$$h_\theta(x) = \theta^T x = \theta_0 + \theta_1 x_1. \tag{2}$$

Then, gradient descent should be used to update all the parameters as formulas (3) and (4):

$$\frac{\partial J(\theta)}{\partial \theta_0} = \frac{1}{m}\sum_{i=1}^{m}\left(h_\theta\left(x^{(i)}\right) - y^{(i)}\right)x_j^{(i)} \text{for } j = 0, \tag{3}$$

$$\frac{\partial J(\theta)}{\partial \theta_j} = \left(\frac{1}{m}\sum_{i=1}^{m}\left(h_\theta\left(x^{(i)}\right) - y^{(i)}\right)x_j^{(i)}\right) + \frac{\lambda}{m}\theta_j \text{ for } j \geq 1. \tag{4}$$

Most of the time, classification task needs to be done in the spot market. Generally, we use logistic regression to handle it. It clearly knows that object function should be firstly considered, which is defined as

$$J(\theta) = \frac{1}{m}\sum_{i=1}^{m}\left[-y^{(i)}\log\left(h_\theta\left(x^{(i)}\right)\right) - \left(1 - y^{(i)}\right)\log\left(1 - h_\theta\left(x^{(i)}\right)\right)\right] + \frac{\lambda}{2m}\sum_{j=1}^{n}\theta_j^2. \tag{5}$$

Similarly, in order to minimize this cost function, gradient descent should be applied to train this model as formulas (6) and (7):

$$\frac{\partial J(\theta)}{\partial \theta_0} = \frac{1}{m}\sum_{i=1}^{m}\left(h_\theta\left(x^{(i)}\right) - y^{(i)}\right)x_j^{(i)} \text{for } j = 0, \tag{6}$$

$$\frac{\partial J(\theta)}{\partial \theta_j} = \left(\frac{1}{m}\sum_{i=1}^{m}\left(h_\theta\left(x^{(i)}\right) - y^{(i)}\right)x_j^{(i)}\right) + \frac{\lambda}{m}\theta_j \text{for } j \geq 1. \tag{7}$$

It is easy to know that the value of $y^{(i)}$ is 0 or 1, which is totally different from the linear regression.

Different from traditional low-depth learning, deep learning increases the number of layers and usually changes the structure of the model. In addition, it emphasizes the learning of features. Unlike traditional hand-designed feature extractors based on professional domain knowledge, deep learning extracts the feature from the input layer to the output layer and builds the mapping from the latent information to the semantics at a high level to obtain the characteristic expression of the data from the general learning process. Typical deep learning models include deep belief nets (DBNs), convolution neural networks (CNNs) [15], generative adversarial networks (GANs), recurrent neural networks (RNNs) [16], and stacked autoencoder (SAE) [17]. For the full connected network, the object function (without regularization) should be shown as

$$J(\theta) = \frac{1}{m}\sum_{i=1}^{m}\sum_{k=1}^{K}\left[-y_k^{(i)}\log\left(\left(h_\theta\left(x^{(i)}\right)\right)_k\right) - \left(1 - y_k^{(i)}\right)\log\left(1 - \left(h_\theta\left(x^{(i)}\right)\right)_k\right)\right]. \tag{8}$$

Clearly, the gradient descent is also needed to minimize. The gradient for the sigmoid function can be computed as

$$g'(z) = \frac{\mathrm{d}}{\mathrm{d}z}g(z) = g(z)(1 - g(z)). \tag{9}$$

Then, in order to optimize all the parameters, the backpropagation algorithm is needed to be implemented.

Reinforcement learning [18], also known as evaluating learning and reinvigorating learning, is an effective technique for machine learning. Its foundation is to solve the problem of decision-making. In other words, it is a method to learn how to make correct decisions by itself. Reinforcement learning mainly consists of the four factors: individuality, situational state, behavior, and award. In the learning procedure, the individual learns on the basis of the situation, and the search tactics make the best choice, leading to the change of the state, so as to obtain the reward or penalty of feedback from the system. According to these reward and punishment values, the current strategy is adjusted and a new epoch of learning is processing, and the loop is repeated until the system evaluates the individual under certain conditions. There are several typical methods for reinforcement learning such as the Sarsa algorithm and Deep Q Network (DQN) [19] and Q-Learning method.

For DQN, in addition to using a DCNN (deep convolutional neural network) to approach the present value function, another independent network is implemented to yield the goal Q value [20]. Explicitly, $Q(s, a|\theta_i)$ indicates the value of the output layer in the network, $Q(s, a|\theta_i^-)$. The output of the network represents the target, and generally, $Y_i = r + \gamma\max_{a\prime} Q(s', a'|\theta_i^-)$ approximates the goal Q value. It updates the parameters of the network by minimizing a loss function, that is, the difference between the actual value of Q and the goal Q. The loss function of mean square error is indicated as

$$L(\theta_i) = E_{s,a,r,s'}\left[(Y_i - Q(s, a|\theta_i))^2\right]. \tag{10}$$

We obtain the gradient by partially derivative of the variable, as shown in

$$\nabla_{\theta_i} L(\theta_i) = E_{s,a,r,s'}\left[(Y_i - Q(s, a|\theta_i))\nabla_{\theta_i} Q(s, a|\theta_i)\right]. \tag{11}$$

The purpose of migration learning [21] is to use the relevance of learning objectives and existing knowledge to apply existing knowledge to relevant but different areas to deal with the correlated questions. In many cases, a few tag samples in some application scenarios are even difficult to acquire samples and can not help construct the robust models. Migration learning can transfer the model parameters in related scenarios to another scenario to build the structure of models, by which the new model's adaptive ability is improved. Quintessential migration learning methods include Tr Ada Boost (transfer adaptive boosting), Co CC (coclustering based classification), and self-learning.

Migration learning [22] refers to a method of migrating knowledge from a guidance model T to a learning model S. Therefore, the mean square error loss function can be used to train the parameters of the learning model S as shown in

$$L_{D^t}^{MSE}(\theta_S) = \sum_{i=1}^{|D|}\left(q_i^T - q_i^S\right)|\theta_{s2}^{\ 2}. \tag{12}$$

Another way to migrate the Q-value function is to migrate only the action $a_{i,\text{best}} = arg\max_a(q_i)$ corresponding to the maximum Q value from T to S. Then, we use Negative Log-Likelihood (NLL) to predict the same optimal action value to train the relevant parameters of the learning model S as shown in

$$L_{D^T}^{NLL}(\theta_S) = -\sum_{i=1}^{|D|}\log P\left(a_i = a_{i,\text{best}}|x_i, \theta_s\right). \tag{13}$$

And in order to make the result more precise, Hinton [23] used Kullback-Leibler Divergence (KLD)to define the loss function as shown in

$$L_{D^T}^{KL}(\theta_S) = \sum_{i=1}^{|D|}\text{soft}\max\left(\frac{q_i^T|\theta_s}{\tau}\right)\ln\frac{\text{soft}\max\left(q_i^T|\theta_s/\tau\right)}{\text{soft}\max\left(q_i^S|\theta_s\right)}. \tag{14}$$

6. Conclusions

This paper studies the front-end interactive platform scheme of the power spot system in the southern region, puts forward the construction principle and architecture design of the system, and introduces the two core modules of market declaration and market release in detail. The proposed electricity spot market front-end interactive platform has the following characteristics: (1) based on high performance, high availability middleware, Internet technology platform for distributed system-oriented development, increasing the security isolation between the system and reliability, and with "loose coupling" business architecture, effectively improves the stability and reliability of the system; (2) it timely and accurately grasps the characteristics of customers' electricity consumption behavior through the analysis of user behavior, supports the decision-making of power marketing and dispatching of enterprises, and improves the service level of government, industry, and commerce and other departments; (3) it uses intelligent customer service to provide customers with all-round professional consulting services in the field of the power market. According to the construction principles and architecture design of high availability, we analyze and discuss the user behavior and intelligent customer service and design the technical support system scheme for the southern regional power spot market because the design can meet the demand of high concurrency and high-frequency trading in the future market. Meanwhile, it also provides an important reference for the construction of a trading platform in the domestic electric power spot market.

Nowadays, some power companies aim to improve quality and efficiency and fully apply technologies such as cloud computing, big data, the Internet of Things, mobile networks, and artificial intelligence. As an important driving force of the new round of scientific and technological revolution and industrial transformation, artificial intelligence is profoundly changing people's production, life, and learning methods and promoting the intelligent era of human society, human-machine synergy, cross-border integration, and sharing. Therefore, the application of artificial intelligence-related technology can be better incorporated into the grid spot system research, which can improve the performance of the system. For example, how to do real-time load forecasting of the sales company's proxy users and then improve the performance of the corresponding system modules will involve a large amount of data accumulation and calculation, and these can be solved by artificial intelligence, big data, and other technologies. Therefore, I believe that artificial intelligence will bring more surprises in future research.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] H. Ahmadi and A. Akbari Foroud, "Improvement of the simultaneous active and reactive power markets pricing and structure," *IET Generation, Transmission and Distribution*, vol. 10, no. 1, pp. 81–92, 2016.

[2] National development and reform commission, "Circular on the Implementation of Pilot Construction of Electric Power Spot Market," http://www.ndrc.gov/GZDT%20/201709/t20170905_860117.html.
[3] I. Savelli, A. De Paola, and F. Li, "Ex-ante dynamic network tariffs for transmission cost recovery," *Applied Energy*, vol. 258, 2020.
[4] O. Terreros, J. Spreitzhofer, D. Basciotti et al., "Electricity market options for heat pumps in rural district heating networks in Austria," *Energy*, vol. 196, 2020.
[5] K. M. Currier and S. Rassouli-Currier, "Grid parity and cost reduction incentives for "green producers" in electricity markets," *International Advances in Economic Research*, vol. 24, no. 1, pp. 65–78, 2018.
[6] E. Barazza and N. Strachan, "The impact of heterogeneous market players with bounded-rationality on the electricity sector low-carbon transition," *Energy Policy*, vol. 138, 2020.
[7] N. Good, E. A. Martínez Ceseña, C. Heltorp, and P. Mancarella, "A transactive energy modelling and assessment framework for demand response business cases in smart distributed multi-energy systems," *Energy*, vol. 184, pp. 165–179, 2019.
[8] G. Santos, T. Pinto, I. Praça, and Z. Vale, "Iberian electricity market ontology to enable smart grid market simulation," *Energy Informatics*, vol. 1, no. 1, 2018.
[9] T. Gibson, "Grid trouble in paradise," *Mechanical Engineering*, vol. 137, no. 12, pp. 42–47, 2015.
[10] H. L. López-Salamanca, L. V. Arruda, L. Magatão, and J. E. Normey-Rico, "Optimization of grid-tied microgrids under binomial differentiated tariff and net metering policies: a Brazilian case study," *Journal of Control, Automation and Electrical Systems*, vol. 29, no. 6, pp. 731–741, 2018.
[11] V. V. S. Madhuri and P. Srividyadevi, "Energy monitoring and routing for impending challenges in SMART GRID," *International Journal of Recent Technology and Engineering*, vol. 8, no. 2, pp. 5094–5097, 2019.
[12] K. Singh, "Networks and the diffusion of off-grid solar technologies," *Low Carbon Economy*, vol. 8, no. 2, 2017.
[13] M. Ito, A. Takano, T. Shinji, T. Yagi, and Y. Hayashi, "Electricity adjustment for capacity market auction by a district heating and cooling system," *Applied Energy*, vol. 206, pp. 623–633, 2017.
[14] D. Banerjee and S. Dutta, "Predicting the housing price direction using machine learning techniques," in *Proceedings of the 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering*, pp. 2998–3000, Chennai, India, September 2017.
[15] Y. LeCun, B. Boser, J. S. Denker et al., "Backpropagation applied to handwritten zip code recognition," *Neural Computation*, vol. 1, no. 4, pp. 541–551, 1989.
[16] S. Hochreiter and J. Schmidhuber, "Long short-term memory," *Neural Computation*, vol. 9, no. 8, pp. 1735–1780, 1997.
[17] X. Yuan, C. Ou, Y. Wang, and C. Yang, "Nonlinear VW-SAE Based Deep Learning for Quality-Related Feature Learning and Soft Sensor modeling," in *Proceedings of the IECON 2018-44th Annual Conference of the IEEE Industrial Electronics Society*, pp. 5400–5405, Washington, DC, USA, 2018.
[18] K. Yu, L. Jia, Y. Chen, and W. Xu, "Deep learning: yesterday, today, and tomorrow," *Journal of Computer Research and Development*, vol. 50, no. 9, pp. 1799–1804, 2013.
[19] V. Mnih, K. Kavukcuoglu, D. Silver et al., "Human-level control through deep reinforcement learning," *Nature*, vol. 518, no. 7540, pp. 529–533, 2015.
[20] L. J. Lin, *Reinforcement Learning for Robots Using Neural Networks*, Carnegie Mellon University, Pittsburgh, 1992.
[21] D. L. Silver and K. P. Bennett, "Guest editor's introduction: special issue on inductive transfer learning," *Machine Learning*, vol. 73, no. 3, pp. 215–220, 2008.
[22] A. A. Rusu, S. G. Colmenarejo, C. Gulcehre et al., "Policy Distillation," 2015, https://arxiv.org/abs/1511.06295.
[23] G. Hinton, O. Vinyals, and J. Dean, "Distilling the Knowledge in a Neural Network," 2015, https://arxiv.org/abs/1503.02531.

Hindawi
Scientific Programming
Volume 2022, Article ID 6475022, 11 pages
https://doi.org/10.1155/2022/6475022

Research Article

Design of Logistics Economic Management Measures System in the Era of Internet of Things

Yulong Huang

Business School, Southwest Minzu University, Chengdu, Sichuan 610041, China

Correspondence should be addressed to Yulong Huang; ylhuang@swun.edu.cn

Received 24 January 2022; Revised 19 March 2022; Accepted 7 April 2022; Published 16 May 2022

Academic Editor: Ahmed Farouk

In order to test whether the intelligent logistics system based on the Internet of things is an important guarantee for an enterprise to have supply chain competitiveness and save a lot of costs in production and sales, this paper puts forward the innovative architecture and application of the new technology of intelligent logistics system based on the Internet of things, constructs the PLS path model and coordination degree measurement model, and measures and analyzes the coordinated development level of the "logistics regional economy" composite system and the coordinated development level of each subsystem, the coordination degree of the "logistics regional economy" composite system, and the coordination degree of each subsystem. It has effectively solved the problems of low operation efficiency and high labor cost in the procurement and inventory link; moreover, the direct effects of the development of logistics industry on the rationalization and upgrading of industrial economic structure are −0.2269 and 0.0289 respectively, which are significant at the level of 1%. The overall cointegration test shows that China's logistics industry and economic growth maintain a long-term and stable equilibrium relationship.

1. Introduction

Internet of things is the effective integration of modern computer technology, artificial intelligence technology, and perception technology to form a systematic, aggregated, and controlled information management technology. It belongs to the third revolutionary innovation of information technology, as shown in Figure 1 [1]. In the logistics industry, the use of modern Internet of things technology can have a strong impact on the traditional logistics economic management, reestablish the recognition of logistics enterprises for science, technology, and information, improve the intelligent monitoring and management of logistics enterprises, and promote the sharing of information resources among logistics enterprises [2, 3]. Finally, to achieve the goal of win-win, the Internet of things is an important part of information technology in the new era. In the technical system of the Internet of things, its core is still the Internet, and the Internet of things is the extension and expansion of the Internet. The Internet of things integrates intelligent perception and recognition technology with the network. In the application layer, it is mainly to share information across regions, analyze information, and realize intelligent management services under the Internet of things technology [4]. The concept of Internet of things needs to be realized through infrared sensors, GPS positioning, laser scanning, and sensing devices so as to provide channels for information exchange between different items and realize intelligent identification, tracking, and monitoring of items.

2. Literature Review

In a new economic normal, Yang and Kim actively change management ideas and innovate management methods to ensure that the traditional logistics industry can survive and develop in the fierce market competition. As a new product of an era, the Internet of things has brought hope to the logistics industry [5]. Bouras et al. found that the Internet of things technology has brought rare development opportunities to the logistics industry and effectively promoted the development of the traditional logistics industry towards a modern, mainstream, and forward-looking trend [6].

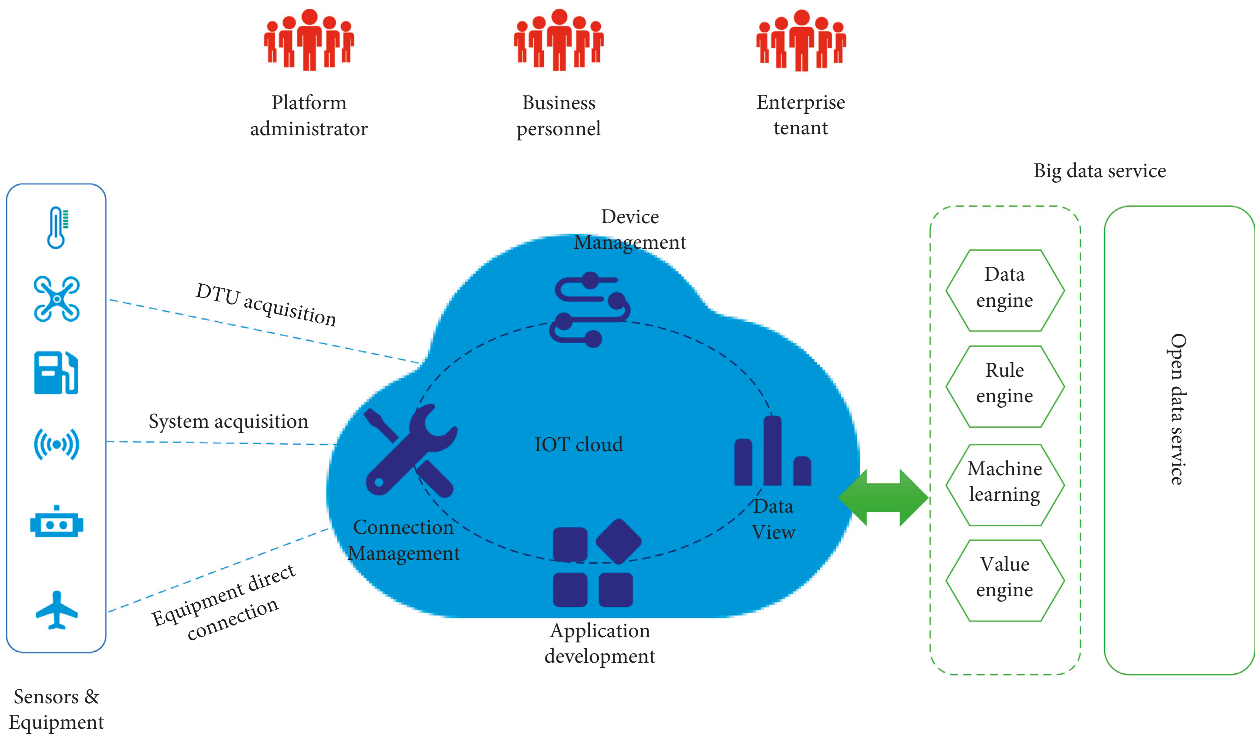


Figure 1: Flowchart of the Internet of things.

Sullivan proposed that in the new era, the Internet of things is a unique information technology, which indicates the arrival of a new information age [7]. Chen et al. found that the Internet of things technology can effectively connect things with things. The Internet is a key technology, which promotes its effective expansion and extension. It extends information exchange to the exchange of things. The emergence of the Internet of things technology is regarded as the third wave of information technology and truly integrates Internet technology into real life [8]. The fundamental starting point for NG and Wakenshaw to establish a network system is to monitor and control goods and improve management efficiency and quality [9]. Mahalle et al. proposed that, in general, the construction of the Internet of things needs to be based on communication equipment, mainly infrared sensors, GPS sensing devices, and so on, and connected with the network to conduct information smoothly [10]. Fenza found that for the management of goods, the Internet of things system needs to carry out the following three steps: first, identify goods and store them by category; second, with the help of intelligent identification equipment, the article attributes are read and the obtained information is converted; third, truthfully transmit the item information to the network, transfer the information to the control center with the help of the Internet, and centrally manage the items [11]. By using intelligent identification technology, scanning, sorting and uploading item information, and storing the information in the information management system, objects and objects can know each other's needs and respond positively. For example, the clothing information includes the requirements for water temperature. Arch et al. found that due to its wide application range, the Internet of things needs to be supported by cloud computing. Cloud computing is to integrate all information and resources into the network with the help of the network so that users can obtain them anytime and anywhere [12]. Edwards proposed that the Internet of things itself does not have an independent computing carrier, so the calculation of all information is allocated to the corresponding computing system, and cloud computing can effectively solve this situation [13]. Aachen and others found that the Internet of things calculates and processes huge data information through cloud computing platform and pattern recognition M2M and other computing cardinality, which is also a test of cloud computing technology [14]. In the traditional logistics system, due to the influence of objective factors such as road conditions and geographical location, the delivery time is long, and the logistics information management is difficult [15]. Logistics management software has the functions of predicting logistics delivery time and goods query, which can effectively avoid the delay of logistics due to information errors. At the same time, with the help of supply chain-related facilities, effectively reduce the material waste in the logistics process, reasonably allocate resources, reduce the logistics cost investment to a certain extent, and maximize economic benefits. In addition, customers can query the express information through the mobile terminal. The visual management mode increases the openness and transparency of logistics, further refines the logistics process, promotes the increasingly standardized logistics links, and can quickly find the responsible person in case of an accident.

3. Method

By the end of 2011, the operating mileage of China's railways (including local and cooperative railways) had reached 93200 kilometers, about 1.8 times that of 1978. The railway business quality has been improved rapidly, in which the mileage of double track has increased from 7360 km in 1978 to 29884 km in 2011, and the proportion of double track mileage in the total length of business line has increased from 15.7% in 1978 to 45.24%. The electrified railway increased from 100000 km in 1978 to more than 34300 km in 2011, and the proportion also increased from 1.9% to 51.98% of the total length of business lines. The automatic block mileage increased from 5981 km in 1978 to 37500 km in 2011, and the proportion increased from 12.3% in 1978 to 56.61%. Although railway construction has made some achievements, at present, China's transportation network density is far lower than that of developed countries. The railway network density is only 38% of that of the United States, 8% of that of Japan, and 17% of that of Germany. The railway double track rate and electrification rate are less than 50%. Figure 2 shows the railway development process [16].

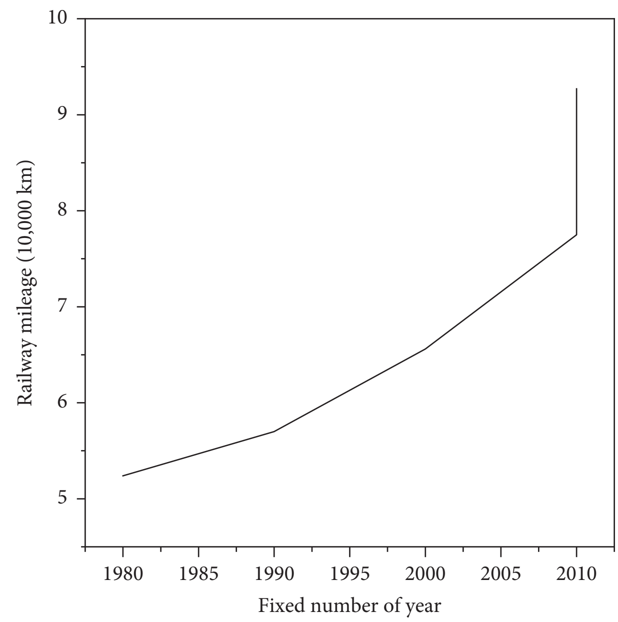


Figure 2: Railway development history.

After the reform and opening up, China's civil aviation construction has developed rapidly. In 1978, the mileage of civil aviation was only 148900 kilometers. By the end of 2011, it had reached 3490600 kilometers. The average is increasing every year 101200 kilometers. The performance of civil aviation construction is not only reflected in the increase of navigation mileage, but also greatly improved aviation operation efficiency. In 2010, the average daily utilization rate of registered transport aircraft in the whole industry was 9.35 hours, including 9.76 hours for large- and medium-sized aircraft and 5.15 hours for small aircraft. In 2010, the average seating rate of regular flights was 80.2%, and the average carrying rate of regular flights was 71.6%. Figure 3 shows the development process of civil aviation [17].

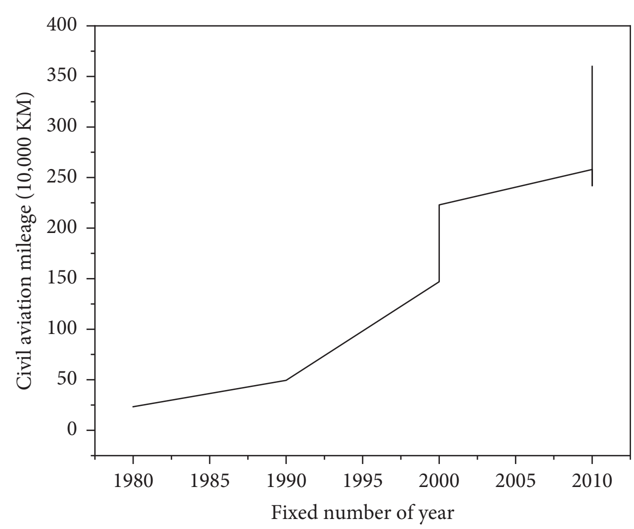


Figure 3: Development history of civil aviation.

Pipeline transportation is developed with the growth of oil and natural gas. It has the advantages of large transportation volume, less land occupation, low energy consumption, low cost, and high reliability. The construction of China's pipeline network began in the late 1950s. Before 1970, most of China's pipelines were distributed in the western region. With the successive development of Daqing oil, Shengli, North China, Liaohe, and other large- and medium-sized oilfields, pipeline transportation in the eastern region has developed greatly. In 1978, the total length of pipeline transportation lines in China was 8400 km, and by the end of 2007, it had reached 54600 km (Figure 3–6). Chinahas gradually formed a cross-regional oil and gas pipeline network industrial pattern [18, 19]. The national oil and gas pipeline network was gradually improved, and a product oil pipeline to send oil from the west to the East and oil from the north to the south was built.

Logistics demand is composed of the needs with payment capacity generated by social and economic activities in various links of logistics. It is reflected by various logistics demand quantities such as transportation, warehousing, distribution, and circulation processing. Freight volume and freight turnover reflect the operation of the national economy and are relatively comprehensive indicators representing the general situation of logistics demand [20]. As can be seen from Figure 5, after 1978, the freight volume and freight turnover increased steadily. Particularly after 2006, affected by the national macroeconomic regulation and control policies, all localities accelerated investment in the development of modern logistics industry, and the freight volume and freight turnover increased rapidly. By the end of 2011, the freight volume was 36969.61 million tons and the freight turnover was 15932.4 billion ton kilometers, 14.86 and 17.21 times that of 1978, respectively.

Judging from the freight volume completed by various modes of transportation, with the attention of the central and local governments to highway construction, highway

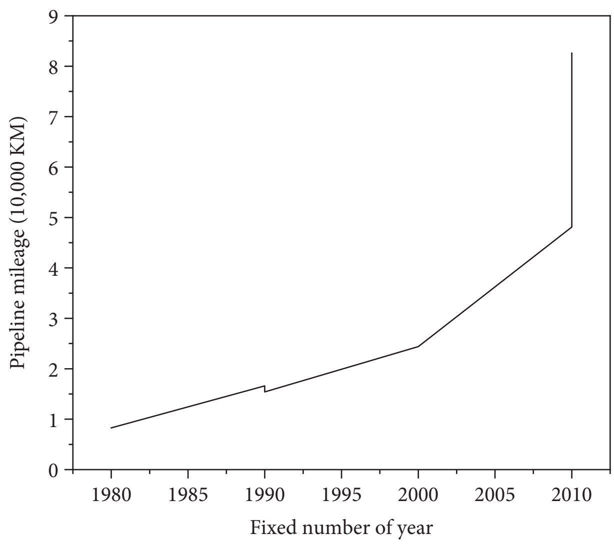


Figure 4: Development history of pipeline in China.

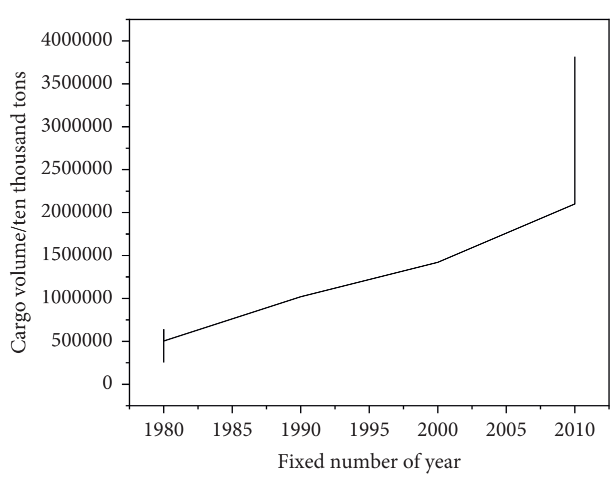


Figure 5: Development history of freight volume in China.

transportation has become the leading mode of transportation since the 1980s. In 1978, the proportion of highway freight volume in the total freight volume was only 34.21%, up to 75.4% in 1984, and has remained above 70% since then. This shows the importance of road transportation for the logistics industry. After 1978, the railway freight volume has maintained an increasing trend, but the ratio of railway freight volume to the total freight volume has been in a downward trend. In 1978, the proportion was 44.28%; in 1986, it was 15.79%; and in 2011, it was only 10.63%. The proportion of waterway transportation in the total freight volume has been increasing slowly since 1979, accounting for 11.59% of the total freight volume in 2011. Although the cargo volume of air and pipeline transportation has maintained an upward trend since 1978, the proportion of these two transportation modes in the cargo volume has been low, almost less than 2%. It can be seen from the above analysis that at present, the main modes of transportation are highway, railway, and water transportation.

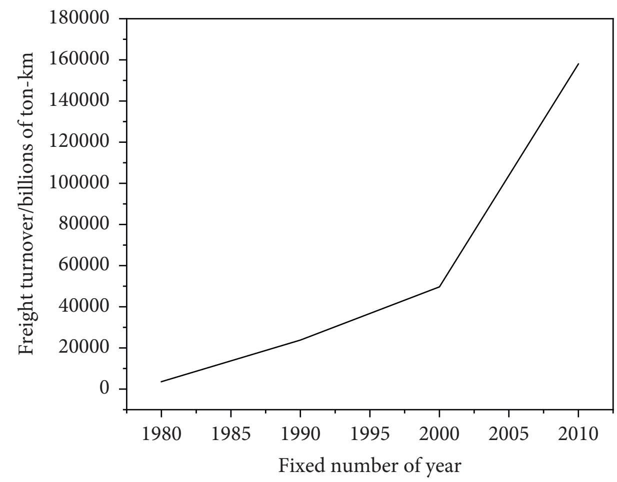


Figure 6: Development history of freight turnover in China.

Procurement is also particularly important for logistics. Although procurement is the first step in the production process, in order to save costs, the company adopts the form of logistics outsourcing for transportation and the first step of goods delivery; that is, the supplier of Party B shall supervise the transportation and quality of goods. However, there are unwritten regulations in the industry: due to the particularity of crude oil and ester lipid materials, suppliers will use transportation devices far higher than national standards in undertaking transportation so as to ensure the quality of product delivery. This measure does realize the service differentiation of supply chain management in suppliers and ensure the lowest cost of the whole supply chain, but it undoubtedly increases the production cost for a large number of small- and medium-sized science and technology production enterprises represented by economic scale. Therefore, after weighing multiple variable factors such as transportation route, plant site distance, and temperature deviation, we choose to reach an agreement on self-regulation in transportation with suppliers in the procurement agreement so that the responsibilities of freight drivers in the delivery link are greatly reduced, and higher standards are put forward for goods acceptance and warehousing.

After the crude oil ester and lipid products enter the inventory state, due to the complexity required by the project, they will be classified and placed according to different requirements and numbers, summarized and recorded by the special management personnel of the warehouse, and fed back to the production office. The production office shall uniformly feed back to the human resources department of the functional department for unified performance statistics. The personnel, working hours, and important matters involved in the whole process of goods delivery are as follows: (due to the confidentiality of the customer's business, the names of the materials involved are all substitute names and only represent some materials) as shown in Figure 7 [21, 22].

Therefore, the company's inventory management model can be used: allow shortage—noninstantaneous delivery model. According to the model assumptions and storage

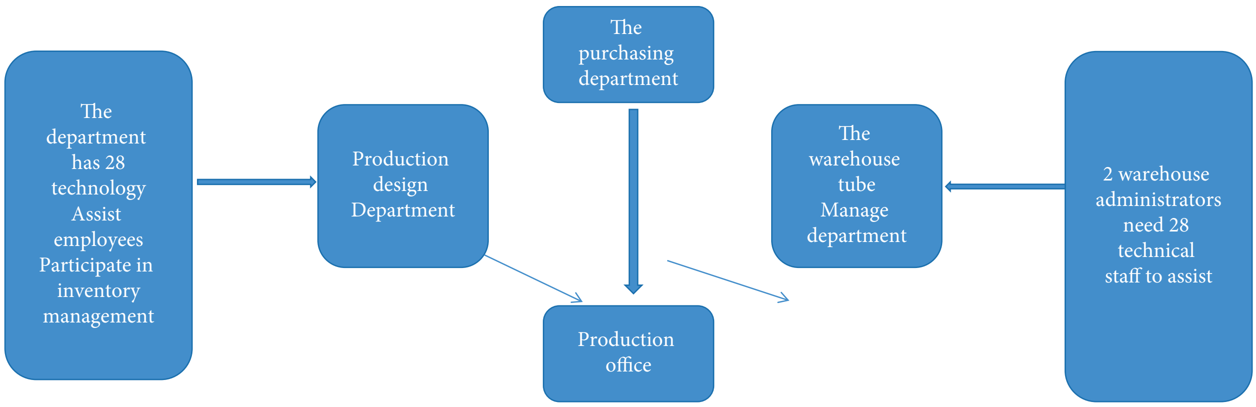


Figure 7: Organization chart of production department.

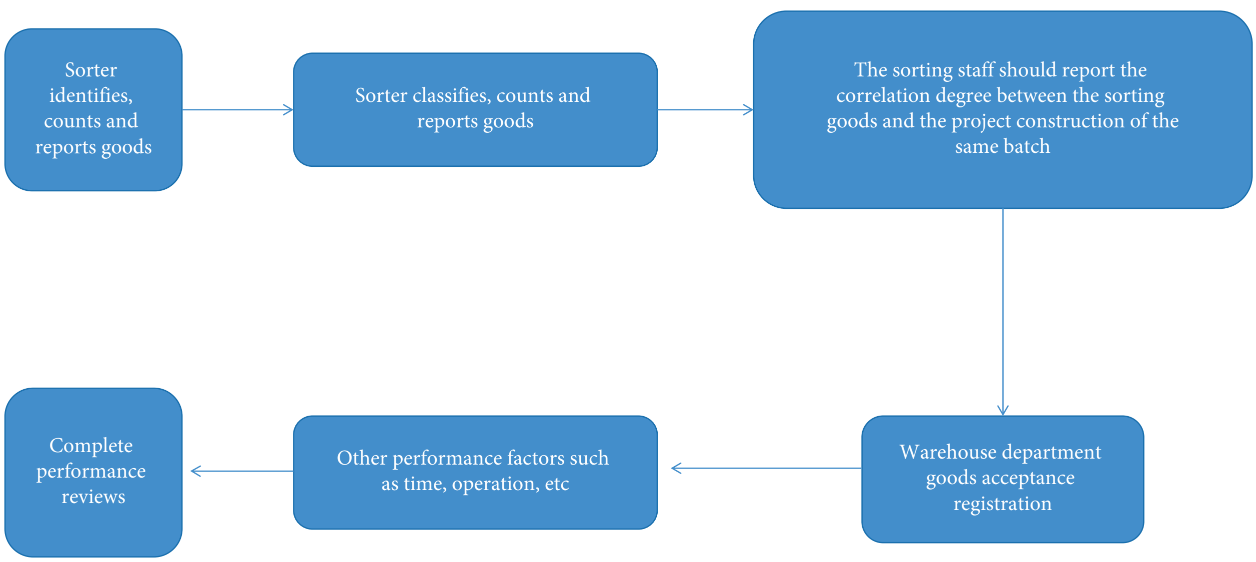


Figure 8: Workflow chart of performance appraisal.

state diagram, the average total cost (i.e., cost function) in [0, t] time is derived, and then the optimal inventory strategy is determined.

From the perspective of $[0, t_1]$, the maximum out of stock quantity $B = D \cdot t_1$.

From the perspective of $[0, t_1]$, the maximum stock-out $B = (P - D)(t_2 - t_1)$.

So, $Dt_1 = (P - D)(_t^2 - t_1)$; from this solution,

$$t_1 = \frac{(P - D)}{p} t_2. \tag{1}$$

From the perspective of $[t_2, t_3]$, the maximum out of stock quantity $A = (P - D) \cdot (t_3 - t_2)$, and the maximum inventory $A = D(t - t_3)$. So, $(P - D)(t_3 - t_2) = D(t - t_3)$; from this solution,

$$t_3 - t_2 = \frac{D}{P}(t - t_2). \tag{2}$$

In $[0, t]$ time, the storage fee is $(A/2)C_1(t - t2 = (1/2)C_1(P - D))(t_3 - t2(t - t_2))$.

The shortage fee is $(1/2)C_2 D t_1 t_2$; substituting into (1) and (2), after finishing, the following is obtained:

$$C(t_1, t_2) = \frac{(P - D)D}{2P}\left[C_1 t - 2C_1 t_2^2 + (C_1 + C_2)\frac{t_2^2}{t} + \frac{C_3}{t}\right]. \tag{3}$$

$$\text{Solving equations } \begin{cases} (\partial C(t, t_2)/\partial t) = 0 \\ (\partial C(t, t_2)/\partial t_2) = 0 \end{cases},$$

$$\text{Get: } t^* = \sqrt{\frac{2C_3}{C_1 D}} \cdot \sqrt{\frac{C_1 + C_2}{C_2}} \cdot \sqrt{\frac{P}{p - D}},$$
$$t_2^* = \left(\frac{C_1}{C_1 + C_2}\right) t^*. \tag{4}$$

It is easy to prove that the cost $C(t^*, t_2^*)$ at this time is the minimum value of the cost function $C(t, t^2)$. Therefore, the reference values of the optimal inventory strategy of the model are as follows:

Optimal inventory cycle:

$$t^* = \sqrt{\frac{2C_3}{C_1 D}} \cdot \sqrt{\frac{C_1 + C_2}{C_2}} \cdot \sqrt{\frac{P}{P - D}}. \tag{5}$$

Economic order quantity:

$$\begin{aligned} Q^* &= Dt^* \\ &= \sqrt{\frac{2\ DC_3}{C_1 D}} \cdot \sqrt{\frac{C_1 + C_2}{C_2}} \cdot \sqrt{\frac{P}{P - D}}. \end{aligned} \tag{6}$$

Shortage replenishment time:

$$\begin{aligned} t_2^* &= \left(\frac{C_1}{C_1 + C_2}\right) t^* \\ &= \sqrt{\frac{2C_3}{C_1 D}} \cdot \sqrt{\frac{C_1}{C_1 + C_2}} \cdot \sqrt{\frac{P}{P - D}}. \end{aligned} \tag{7}$$

Start supply time:

$$\begin{aligned} t_1^* &= \frac{(P - D)}{P} t_2^* \\ &= \sqrt{\frac{2C_3}{C_1 D}} \cdot \sqrt{\frac{C_1}{C_1 + C_2}} \cdot \sqrt{\frac{P - D}{P}}. \end{aligned} \tag{8}$$

End of supply:

$$t_3^* = \frac{D}{p} t * + \frac{(p - D)}{p} t_2^*. \tag{9}$$

Maximum stock:

$$A^* = D\left(t^* - t_3^*\right). \tag{10}$$

Maximum stock-out:

$$B^* = Dt_1^*. \tag{11}$$

Average total cost:

$$C^* = \frac{1}{t}\left[\frac{1}{2} C_1 (P - D)(t_3 - t2)\left(t - t2 + \frac{1}{2} C_2 D t_1 t_2 + C_3\right)\right] = \frac{2C_3}{t^*}. \tag{12}$$

Table 1 above fully shows that in the actual procurement of the company, the control and management of the procurement process is a key step to solve the cost problem, and optimizing the logistics system is an important way to control the cost. Ordinary transport vehicles cannot carry out real-time accurate positioning in the vehicle positioning link; that is, they cannot comprehensively analyze the transportation conditions in combination with the information of the carriage adjustment system and the position of the vehicle [23]. At present, the methods to solve such problems are as follows: first, the cockpit or driver carries out business positioning and communication feedback through the mobile terminal app. This method has the disadvantages of cumbersome and inconvenient operation and management, which increases the risk of transportation outsourcing of the company. Second, the disadvantage of this method is that the cost is too high. For the installation of the finished product positioning system and communication tools, it is first necessary to ensure smooth use. Second, the company's independent information system needs real-time data monitoring [24]. To sum up, the company has two main problems in the logistics and transportation link. First, the physical factors of the environment in which the raw materials are located need to be monitored, controlled, and adjusted in real time. Second, the transportation positioning system needs to be convenient and cannot be independent of the middle platform. The specific performance of these two problems and the disadvantages of the solution are shown in Table 2 below.

The batch crude oil, raw ester, and raw grease sorted and identified by the "sorting team" shall be classified and placed according to different requirements according to storage requirements. If 1# crude oil needs to be partially stored and partially used, it shall be placed in area a for long-term use after identification; 2# crude oil shall be taken from all inventories in batches and shall be placed in non-long-term use area B after identification; 1# raw ester shall be protected from light and high temperature ⟶ after identification, it shall be placed in non-sunlight and non-high-temperature area C; 2# raw ester shall be protected from light and liquid ⟶ after identification, it shall be placed in non-sunlight and non-wet area D; 1# raw fat needs to be close to water source; no fire ⟶ after identification, it shall be placed in non-fire source wet area E; 2# raw grease shall be kept away from the fire at the tuyere. After identification, it shall be placed in the non-tuyere wet area F, and so on, but the traditional goods homing operation of the company adopts nonintelligent homing operations such as manual vehicle + manual handling (this method may be applicable to enterprise sorting under other different needs), which prolongs the working hours, increases the workload and has low efficiency, seriously affects the production efficiency of the whole production link, and improves the labor cost. Therefore, the problem in the homing storage stage is that under the current production situation of the company, manual homing operation is not conducive to project requirements and sorting homing, as shown in Table 3.

After manual recording, the company's traditional sorting and sorting work will register the information of identification personnel and sorting work, and the warehouse administrator will summarize and feed back the situation of the production office within a certain period so as to realize performance statistics. With the increase of the quantity of goods and the complexity of manual operation, when the identity information cannot be effectively and timely identified, the problems in inventory management are as follows: first, it will increase procurement costs and management costs; second, it is difficult to identify the "sorting team" information efficiently and quickly and feed it back in time; and third, the connection between safety period and production cycle is chaotic. To sum up, the company has three main problems in the logistics and warehousing link: first, the warehousing and sorting cannot realize intelligent and efficient identification and classification; second, automatic placement cannot be realized after

Table 1: Purchase of certain crude oil—cost correspondence.

Optimal inventory cycle	Economic order quantity	Shortage replenishment time	Start supply time	End supply time	Maximum inventory	Maximum backorder	Average total cost
26.45 days (26 days)	21165 pieces/ time	7.55 days (8 days)	1.52 days (2 days)	22.67 days (23 days)	3023 pieces	1207 pieces	604.68 yuan/ day

Table 2: Transportation problems and shortcomings of traditional solutions.

Problems encountered in transportation	Specific performance of traditional solutions	Disadvantages of traditional solutions	Effect to be achieved	Problems encountered in transportation
Transportation cannot realize real-time monitoring and quality control	Temperature, humidity, pH	Special device	Expensive and impractical	Low cost and timeliness
The transportation positioning system is not convenient and independent	Real-time positioning and data feedback	App, finished GPS	Cumbersome operation and increasing control cost	Convenient and complete with company a

Table 3: Storage of different crude oil esters and esters.

Project materials	Personnel	Region	Important matters	Other
1# crude oil	3 (2 technicians + 1 warehouse keeper)	A	Partial storage and partial ready to use	Reference 1# document
2# crude oil	2 (1 technician + 1 warehouse keeper)	B	Full inventory; batch withdrawal	Reference 2# document
1# orthoester	4 (3 technicians + 1 warehouse keeper)	C	Full inventory; batch withdrawal	Reference 3# document
2# orthoester	3 (2 technicians + 1 warehouse keeper)	D	Avoid light; avoid liquid	Reference 4# document
1# crude fat	2 (1 technician + 1 warehouse keeper)	E	Near water source; prohibit cooking	Reference 5# document
2# crude fat	3 (2 technicians + 1 warehouse keeper)	F	Shelter; prohibit cooking	Reference 6# document

Table 4: Storage problems and shortcomings of traditional solutions.

Problems encountered in warehousing	Specific performance	Traditional method	Disadvantages of traditional methods	Effect to be achieved
The warehouse cannot realize intelligent sorting and cargo identification	Weight measurement and manual experience identification	Manual operation device identification	The operation is complex, time-consuming, and laborious	Reduce ineffective work
The warehouse cannot realize intelligent classified placement	Manual trolley and manual placement	Manual experience classification	Time-consuming, repetitive processes, inefficient	Save time and project cost
The warehouse cannot be effectively identified	Files recording	Form management	Increase management workload, not intuitive	Concise, clear, and intelligent

warehouse sorting; and third, the statistical work cannot be effectively identified after warehousing and sorting. The specific performance of these three problems and the disadvantages of other solutions are shown in Table 4.

According to the above problems, the performance process assessment scheme is established. The company has set up a performance assessment workflow in the production department to conduct the above performance assessment at different process stages. The workflow is shown in Figure 8.

According to the special operability of the company's production and supply links, the technical assessment is focused on the operation methods of crude oil, raw ester, and raw fat. The correctness of operation is an important guarantee for production design and sales links. However, the company currently adopts the methods of manual form registration and experience sharing to assess the technical performance of this operation. The assessment method is single and cannot accurately assess the technical operation. Under this system, the company tries to improve the performance system and assessment method and optimize the system through a certain performance incentive system. However, this method has fundamental limitations. For the links of manual operation, it can only be assessed in terms of quantity, man-hour, and completion degree, which cannot achieve the key role of controlling quality [25].

Based on the assessment of the original technical data, the company assesses the technical results in terms of goods sorting volume, identification volume, warehouse transportation volume, and project matching-related volume. However, for the company's project construction and sorter department span, some sorters have the problems of lag and delay in implementation, which will also affect the performance statistical feedback of warehouse management, so as to lag and interfere with the performance evaluation of the

Table 5: Performance problems and shortcomings of traditional solutions.

Problems encountered in performance	Specific performance	Traditional method	Disadvantages of traditional methods	Effect to be achieved
The accurate assessment of technical operation process cannot be realized	Fuzzy operation assessment and incomplete technical indicators	Form registration experience sharing	The operation is complex and easy to cause production lag	Assessment and specification of precision technology operation
There are delays and errors in the statistics of technical results	Implementation delay and strong subjectivity of judgment	Form registration, experience sharing	Waste of resources and failure to comply with relevant systems	Accurately count the quantity and objectively complete the sorting

Table 6: Test results.

Inspection name	TL		TS	
	Inspection value	*P* value	Inspection value	*P* value
Spatial fixed effect LR test	662.8552	0.0000	1100.2595	0.0000
Time fixed effect LR test	180.6226	0.0000	148.8757	0.0000

whole department of the production department. In addition, in the data statistics, the main sorters from the production design department are subjective in judging the accuracy of goods, and there are a certain amount of mistakes in the sorting and placement process, resulting in the waste of "leftover materials" for the company. Therefore, it is of practical significance to optimize the performance appraisal system of the company, as shown in Table 5 [25].

4. Results and Analysis

The spatial autocorrelation test shows that there is an obvious spatial dependence in the rationalization and upgrading of China's industrial economic structure. Since different fixed effects will affect the estimation results of the model, it is necessary to determine whether there are significant fixed effects in time and space according to the likelihood ratio test (LR). It can be seen from Table 6 that LR test shows that there are significant spatial individual fixed effect and time fixed effect. It is necessary to establish a time-space double fixed effect model to analyze the impact of logistics industry development on industrial economic structure optimization.

Table 5 gives the estimation results of the model in the form of two spatial weight matrices. It can be seen from Table 6 that the values of Wald test and LR test are significant at the level of 1% regardless of the form of spatial weight matrix, which shows that it is reasonable to adopt the spatial panel Dobbin model with dependent variable lag term and independent variable lag term. In addition, from the model estimation results, the log likelihood value, goodness of fit, and other statistics of the two forms of spatial weight matrix models have good goodness of fit. In comparison, the estimation result of economic distance weight matrix model is better than that of spatial adjacency weight matrix model. Therefore, the estimation result of economic distance weight matrix as spatial weight matrix is selected for analysis. In the spatial effect model, due to the spatial correlation, the traditional independent variable coefficient and significance level can no longer be used as the basis to measure the influence and significance of variables. The application of point estimation (IV/GMM) method and test results of one or more spatial regression models may lead to wrong conclusions. Using partial differential method to explain the influence of independent variables on dependent variables may also lead to the bias of results. In view of the above problems, it is believed that using the direct and indirect effects of independent variables can better explain the spatial panel data model. The direct effect is the change of the dependent variable caused by the change of the independent variable of a spatial unit, which includes the feedback effect after the independent variable affects the dependent variable of adjacent spatial units. The indirect effect is that the change of independent variable of a spatial unit leads to the change of dependent variable of adjacent spatial units. The upper part of Table 7 shows the coefficient estimation results of independent variables, and the lower part shows the direct and indirect effects of independent variables.

From the model estimation results in Table 6, the following conclusions can be drawn:

(1) The estimated values of $W * LN$ (TL) and $W * LN$ (TS) coefficients of the model are 0.2529 and 0.4569 respectively, which are significant at the level of 1%, indicating that there is a spatial positive correlation between the rationalization of industrial economic structure and the upgrading of industrial economic structure in China's provinces. Each province and region are not completely independent in the adjustment and optimization of industrial economic structure, and there is a significant positive spillover effect. This effect shows that the provinces and regions with high rationalization and upgrading index of industrial economic structure are close to each other. In terms of policy measures, there are demonstration effects and learning effects between adjacent provinces. The industrial economic structure adjustment policies and development direction of a region have a positive impact on its adjacent regions.

Table 7: Estimation results of spatial Doberman model.

Parameter	TL		TS	
	Economic distance matrix	Spatial adjacency matrix	Economic distance matrix	Spatial adjacency matrix
W ∗ LN (TL) or W ∗ LN (TS) LN (WL)	0.2529**(4.3992)	0.1789** (3.4721)– 0.1618*** (−8.2164)	0.4569** (10.1769) 0.02150** (3.6612)	0.3228** (5.9881) 0.0243** (3.5628)
LN (DK)	0.3296** (9.2061)	0.2423** (7.928)	0.2065** (6.4285)	0.2725** (7.9475)
LN (HR)	−0.4025*** (−6.8746)	−0.3428** (−6.1334)	0.3064** (5.9372)	0.3919*** (7.5336)
W ∗ LN (WL)	−0.3719** (−5.4256)	−0.3509*** (−8.6854)	0.0621** (2.6065)	0.0466** (2.5102)
W ∗ LN (DK)	−0.0652 (−0.6129)	0.0632 (0.8128)	−0.2075*** (−5.0146)	−0.2209*** (−5.5536)
Direct effect LN (DK)	0.3290 (8.9768)	0.2563 (7.5806)	0.1964 (6.3733)	0.2616 (7.9546)
Indirect effect LN (DK)	−0.0426 (−0.3739)	0.0760 (1.5636)	−0.1989 −(2.9596)	−0.1757 (−4.1284)
Direct effect LN (HR)	−0.3964 (−6.4888)	−0.3412 (−6.2413)	0.3850 (5.7224)	0.4227 (7.5636)
Indirect effect LN (HR)	0.3542 (−0.4893)	0.1707 (0.9632)	−0.2053 (−4.6931)	−0.2264 (−4.8366)

A province adopts measures to promote the adjustment and optimization of industrial economic structure, and its neighboring provinces also adopt similar measures, resulting in a positive spatial spillover effect.

(2) The direct effects of the development of logistics industry on the rationalization and upgrading of industrial economic structure are −0.2269 and 0.0289, respectively. The feedback effect can be obtained by calculating the difference between the direct effect of the independent variable and the coefficient of the independent variable. The feedback effect of the development of logistics industry on the rationalization and upgrading of industrial economic structure is −0.0053 and 0.0054, respectively, which is 1.8% and 29.7% of the direct effect. This shows that with the development of logistics industry, the rationalization and upgrading index of industrial economic structure in each province tends to rise; that is, the development of logistics industry can promote the rationalization and upgrading process of industrial economic structure in this region. The reasonable explanation of this phenomenon is that the logistics industry is a composite industry formed by the integration of traditional transportation, warehousing, postal industry, and emerging technology industries, with extensive industrial linkage. On the one hand, the development of logistics industry can produce large-scale resource agglomeration effect and market effect, improve the efficiency of resource flow, optimize the allocation of resources at the industrial level, avoid surplus and shortage, reduce the information search cost caused by industrial division of labor, and promote the process of rationalization of industrial economic structure. On the other one is the fact that the development of logistics industry can not only drive the development of transportation, post and telecommunications, and warehousing in the circulation sector, but also drive the development of finance, insurance, commerce, tourism, and other related tertiary industries through derivative demand. Moreover, it can also improve the operation efficiency of the secondary and tertiary industries, reduce the operation cost, guide the relevant industries in the primary and secondary industries to restructure the business process and organizational economic structure according to the concept of logistics industry, and realize the economic, reasonable, and efficient operation mode.

(3) The indirect effects of logistics development on the rationalization and upgrading of industrial economic structure are −0.4146 and 0.0613, respectively, which are significant at the level of 1% and 5%. The reasonable explanation of this phenomenon is that the transportation infrastructure is an important part of the logistics industry and has the network attribute. The production factors in the advantageous areas diffuse to the relatively backward surrounding areas through the network transportation infrastructure; it has promoted the development of various industries in surrounding areas.

(4) China's fixed asset investment promotes the upgrading of industrial economic structure and inhibits the rationalization of local industrial economic structure. This phenomenon may be caused by the fact that the current investment in fixed assets mainly tends to industrial industries, and the proportion of investment in the primary and tertiary industries is low, resulting in the unbalanced development of industrial economic structure. The indirect effect of China's fixed asset investment on the rationalization of industrial economic structure is negative and not significant, and the indirect effect on the upgrading of industrial economic structure is significantly negative, which shows that China's fixed asset investment has no obvious effect on the rationalization of industrial economic structure in adjacent areas and has an inhibitory effect on the upgrading of industrial economic structure. The direct effect of human capital on the rationalization of industrial economic structure is significantly negative, and the

direct effect on the upgrading of industrial economic structure is significantly positive, indicating that human capital can promote the optimization of local industrial economic structure.

5. Conclusion

Firstly, this paper analyzes the relationship between logistics industry and economic growth by using time series data, cointegration theory model, and Granger causality test. Then, using China's provincial panel data, this paper constructs a multidimensional factor panel data model including classical economic growth. Using the spatial lag model, this paper empirically analyzes the contribution of the development of logistics industry to regional economic growth, focuses on the current situation and problems of the company's manual logistics system, and analyzes and summarizes the defects and problems in the current company's supply chain. Secondly, after investigating the company's procurement and inventory process, it further puts forward the theoretical construction standards and technical requirements of intelligent logistics system based on the Internet of things. Finally, based on the provincial panel data from 1997 to 2011, the spatial panel Dobbin model is constructed by introducing the spatial lag term of dependent variable and the spatial lag term of independent variable, and the impact of the development of logistics industry on the optimization of industrial economic structure is analyzed from two aspects: the rationalization of industrial economic structure and the upgrading of industrial economic structure. The overall cointegration test shows that China's logistics industry and economic growth maintain a long-term and stable equilibrium relationship. Granger causality test shows that economic growth is not the reason for the growth of logistics network mileage and logistics effectiveness, and logistics industry is not the reason for economic growth. There is a significant positive spatial autocorrelation between logistics industry, and economic growth. Among the factors affecting regional economic growth, the development of logistics industry can promote regional economic growth, but the output elasticity coefficient is low. Among the neoclassical economic growth factors, capital and labor force have a greater contribution to economic growth. Among the factors of new economic growth, human capital has a significant positive impact on economic growth, while global trade and local government expenditure have a positive effect on economic growth, but not significant. Among the influencing factors of new economic geography, transportation infrastructure and market scale play a significant positive role in promoting economic growth. There is a significant positive spatial autocorrelation between the rationalization of industrial economic structure and the upgrading of industrial economic structure, and there are significant differences among the eastern, central, and western regions. The development of logistics industry not only promotes the optimization of industrial economic structure in this region, but also promotes the optimization of industrial economic structure in other regions, which shows that the development of logistics industry plays a positive role in promoting the optimization of China's industrial economic structure.

Data Availability

The data used to support this study are included within.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] A. Bouras, B. Eynard, S. Foufou, and K. D. Thoben, "[IFIP advances in information and communication technology] product lifecycle management in the era of internet of things," *Review of Product-Service System Design Methods*, Springer International Publishing, New York, NY, USA, 2016.

[2] L. Yin, W. Pan, J. Kuang, and M. Zhuang, "Application of bootstrap-DEA with fuzzy computing in performance evaluation of forklift leasing supplier," *IEEE Access*, vol. 8, 2019.

[3] Y. Chen, W. Zheng, W. Li, and Y. Huang, "The robustness and sustainability of port logistics systems for emergency supplies from overseas," *Journal of Advanced Transportation*, vol. 2020, Article ID 8868533, 10 pages, 2020.

[4] S. A. Elvy, "Commodifying consumer data in the era of the internet of things," *Boston College Law Review*, vol. 59, no. 2, pp. 424–522, 2018.

[5] J.-M. Yang and J.-H. Kim, "A study on the controllability function and sevice design for disaster damage reduction in the iot environment," *Journal of the Korea Society of Computer and Information*, vol. 21, no. 2, pp. 43–49, 2016.

[6] A. Bouras, B. Eynard, S. Foufou, and K. D. Thoben, "[IFIP advances in information and communication technology] product lifecycle management in the era of internet of thingsProduct lifecycle management in the era of internet of things," *Foot Plantar Pressure Estimation Using Artificial Neural Networks*, Springer International Publishing, New York, NY, USA, 2016.

[7] C. Sullivan, "Eu gdpr or apec cbpr? a comparative analysis of the approach of the eu and apec to cross border data transfers and protection of personal data in the iot era," *Computer Law & Security Report*, vol. 35, no. 4, pp. 380–397, 2019.

[8] J. Chen, O. Gusikhin, W. Finkenstaedt, and Y.-N. Liu, "Maintenance, repair, and operations parts inventory management in the era of industry 4.0," *IFAC-PapersOnLine*, vol. 52, no. 13, pp. 171–176, 2019.

[9] I. C. L. Ng and S. Y. L. Wakenshaw, "The internet-of-things: review and research directions," *International Journal of Research in Marketing*, vol. 34, no. 1, pp. 3–21, 2017.

[10] P. N. Mahalle, M. S. Pathan, and V. V. Kimbahune, "Special issue on internet of things, next generation networks, data mining, and cloud computing 2017 - part ii," *International Journal of Synthetic Emotions*, vol. 8, no. 2, p. 76, 2017.

[11] G. Fenza, "Editorial," *International Journal of High Performance Systems Architecture*, vol. 8, no. 1-2, pp. 1-2, 2018.

[12] A. G. Woodside, S. Sood, and Sood, "Vignettes in the two-step arrival of the internet of things and its reshaping of marketing management's service-dominant logic," *Journal of Marketing Management*, vol. 33, no. 1-2, pp. 98–110, 2016.

[13] J. S. Edwards, "Management of cyber physical objects in the future internet of things: methods, architectures and applications," *Computing Reviews*, vol. 57, no. 10, p. 584, 2016.

[14] M. A. R. R. H. Aachen, “Reference architectures for the internet of things,” *Zeitschrift für wirtschaftlichen Fabrikbetrieb*, vol. 115, no. s1, pp. 97–100, 2020.
[15] S.-B. Tsai and K. Wang, “Using a novel method to evaluate the performance of human resources in green logistics enterprises,” *Ecological Chemistry and Engineering S*, vol. 26, no. 4, pp. 629–640, 2019.
[16] V. G. Basareva, “Small businesses in a system of measures aimed at recovering the trajectory of economic growth,” *Studies on Russian Economic Development*, vol. 28, no. 5, pp. 521–527, 2017.
[17] E. G. Hansen and S. Schaltegger, “The sustainability balanced scorecard: a systematic review of architectures,” *Journal of Business Ethics*, vol. 133, no. 2, pp. 193–221, 2016.
[18] M. R. Palattella, M. Dohler, A. Grieco, G. Rizzo, J. Torsner, and T. Engel, “Internet of things in the 5G era: enablers, architecture, and business models,” *IEEE Journal on Selected Areas in Communications*, vol. 34, no. 3, pp. 510–527, 2016.
[19] C. Perera, C. H. Liu, and S. Jayawardena, “The emerging internet of things marketplace from an industrial perspective: a survey,” *IEEE Transactions on Emerging Topics in Computing*, vol. 3, no. 4, pp. 585–598, 2015.
[20] C. Arnold, D. Kiel, and K.-I. Voigt, “How the industrial internet of things changes business models in different manufacturing industries,” *International Journal of Innovation Management*, vol. 20, no. 8, pp. 1640015–1640035, 2016.
[21] D. Mishra, A. Gunasekaran, S. J. Childe, T. Papadopoulos, R. Dubey, and S. Wamba, “Vision, applications and future challenges of Internet of Things,” *Industrial Management & Data Systems*, vol. 116, no. 7, pp. 1331–1355, 2016.
[22] M. A. Razzaque, M. Milojevic-Jevric, A. Palade, and S. Clarke, “Middleware for internet of things: a survey,” *IEEE Internet of Things Journal*, vol. 3, no. 1, pp. 70–95, 2016.
[23] L. Wu, C.-H. Chen, and Q. Zhang, “A mobile positioning method based on deep learning techniques,” *Electronics*, vol. 8, no. 1, p. 59, 2019.
[24] J. Lin, W. Yu, N. Zhang, X. Yang, H. Zhang, and W. Zhao, “A survey on internet of things: architecture, enabling technologies, security and privacy, and applications,” *IEEE Internet of Things Journal*, vol. 4, no. 5, pp. 1125–1142, 2017.
[25] X. Sun and N. Ansari, “Edgeiot: mobile edge computing for the internet of things,” *IEEE Communications Magazine*, vol. 54, no. 12, pp. 22–29, 2016.

Hindawi
Scientific Programming
Volume 2022, Article ID 4145241, 11 pages
https://doi.org/10.1155/2022/4145241

Research Article

Analysis of the Influencing Factors of English Majors' Cross-Cultural Communicative Competence under Mobile Internet

Hongwei Luo [1,2]

[1]School of International Cooperation, Pingdingshan Polytechnic College, Pingdignshan 467001, Henan, China
[2]Graduate School, St. Paul University Philippines, Tuguegarao 3500, Cagayan, Philippines

Correspondence should be addressed to Hongwei Luo; lining@hncj.edu.cn

Received 14 January 2022; Revised 29 March 2022; Accepted 31 March 2022; Published 5 May 2022

Academic Editor: Ahmed Farouk

In order to study the influencing factors of cross-cultural communicative competence of English majors under mobile Internet, firstly, we made an empirical study on cross-cultural communication teaching for English majors. Then, we performed a comparative experiment between the mobile Internet-assisted high school English cross-cultural communication teaching model and the traditional teacher culture teaching-based teaching model. Finally, through questionnaires, informal interviews, and teachers' observation of the teaching process, this paper aims to make an empirical study on the feasibility and effectiveness of mobile Internet assisted foreign language teachers in cultivating students' awareness and ability of cross-cultural communication, so as to provide a basis for the follow-up research of cross-cultural communication teaching for English majors. The experimental results show that 93.4% of the students are satisfied with the mobile network-assisted English cross-cultural communication teaching model, and the integration of mobile network technology into English cross-cultural communication teaching has brought great changes to the teaching process. Compared with the traditional teaching mode of "chalk and blackboard," multimedia organically integrates text, pictures, audio, video, and network, which greatly attracts the attention of teachers and students.

1. Introduction

In order to realize the exchange of information, the dissemination and innovation of knowledge, and the creation of material and spiritual wealth under the background of internationalization and diversification, the talents trained by higher education need not only complete professional skills and knowledge but also advanced cross-cultural communication awareness and cross-cultural communication ability to meet the needs of social and national progress and development. Cross-cultural communication should be two-way and equal communication. English teaching overemphasizes the teaching of English language knowledge. At present, the strong culture of English-speaking countries continues to penetrate. Some English learners have become the "language endorsement tool" of western culture. They do not give equal voice to their mother tongue and lack a correct understanding of the status of their mother tongue (Figure 1). In addition, various western cultures are constantly infiltrating, and the inheritance of the "essence of mother tongue culture" is gradually emptied. Learners' cultural balance has been shaken, their values have been misunderstood, and they have lost their pride and self-confidence in their national culture and even lost the recognition of the cultural identity of the Chinese nation. For example, many students only know how to celebrate Christmas and Valentine's day in the west, but they know little about China's Dragon Boat Festival and Double Ninth Festival. English teaching ignores the cultural background of the other party as the subject of cross-cultural communication and violates the law of cross-cultural two-way communication. The teaching of Chinese culture does not run through all levels of English teaching, and English learners cannot well express, spread, and carry forward

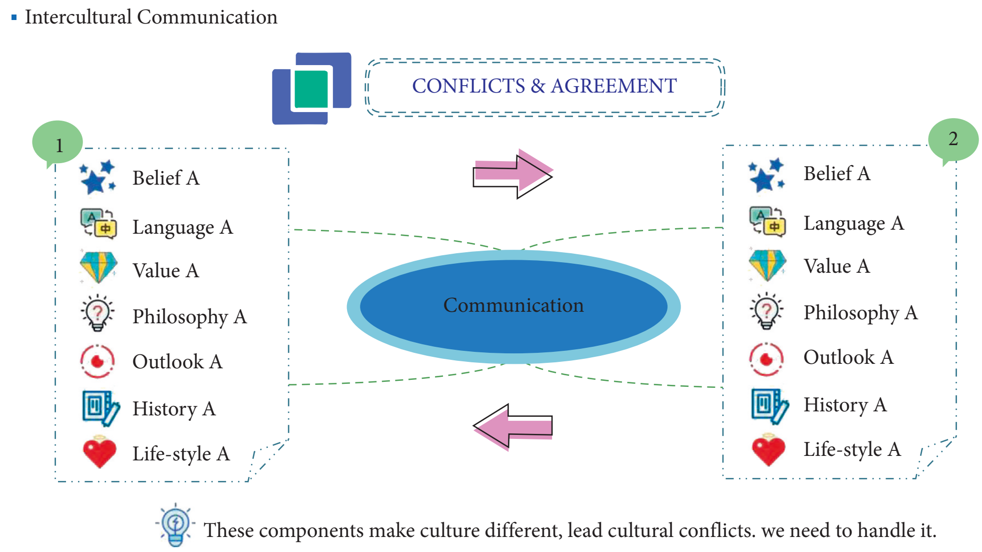


Figure 1: Mobile network teaching.

Chinese culture. Today, with the coexistence of economic globalization and cultural diversity, there is a greater need for foreign trade and foreign affairs compound talents with both professional English foundations and relevant professional knowledge and skills to meet the needs of society [1–3]. The core of Internet-assisted instruction includes two aspects: interactive teaching and personalized teaching. Complete learners' personality development is based on interactive teaching. Network-assisted instruction is a teaching method and mode to share teaching resources by relying on network technology. It is also to use modern Multimodal media information technology to establish a multidimensional interactive environment of teaching and learning, so as to stimulate the innovative spirit of education and the autonomous learning spirit of learners. Mobile Internet-assisted instruction mode is an assisted instruction activity based on computer Internet under the guidance of modern education concepts [4]. It makes full use of information technology and mobile Internet technology to transmit course information and integrate it into modern teaching. It closely connects teachers and students for multidirectional and effective communication, always takes students as the center, pays attention to knowledge guidance and ability training, and meets the needs of the current innovative talent training mode, so as to form a practical process of teaching and learning in which teachers and students participate together [5].

2. Literature Review

Hatakeyama and others believe that language is the carrier of culture, and the ultimate goal of foreign language teaching is to cultivate cross-cultural communicative competence [6]. Lilholt and others remind foreign language learners from the perspective of pragmatics that when communicating with native speakers, violating the social and cultural norms of the target language will lead to cultural pragmatic failure and the interruption of communication [7]. For the definition and composition of intercultural communicative competence, many scholars tend to analyze it from three levels: cognition, emotion, and behavior. Heath and others further refined these three levels: the cognitive level includes (1) mastering the linguistic and nonverbal rules of communication in the target language and (2) cultural understanding ability, that is, to understand the thinking mode of the target language, so as to have a deeper understanding of the politics, economy, history, religion, education, related values, ideology, and other aspects of the target language culture [8]. Herrero and others believe that the "transcendence" training model of cross-cultural communicative competence focuses on the attitude and emotion level, including the cognitive level, especially the critical reflection ability. In addition, it is not limited to the target language culture [9]. Bodnar and others believe that information-based teaching refers to the process in which students are the main body of teaching activities; teachers use modern information technology to improve the setting of the teaching system, enhance learners' interest, promote teaching effect, and optimize the distribution and fair use of teaching resources [10]. Van and others believe that the advantage of information-based teaching lies in realizing sufficient teaching interaction, establishing a vivid, intuitive, and interesting learning environment, and completing three-dimensional teaching. Compared with traditional teaching, the characteristics of information-based teaching are as follows: (1) there should be high sharing and real-time teaching information resources; (2) it is saved in digital form, simple and convenient, and has a large amount of storage space [11]. Herrero and others believe that for a long time, in the whole teaching system and classroom teaching practice of English Teaching in China, the teaching of English cross-cultural communicative competence has always been on the edge (Figure 2). The focus of language teaching is mostly on the training of grammar, pronunciation, structural function and listening, speaking, reading, and writing ability, but the training of special cultural communicative competence is rarely involved [9]. Seo and others believe that communicative culture teaching focuses on analyzing the cultural connotation embodied in

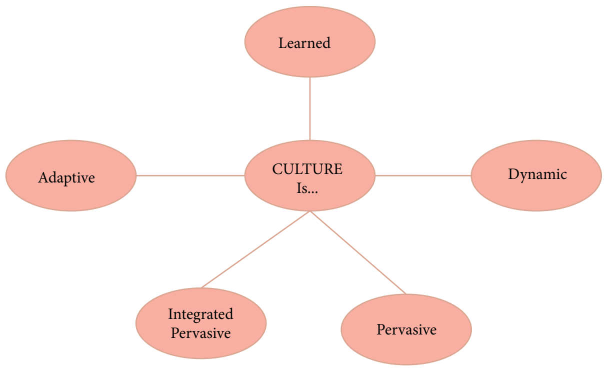


Figure 2: Characteristics of intercultural communication.

people's communicative discourse in audio-visual materials, especially the deep cultural contents embodied in people's discourse, such as values, mode of thinking, behavior habits, interpersonal relations, time orientation, and aesthetic interest [12]. Vaidya and others believe that we should give full play to the advantages of the network and strengthen the teaching of cross-cultural pragmatic knowledge. The richness of network resources provides students with a lot of cultural background knowledge, which helps students consider social and cultural factors when choosing a language and use appropriate language to achieve the success of cross-cultural communication.

3. English under Mobile Network

Instructional design, also known as instructional system design, plays an extremely important role in the process of teaching practice. The traditional instructional design model has been widely used in training and other industries, and its core includes the whole process from analysis, design, development, and implementation to evaluation, as shown in Figure 3.

The following principles should be followed in teaching design. (1) *Systematic Principle*. Instructional design is an organic whole. It is composed of subsystems such as teaching objectives, teaching objects, teaching contents, and teaching methods. Each subsystem is independent and interdependent [13]. Therefore, instructional design is to effectively coordinate each subsystem in order to optimize the teaching effect. (2) *Principle of Subjectivity*. Constructivism holds that learners are the main body of learning activities, so students' subjective initiative needs to be brought into play in the process of teaching. (3) *Feasibility Principle* [14]. Teaching design should meet the subjective and objective conditions and have certain operability. Therefore, teachers need to analyze the conditions such as learners and the learning environment. English teaching models are now classified into the following three categories:

(1) The supplementary model: this model retains the basic structure of the traditional classroom and enhances the interaction between students and teaching content by simply complementing extracurricular online activities based on technology or providing supplementary online learning materials.

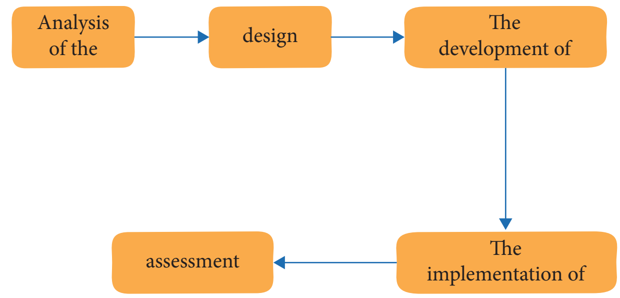


Figure 3: The basic process of instructional design.

(2) The replacement model: this model reduces face-to-face teaching time and instead increases students' online learning time. This model assumes that the effect of online learning in individuals or groups is better than that in the classroom.

(3) The emporium model: this model cancels all face-to-face teaching time, while learners use the online learning resources provided by the learning resource center to study at their own pace. During the learning process, the learning resource center provides teaching software, exercises, hypertext, online tests, and personalized help suitable for learners. The teaching idea of this model no longer depends on when teachers want to teach but on when students want to learn.

3.1. Mobile Network. In order to facilitate the analysis and application of mobile networks, such as network discovery, link prediction, and visualization, researchers abstractly represent the original data of mobile networks as a matrix or vector in a certain way [15]. At present, the representation method of community discovery problem mobile network is mainly an adjacency matrix. This method is introduced hereinafter.

Mobile networks can be represented in the form of graphs. The graph is usually represented by binary $G(V, E)$. For a network with N nodes, $V = \{v_1, v_2, \ldots, v_N\}$ represents the set of network nodes, $E = \{e_1, e_2, \ldots, e_M\}$ represents the set of edges in the network, $e = (v_i, v_j)$ represents the edge between node i and node j, and $M = IE(G)$ is the number of edges connected to the network. General mobile networks can be represented by $N \times N$ adjacency matrix A. Its definition is as follows:

$$A_{ij} = \left\{ \begin{matrix} 1, & i \\ 0, & \text{otherwise} \end{matrix} \right\}. \tag{1}$$

The adjacency matrix of an undirected graph is symmetric, but not necessarily a directed graph. This paper discusses the undirected weighted graph. Each row of the adjacency matrix can be regarded as a vector corresponding to a node. The representation method of the adjacency matrix is shown in Figure 4.

The adjacency matrix can maximize the characteristics of network structure and accurately represent the connection

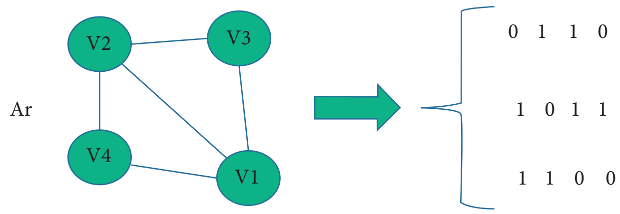


Figure 4: Network and its adjacency matrix.

relationship. This method is simple, direct, and convenient for statistics and connects the mobile network with the graph. Therefore, the development of graph theory also provides theoretical support for this method. The similarity algorithm based on common nearest neighbor mainly includes CN (common neighbor) algorithm, AA (Adamic ADAR) algorithm, and PA (preferred attachment) algorithm. Similarity algorithms based on node path length mainly include LP (local path) algorithm and RW (random walk) algorithm [16].

3.1.1. CN Algorithm. For any two nodes in the mobile network, the more the elements in their common neighbor set, the higher the probability of high correlation between them. The calculation formula is as follows:

$$\mathrm{sim}(x, y) = T(x) \cap T(y). \tag{2}$$

In formula (2), $T(x)$ represents the neighbor node set of node x and $T(y)$ represents the neighbor node set of node y. $T(x) \cap T(y)$ force represents the intersection of two neighbor node sets, that is, their common neighbor nodes. The value of $\mathrm{sim}(x, y)$ is equal to the number of common neighbor nodes and represents the similarity between nodes x, y.

3.1.2. AA Algorithm. AA (Adamic ADAR) algorithm was not applied in the field of network discovery at first. AA algorithm was first used in the field of information retrieval to analyze the similarity between web pages. It is found that the AA algorithm can be well applied in the field of network discovery. The calculation method is as follows:

$$\mathrm{sim}(x, y) = \sum_{z} \frac{1}{\log|T(z)|}, \tag{3}$$

$$z \in T(x) \cap T(y). \tag{4}$$

In formulas (3) and (4), $T(x) \cap T(y)$ represents the intersection of two neighbor node sets, that is, their common neighbor node, representing an element in the intersection. The algorithm first calculates the number of neighbor nodes of the z node, which is represented by $|T(z)|$, then calculates the reciprocal of the pair of $|T(z)|$ values, and then calculates all the qualified z according to the above steps and adds the results. The final result is the similarity between nodes x and y.

3.1.3. Jaccard Algorithm. Compared with the CN algorithm, the first two steps of the Jaccard algorithm are the same as the CN algorithm. First, obtain the intersection of two neighbor node sets, then perform a union operation on the two neighbor node sets to obtain the union of the two neighbor node sets, and then calculate the ratio of the number of elements contained in the intersection and union, which represents the similarity between the two nodes. The calculation method is as follows:

$$\mathrm{sim}(x, y) = \frac{|T(x) \cap T(y)|}{|T(x) \cup T(y)|}. \tag{5}$$

In formula (5), $T(x)$ represents the neighbor node set of node x, $T(y)$ represents the neighbor node set of node y, $T(x) \cap T(y)$ represents the intersection of two neighbor node sets, that is, their common neighbor node, and $T(x) \cup T(y)$ represents the union of two neighbor node sets, that is, all their neighbor nodes [17].

3.1.4. RA Algorithm. When the RA algorithm is applied to the field of community discovery, the goal of the algorithm changes and is no longer used to allocate resources. At this time, the algorithm takes the common neighbor node between nodes as the channel for allocating resources among nodes. The algorithm sets that any node initially carries a unit of resources, and the resources of the node can be evenly divided by its neighbor nodes. The number of resources obtained between the source node and the target node is the similarity between them. The similarity calculation method is as follows:

$$\mathrm{sim}(x, y) = \sum_{z} \frac{1}{T(z)}, \tag{6}$$

$$\mathrm{sim}(x, y) = \frac{|T(x) \cap T(y)|}{\sqrt{T(x) \cup T(y)}}. \tag{7}$$

It can be seen from formulas (6) and (7) that this formula is similar to formula (4). $T(x) \cap T(y)$ represents the intersection of two neighbor node sets, that is, their common neighbor node, and z represents an element in the intersection. The algorithm first calculates the number of neighbor nodes, represented by $|T(z)|$, then calculates the reciprocal of $|T(z)|$, then calculates each element in $T(x) \cap T(y)$ according to the above steps, and adds the results. The final result is the similarity between nodes x and y [18].

4. Experimental Analysis

4.1. Research Object. This research is carried out among 80 middle school students in a third middle school (Appendix (available here)). The research object is all the students in two classes of grade two in the high school. Each class has 40 people. The students participating in the study were divided into two groups, class A as the experimental group and class B as the control group. See Table 1.

4.2. Teaching Methods. In the teaching process of this study, the researchers provide learners with a variety of learning

Table 1: Basic information of students in class AB.

Group	Number of people	Average English test score
Experimental class	40	71.03 ± 2.31
Control board	40	70.03 ± 1.31

materials. These teaching materials are selected from a variety of computer-aided teaching software, such as person to person and U.S.A. The main reason for choosing the content of this kind of teaching software is its strong operability and whether it is vivid and interesting. At the same time, researchers also use a large number of satellite TV programs, DVD movies, network resources, and their own teaching courseware. The teaching courseware truthfully reflects the teaching ideas and teaching strategies used by professors in the teaching process, such as the use of constructivism theory and strategy. The use of these strategies is difficult to show through the traditional teaching classroom, but with the help of the mobile Internet, these strategies can effectively show the teaching content to learners comprehensively and truthfully. Another way is to use the network for autonomous learning. There are many network resources to choose from [19]. We believe that the most effective learning method in the teaching process is the combination of teachers' classroom-guided learning and network autonomous learning. Students can conduct online learning under the management and control of teachers and ask questions to teachers by sending e-mail or instant chat, or submit homework, or have student interaction.

4.3. Research Methods. The experimental teaching time starts in August and ends in January next year. The teaching involves two nature classes. The final examination of the first semester (September to August of the second year) of the two classes shows that the effective English scores of the students in the two classes are very close; that is to say, the mastery of the social and cultural background knowledge of the two classes is very similar. The students in class A of the experimental class were arranged to study in the online mobile Internet classroom with the help of mobile Internet devices and networks, while class B of the experimental class was assigned to study in the previous traditional classroom. For class A students, teachers use a variety of Internet technologies to motivate students to improve their learning motivation, encourage students to learn independently in the learning process, and persuade students to actively interact and cooperate with other learners in the learning process. At the same time, teachers focus on cultivating students' learning strategies and skills in the teaching process. With the help of the Internet, teachers try their best to provide students with a real situational environment and language environment, so that students can experience the real cultural environment. Internet mobile Internet devices can provide text formats, audio files, pictures, and video files, which makes students more truly integrate into the target language and cultural environment and more intuitively understand cultural phenomena. Through simulation and other Internet technologies, abstract cultural concepts are displayed to students in specific and understandable forms.

After 14 weeks of mobile Internet-assisted cross-cultural communication teaching process, as an important part of the project conclusion, the researcher conducted a semester-end questionnaire survey on 40 students in class A (experimental class). The questionnaire includes three parts. The first part consists of five declarative sentence patterns (agree/disagree), which aims to investigate students' attitudes toward mobile Internet-assisted English intercultural communication teaching. The second part includes twenty-five declarative sentence patterns (agree/disagree), which aims to find out the role of mobile Internet-assisted English cross-cultural communication teaching in cross-cultural communication awareness, initiative, and interaction in the whole process of cross-cultural communication teaching. The third part includes two open-ended questions, asking students to put forward their own suggestions and opinions on teaching methods.

4.3.1. Interview. The researcher conducted informal face-to-face interviews with 40 students in the experimental class and recorded the interview content after winning the consent of the interviewees for analysis, induction, and summary. During the interview, the researcher conducted face-to-face communication with 40 students in turn. The purpose of the interview is to confirm whether the students have a comprehensive understanding of the contents of the questionnaire and give truthful feedback, trying to find out as much information as possible that cannot be displayed in the questionnaire [20].

4.3.2. Questionnaire. After 14 weeks of multimedia-assisted intercultural communication teaching, as an important part of the project, the researchers conducted a semester-end questionnaire to 3–5 students in class A (experimental class). The questionnaire consists of three parts. The first part consists of five declarative sentence patterns (agree/disagree), which aims to investigate students' attitudes toward multimedia-assisted English cross-cultural communication teaching. The second part includes twenty-five declarative sentence patterns (agree/disagree), which aims to find out the role of multimedia-assisted English cross-cultural communication in the whole process of cross-cultural communication awareness, initiative, and interaction to the effect. The third part includes two open-ended questions, asking students to put forward their own suggestions and opinions on teaching methods.

4.3.3. Data Collection. The data were collected from two tests, a questionnaire, an informal interview, and the researcher's observation. The purpose of data analysis is to detect any significant changes in all items. The researchers carefully analyzed the data from two tests and a questionnaire. The records of informal interviews with students and the observation notes of teachers on students' behavior during teaching are also used as the raw materials for data analysis, from which researchers can obtain effective results [19].

4.4. Result Analysis. Figure 5 and Table 2 show the performance data of the pretest and posttest. We can clearly see many changes in the research data. Overall, the posttest shows that the average score of students studying in the mobile Internet classroom is much higher than that of students studying in the traditional classroom. The gap in students' average scores strongly supports this view. The mobile Internet-assisted English cross-cultural communication teaching method can improve academic performance more effectively than traditional teaching methods.

From Figure 6 and Table 2, we can clearly see that the average scores of preexperiment tests of class A and class B are very close, class A (72.4 points) and class B (71.1 points). However, after 17 weeks of comparative experimental teaching, the average scores of the two classes were significantly improved: class A increased from 72.4 in the pretest to 78.9 in the posttest; The average score of the control class (class B) increased from 71.1 in the pretest to 73.2% in the posttest. However, the scores of the two tests obviously show that the experimental class (class A) has a great improvement in performance. However, there was no significant change in the two test scores of the control class (class B) (improvement of 0.4). In terms of passing rate, class A has increased by 6.5%, while class B has only increased by 2.1% for the pretest [21]. Figure 6 more clearly shows the difference between pretest and posttest between the experimental class and control class.

The test results show that after the experimental study, the average score and passing rate of class B students have also improved to a certain extent—the average score has increased by 0.4 points and the passing rate has increased by 2.9%. However, researchers believe that the improvement of these two aspects is mainly due to the efforts of students in the learning process and the supervision of teachers. When teachers use mobile Internet-assisted teaching methods for class A students in the teaching process, class B students are also under pressure to study harder. The students of class B believe that although teachers adopt different teaching methods, they will be able to make progress in their academic performance through their efforts. Therefore, the progress of class B students' academic performance should be attributed to students' efforts rather than teaching methods.

The research results further confirm the theoretical analysis of the effectiveness of mobile Internet technology-assisted instruction explained in the previous chapters. Mobile Internet-assisted cross-cultural communication teaching solves the problems existing in cross-cultural communication teaching and promotes students' learning of cross-cultural communication theory. The results of the study provide strong practical support for the possibility of mobile Internet-assisted English cross-cultural communication teaching [22].

In Table 3, statement 1 shows that 96.3% of the students in the experimental class affirmed the effectiveness of audio and video materials of mobile Internet-assisted English intercultural communication teaching materials. The affirmative laws of statement 2 and statement 3 are 84% and 84.5%, respectively. Students agree that the display of intercultural communication teaching materials in the form

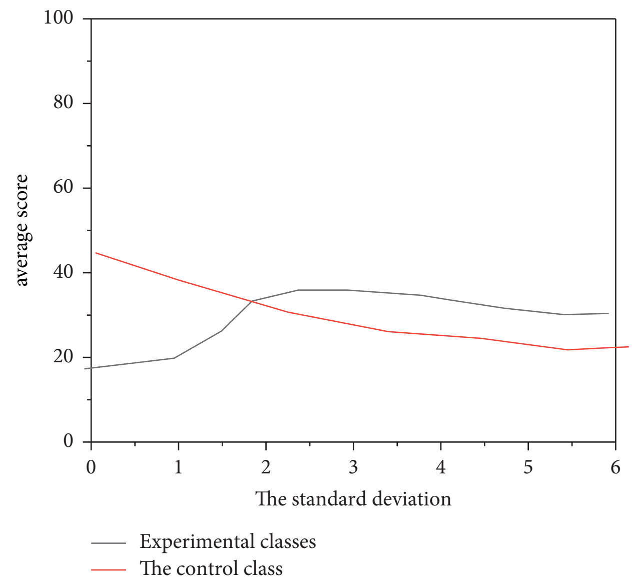


FIGURE 5: Results of experimental class and control class before and after the experiment.

TABLE 2: Comparison of two test results.

Class	Pretest		Posttest	
	Average	Passing rate (%)	Average (%)	Passing rate (%)
Experimental class	72.4	73.4	78.9	81.9
Control class	71.1	76.1	73.2	79

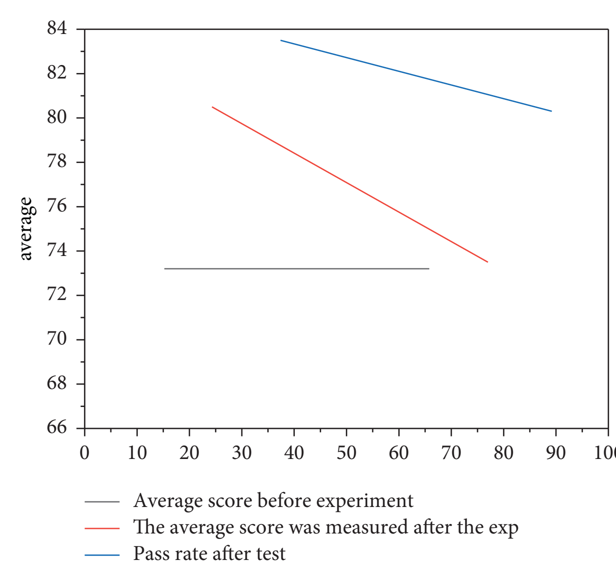


FIGURE 6: Comparison of pretest and posttest between the experimental class and control class.

Table 3: Students' attitudes toward mobile Internet-assisted English intercultural communication awareness training.

Statement content	Agree or not (%)
(1) I think the learning method of listening and watching in mobile Internet-assisted teaching is very effective.	96.3
(2) Mobile Internet-assisted English cross-cultural communication teaching method makes cultural knowledge easier to understand.	84
(3) Mobile Internet culture video materials are real and vivid.	84.5
(4) Mobile Internet-assisted English intercultural communication teaching method is fresh and interesting.	93.7
(5) Compared with traditional teaching methods, I prefer the teaching model of cross-cultural communication assisted by mobile Internet	91.3

of mobile Internet is more authentic, reliable, vivid, and easier to understand than traditional textbooks. Statement 4 shows that 93.7% of the students in the experimental class believe that the mobile Internet-assisted foreign culture teaching method is more fresh and interesting than the traditional English culture teaching method. Statement 5 shows that 91.3% of students prefer the model of mobile Internet-assisted English cross-cultural communication teaching.

In a word, the data in Figure 7 shows that the method of mobile Internet-assisted English cross-cultural communication teaching cultivates and enhances students' awareness of cross-cultural communication in the learning process.

In Table 4, statement 11 shows that 91.4% of the students in the experimental class think that they can easily adapt to the mobile Internet-assisted intercultural communication teaching environment. Statement 12 shows that 87.9% of the students believe that the mobile Internet-assisted English cross-cultural communication teaching method has strengthened their attention and memory of cross-cultural communication knowledge. Statement 13 shows that 78.9% of the students believe that the mobile Internet-assisted English intercultural communication teaching method enhances the efficiency of their cultural knowledge learning. For statement 14, 84.2% of the students were satisfied with their performance in the process of mobile Internet-assisted English intercultural communication teaching. 87.6% of the students agreed with statement 15 "I think the mobile Internet assisted English intercultural communication teaching model can better improve my cultural learning."

In short, Figures 7 and 8 show many advantages of the mobile Internet-assisted English intercultural communication teaching model in cultivating students' autonomous learning of intercultural communication knowledge. The results of qualitative rating (qualitative evaluation) correspond to the theories mentioned in the previous chapter. The mobile Internet learning environment was originally designed for learners' independent learning. Mobile Internet provides learners with real knowledge input, meaningful language learning tasks, and timely feedback, and learners can reasonably arrange learning time according to learners' learning plan [22].

Figures 9–11 show that after the mobile Internet-assisted English cross-cultural communication teaching, most of the students in the experimental class think that they are more willing to communicate with teachers, interact more actively with classmates, and have a dialogue with foreigners more confidently than before. The mobile Internet helps to cultivate students' awareness of cross-cultural communication in cross-cultural communication teaching and encourages them to communicate actively [23].

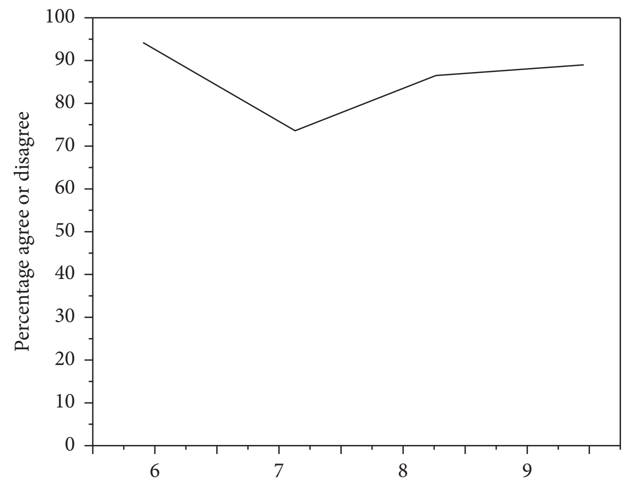


Figure 7: The impact of mobile Internet on students' awareness of cross-cultural communication.

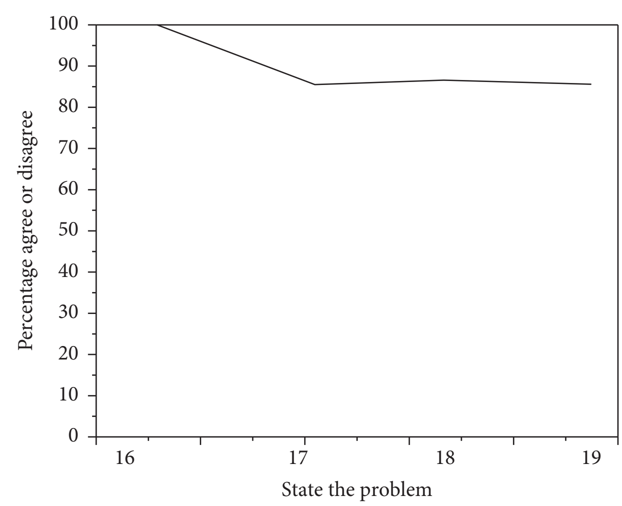


Figure 8: The influence of multimedia-assisted English intercultural communication teaching on students' cultural learning independence.

"For connecting with the same age students in English-speaking countries through the Internet," 75% of teachers think it is necessary, 15% of teachers think it is absolutely

Table 4: Effect of mobile Internet-assisted English intercultural communication teaching on students' self-confidence in the learning process.

Statement content	Agree or not (%)
(11) I think I can easily adapt to the mobile Internet-assisted cross-cultural communication teaching environment.	91.4
(12) I think the mobile Internet assisted English cross-cultural communication teaching method has strengthened my understanding of cross-cultural communication	87.9
(13) Attention and memory of communicative knowledge.	78.9
(14) I think the mobile Internet-assisted English intercultural communication teaching method enhances the efficiency of my cultural knowledge learning.	84.2
(15) I am very satisfied with my performance in the process of mobile Internet assisted English cross-cultural communication teaching	87.6

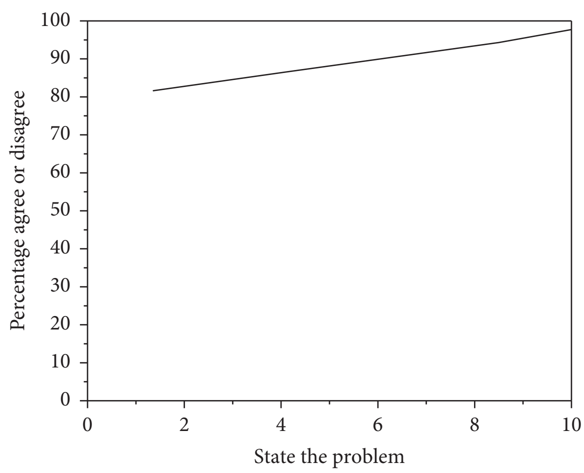


Figure 9: The influence of multimedia-assisted English intercultural communication teaching on students' interaction.

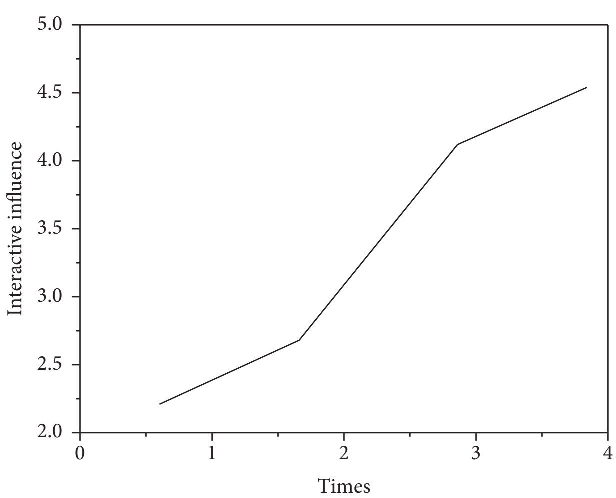


Figure 10: The impact of mobile Internet-assisted English intercultural communication teaching on students' interactivity.

necessary, and 10% of teachers say it is not necessary. For question 14 "The effect of reading English extracurricular books on students' acquisition of English cross-cultural communication knowledge," 50% of teachers think it has a great effect, 30% of teachers think it has a little effect, and 20% of teachers think it has a basic effect. For question 16 "In

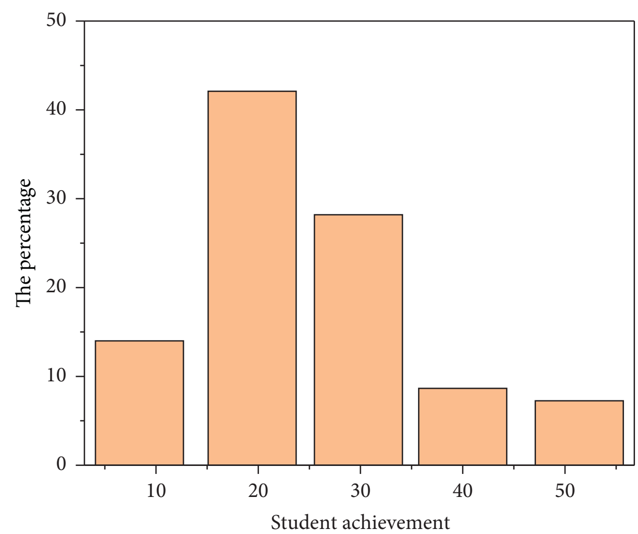


Figure 11: A map of the grades of the students.

addition to the classroom, through which channels can students acquire knowledge of cross-cultural communication," the 30 teachers who participated in the survey agreed that reading English extracurricular books and watching English film and television works are helpful, and the selection rate of these two items reached 100% and 93.3% "taking the initiative to meet foreign friends" to obtain knowledge of cross-cultural communication. To sum up, most teachers believe that the differences in the way of thinking and values between the East and the West are an important reason for the obstacles to cross-cultural communication with English speakers. Therefore, they are concerned about the knowledge of cross-cultural communication in the teaching process, and they will teach in the classroom related to the text [24]. They also believe that Chinese culture and English culture have a good auxiliary role in learning English. At the same time, they also believe that the Internet and English extracurricular reading materials are good ways to cultivate students' cross-cultural communication skills.

5. Conclusion

To sum up, there are many factors affecting the development of cross-cultural communicative competence of English majors, and their solutions are also diversified. First of all, we need to change the teaching concept and set up cultural courses scientifically. Schools need to provide conditions and build platforms to create simulated or real cross-cultural communication scenes for students. While doing a good job in English language training, professional teachers should pay attention to the transmission of customs and culture, ideological culture, and value culture in different countries and gradually cultivate students' ability to communicate across cultural levels through curriculum teaching and practical training, so as to lay a foundation for them to grow into qualified cross-border business talents. The cultivation of English majors' cross-cultural communicative competence meets the requirements of our times, and the task is arduous and very important. At the same time, the application of information network-assisted technology to cross-cultural communication teaching is an effective teaching attempt. On the one hand, it ensures innovation, practicability, popularity, and times of teaching; On the other hand, it meets the demand of the talent market for global cross-cultural communication talents. However, culture is two-way communication. Teachers should also cultivate English majors into excellent communicators of Chinese culture and make Chinese traditional culture go to the world in cross-cultural communication.

There are still some limitations to this study. First of all, in this study, the education of English culture is limited by the teaching itself, which only focuses on the basic theories and skills of English intercultural communication. Second, this multimedia-assisted English intercultural communication study lasted only 17 weeks from August to the end of January of the following year. The time frame is so short that the findings may not represent the full picture of what has changed for students in multimedia classrooms.

Further research is needed to understand this issue thoroughly and to produce more detailed and conclusive results. First of all, apart from social culture, culture covers a wide range. Future researchers can work in other cultures. For example, English and American literature courses or audio and visual courses for English learners. In this way, it will be enough convincing evidence to prove the feasibility and effectiveness of multimedia technology in assisting English intercultural communication teaching.

Appendix

Investigation on the Effect of Online and Offline Mixed Teaching of College English Intercultural Communication

Dear students, Hello! (College English Intercultural Communication) The course is coming to an end, and now we conduct a questionnaire survey on the online and offline mixed teaching methods for this course. The main purpose is to understand the mixed teaching effect. Through the evaluation and reflection of real data, timely feedback of teaching, in order to provide reference experience for mixed teaching methods. This questionnaire is made anonymous, and all the data are used for statistical analysis only. There are no right or wrong questions, please read carefully and complete the questionnaire according to your own personal experience, so that we can improve the mixed teaching. Thank you for your cooperation!

(1) Which college do you come from? (Single choice choice ∗ required answer)

(2) Your gender? (Single choice choice ∗ required answer)

(3) Your grade? (Single choice choice ∗ required answer)

(4) Where is your source? (Single choice choice ∗ required answer)

(5) What grades are you in the starting points of college English students? (Single choice choice ∗ required answer)

(6) Your current English level? (Single choice choice ∗ required answer)

(7) Have you ever been exposed to the online and offline hybrid teaching courses before? (Single choice choice ∗ required answer)

(8) Cross-cultural ability: Skills: Please read the following statement carefully, judge the degree of agreement according to your actual feelings, and light up the corresponding stars that fit your personal views. (1 = Very disagree 2 = Not agree 3 = uncertain 4 = compare agree 5 = Very agree) (please fill in 1–5 numbers score ∗ must answer)

    (1) I can complete unknown tasks through independent learning
    (2) I can locate learning resources (such as people, books, and network resources)
    (3) When others need help, I can express sympathy and give help
    (4) I can listen carefully to different opinions and interpret the meaning and intentions of others
    (5) I can observe the speaker's nonverbal message folder to help me understand the meaning of the fairy words

(9) Cross-cultural ability: Knowledge Please read the following statement carefully, judge the degree of agreement according to your actual feelings, and light up the corresponding stars that match your personal views. (1 = Very disagree 2 = disagree 3 = uncertain 4 = compare agree 5 = Very agree) (please fill in 1–5 number score ∗ must answer)

    (6) I can describe the basic cultural practices of destination language culture (such as eating habits, greeting, greeting and polite behavior)
    (7) I understand the influence of culture on communication in business, education, medical care and other aspects
    (8) I can exchange cultural knowledge in the humanities, science, system, society, economy and other fields

(9) I understand the similarities and differences between the specific ways of thinking and behavior in different cultures
(10) I can explain how business, financial and economic processes affect the functioning of society
(11) I understand the similarities and differences of different cultural ideology, social system, lifestyle and other aspects

(10) Cross-cultural ability: Attitude Please read the following statement carefully, judge the degree of agreement according to your actual feelings, and light up the corresponding stars that match your personal views. (1 = Very disagree 2 = Not agree 3 = uncertain 4 = compare agree 5 = Very agree) (please fill in 1–5 numbers score ∗ must answer)

(11) I am open-minded and interested in others' beliefs, values, traditions, and world outlook
(12) I can actively understand and appreciate the cultural diversity
(13) I am able to face the difficulties in cross-cultural communication strongly
(14) I can tolerate, understand and respect the values of other cultures
(15) I am able to tolerate, understand, and appreciate the different beliefs held by others
(16) I can respect people with different cultural backgrounds, social identities and religious beliefs

(11) Which kind of teaching mode do you prefer? (Single choice choice ∗ required answer)

O Offline face-to-face classroom teaching mode

O Simple online network teaching mode

O Mixed online and offline teaching mode

(12) Do you think it is necessary to combine the traditional classroom and the information-based classroom? (Single choice choice ∗ required answer)

O oblige

O unnecessary

O cannot be designated as

(13) Mixed online and offline teaching needs self-study before class through the platform. Are you willing to study independently? (Single choice choice ∗ required answer)

O be willing

O under protest

O as appropriate

(14) How about the teachers in your class using mixed online and offline teaching? (Single choice choice ∗ required answer)

O is more frequent

O occasionally used

O never use1

(15) Do you reject mixed online and offline teaching? (Single choice choice ∗ required answer)

O Repel

O More like

(16) Has online and offline hybrid learning brought you a great help? (Single choice choice ∗ required answer)

O Help is very big

O Help some help

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] Y. Wang and F. Yuan, "A study on the influence mechanism of PBL teaching model on non-English major students' critical thinking ability," *DEStech Transactions on Social Science, Education and Human Science*, no. 6, pp. 39–41, 2017.
[2] H. A. Sadri and M. Flammia, "Intercultural communication: a new approach to international relations and global challenges (sadri, h.a. and flammia, m.)," *IEEE Transactions on Professional Communications*, vol. 56, no. 1, pp. 81-82, 2013.
[3] J. Y. Hong, H. Ko, L. Mesicek, and M. B. Song, "Cultural intelligence as education contents: exploring the pedagogical aspects of effective functioning in higher education," *Concurrency and Computation Practice and Experience*, vol. 33, 2019.
[4] H. Song, G. A. Fink, and S. Jeschke, *Security and Privacy in Cyber-Physical Systems: Foundations, Principles and Applications*, Wiley-IEEE Press, Chichester, UK, 2017.
[5] T. Raisanen, "The use of multimodal resources by technical managers and their peers in meetings using English as the business lingua franca," *IEEE Transactions on Professional Communications*, vol. 63, no. 2, pp. 172–187, 2020.
[6] N. Hatakeyama, Y. Okada, K. Hayama, T. Kaburagi, and Y. Miyachi, "Training method of communication skills for train dispatchers in abnormal situations," *Quarterly Report of RTRI*, vol. 57, no. 2, pp. 138–143, 2016.
[7] P. H. Lilholt, L. K. E. Hæsum, L. H. Ehlers, and O. K. Hejlesen, "Specific technological communication skills and functional health literacy have no influence on self-reported benefits from enrollment in the telecare north trial," *International Journal of Medical Informatics*, vol. 91, pp. 60–66, 2016.
[8] C. D. C. Heath, T. Mcdaniel, H. Venkateswara, and S. Panchanathan, "Improving communication skills of children with autism through support of applied behavioral analysis treatments using multimedia computing: a survey," *Universal Access in the Information Society*, vol. 20, no. 1, pp. 13–30, 2021.
[9] P. Herrero, "Communication skills [the way ahead]," *IEEE Potentials*, vol. 35, no. 1, p. 4, 2016.
[10] C. A. Bodnar and R. M. Clark, "Can Game-Based Learning Enhance Engineering Communication Skills?" *IEEE Transactions on Professional Communication*, vol. 60, no. 1, pp. 1–18, 2017.

[11] A. J. A. M. Van Deursen, C. Verlage, and E. van Laar, "Social network site skills for communication professionals: conceptualization, operationalization, and an empirical investigation," *IEEE Transactions on Professional Communications*, vol. 62, no. 1, pp. 43–54, 2019.
[12] S. I. Seo, M. Sagong, and S. W. Son, "Global response of submerged floating tunnel against underwater explosion," *KSCE Journal of Civil Engineering*, vol. 19, no. 7, pp. 2029–2034, 2015.
[13] K. Vaidya and J. Ca Mpbell, "Multidisciplinary approach to defining public e-procurement and evaluating its impact on procurement efficiency," *Information Systems Frontiers*, vol. 18, no. 2, pp. 333–348, 2016.
[14] S. Kumar, S. Khan, A. K. Verma, and P. D. Dwivedi, "Identification and characterization of major IgE binding of purified allergenic protein (11 kDa) from Buchanania lanzan," *Food Research International*, vol. 125, Article ID 108640, 2019.
[15] H. Tao, W. Zhao, R. Liu, and M. Kadoch, "Space-air-ground IoT network and related key technologies," *IEEE Wireless Communications*, vol. 27, 2019.
[16] A. A. Ahmed and A. Ali, "A comparative study of QoS performance for location based and corona based real-time routing protocol in mobile wireless sensor networks," *Wireless Networks*, vol. 21, no. 3, pp. 1015–1031, 2015.
[17] X. Wang, T. Yang, M. Wortmann et al., "Analysis of multi-dimensional hydrological alterations under climate change for four major river basins in different climate zones," *Climatic Change*, vol. 141, no. 3, pp. 483–498, 2017.
[18] J. Mahlknecht, D. Merchán, M. Rosner, A. Meixner, and R. Ledesma-Ruiz, "Assessing seawater intrusion in an arid coastal aquifer under high anthropogenic influence using major constituents, sr and b isotopes in groundwater," *The Science of the Total Environment*, vol. 587-588, pp. 282–295, 2017.
[19] K. H. Kim, J. E. Szulejko, H. J. Jo et al., "Measurements of major VOCs released into the closed cabin environment of different automobiles under various engine and ventilation scenarios," *Environmental Pollution*, vol. 215, pp. 340–346, 2016.
[20] A. K. Singh, "Major development under Gaussian filtering since unscented Kalman filter," *IEEE/CAA Journal of Automatica Sinica*, vol. 7, no. 99, pp. 1–18, 2020.
[21] B. Lian, L. Chen, M. Liu, T. Fang, and J. Hu, "The quantitative analysis for the formation of carbon fiber paper and its influencing factors," *Journal of Materials Science*, vol. 55, no. 15, pp. 6566–6580, 2020.
[22] H. S. Du, B. Zhan, J. Xu, and X. Yang, "The influencing mechanism of multi-factors on green investments: a hybrid analysis," *Journal of Cleaner Production*, vol. 239, Article ID 117977, 2019.
[23] T. Zhou, X. y. Ma, X. Liu, and Y. Li, "Quantitative analysis on influencing factors for interface propagation-based thermal conductivity measurement method during solid-liquid transition," *Journal of Central South University*, vol. 26, no. 8, pp. 2041–2055, 2019.
[24] M. U. Nadeem, R. Mohammed, and S. Dalib, "Retesting integrated model of intercultural communication competence (IMICC) on international students from the asian context of Malaysia," *International Journal of Intercultural Relations*, vol. 74, pp. 17–29, 2020.

Hindawi
Scientific Programming
Volume 2023, Article ID 9874567, 1 page
https://doi.org/10.1155/2023/9874567

Retraction

Retracted: Design and Research of Computer-Aided Translation Teaching Course under the Background of Embedded Microprocessor Wireless Communication

Scientific Programming

Received 29 August 2023; Accepted 29 August 2023; Published 30 August 2023

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

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

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

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

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

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

References

[1] X. Yuan and R. Zhu, "Design and Research of Computer-Aided Translation Teaching Course under the Background of Embedded Microprocessor Wireless Communication," *Scientific Programming*, vol. 2022, Article ID 8594212, 14 pages, 2022.

Hindawi
Scientific Programming
Volume 2022, Article ID 8594212, 14 pages
https://doi.org/10.1155/2022/8594212

Research Article

Design and Research of Computer-Aided Translation Teaching Course under the Background of Embedded Microprocessor Wireless Communication

Xiujuan Yuan and Ruike Zhu

School of Foreign Languages, Zhengzhou SIAS University, Zhengzhou 451100, China

Correspondence should be addressed to Ruike Zhu; 18339@sias.edu.cn

Received 23 February 2022; Revised 22 March 2022; Accepted 1 April 2022; Published 30 April 2022

Academic Editor: Ahmed Farouk

The background of wireless communication is the background of the current society. On this basis, the use of embedded microprocessors for computer-assisted translation teaching courses can well cultivate the practical abilities of college students and enable them to quickly integrate into the society. In the context of wireless communication, this article conducts the design and research of computer-assisted translation teaching courses based on embedded microprocessors, explores the use of high-tech system to train students in colleges and universities, and promotes the reform of college classrooms. This research is to use computers for assisted translation and embedded microprocessors for related calculations in translation teaching courses in colleges and universities, which can improve students' learning efficiency to a certain extent. The experimental results show that the concentration of students in computer-assisted teaching is 20% higher than that of students in traditional teaching, and other related data are more than 8% higher. The teaching of computer-assisted translation courses benefits students greatly.

1. Introduction

Under the influence of the globalization process, China, Russia, the United Kingdom, and other countries have realized economic, cultural, and technological exchanges at multiple levels, which has promoted the rapid development of various technologies such as Internet technology, computer technology, big data technology, and cloud computing technology. Under the current situation, the rapid development of informatization and digital technology has made information the key to the development of enterprises and social progress, and wireless communication technology has also been developed by leaps and bounds. It is no exaggeration to say that the development of wireless mobile communication technology is gradually changing the world. Radio was first used in navigation, using the Morse telegraph to send messages between ships and land. Today, radio is used in many forms, including wireless data networks, various mobile communications, and radio broadcasts. As the main training of talents in the current development of our country, the digital construction of classrooms in major colleges and universities and the application of wireless communication technology have become the new research directions of major colleges and universities. Computer-aided translation (CAT) refers to the process of using computer programs to translate natural language into other different natural languages. Wireless power transmission technology has been used in many fields, such as offshore wind power stations to transmit electricity to land and to areas with difficult natural conditions. This is different from automatic translation, which uses word processing software in a simple process, while computer-assisted translation can use database functions and translation programs to provide translators with suggestions and solutions, thereby saving time and money in efficient translation. This ensures the consistency of quality and translation style. CAT is now the main course for postgraduate translation in China. It was originally an elective course set up under the translation course system according to the requirements of the academic postgraduate training program. As a new form of training professional translators, CAT has become an important link in the MTI education system.

The problems, which universities domestic and abroad have been trying to solve, are how to tap into the benefits of scientific research and teaching in colleges and universities in the context of wireless communication technology and how to provide computer-assisted translation courses that really use their advantages. At the beginning of the translation course, experts have fully realized the importance of relying on the strong foundation of domestic universities in the field of wireless communication and computer professional technology research and strive to integrate the two. Among all the courses of MTI, CAT is relatively more important, a door of operability. Because, on the one hand, it has powerful functions and can take advantage of professional English translation and auxiliary software to quickly process a large number of translated texts and provide professional and accurate translation services for English majors. On the other hand, it can also allow students to gradually participate in project work through project simulation training in the classroom under the guidance of professional and technical personnel, ensuring that students can understand and be familiar with the project process and work. Responsibility in the training process in colleges and universities is to lay the foundation for finding suitable jobs in the future and to be useful senior technical and integrated talents with translation skills.

With the advent of the Internet age, major colleges and universities now have higher requirements for the quality of classroom teaching, and they are also considering the application of various advanced technologies to college classroom education. The first thing to do is to apply computer-assisted teaching courses. Classroom, based on this intelligent teaching, has developed. The intelligent teaching tool Rain Classroom provides new research ideas and directions for education reform. Li Da-Hong et al. analyzed the characteristics of Rain Classroom, studied the problems in flipped classroom teaching, and designed a new type of flipped classroom based on Rain Classroom. Teaching mode: The results show that the students in the Rain Classroom learn more than the traditional teaching methods, and the class also improves the teamwork ability [1]. Based on the teaching innovation of computer-aided environmental art design major, Li has better researched various professional directions. The software knowledge that students need to design professional courses is constantly shrinking. In order to allow students to master and use a variety of design software in a short time, Li Y and others build a modular teaching model of environmental art design. Design software promotes designers' rapid and true performance and plays an important role in the process [2]. Zhang explained the application status of computer-aided design in modern clothing design teaching, using typical types of clothing products to use enterprises as the carrier of teaching content, using enterprise actual tasks as classroom teaching methods, and attaching importance to the consistency of student learning and practical work. Students practice teaching and explore the requirements of classroom and enterprise integration technology innovation [3]. Su et al. focused on the construction of a computer-assisted intelligent tutoring system based on a new teaching model and its impact on teachers' sense of self-efficacy in teaching. Based on the actual needs of the ICAI system, the theoretical basis and development principles of the intelligent tutoring system are explained, the system construction of the student model and the teacher model are studied, and the realization of the intelligent tutoring system is analyzed [4]. In view of the shortcomings in the traditional computer-assisted teaching process and combined with the latest development of computer technology, Ma and Miao proposed a computer-assisted teaching application system. The system can take advantage of the characteristics of the physical education system through the latest computer and intelligent technology, and its use will bring greater convenience and better teaching to physical education [5]. Based on the concept of ecological teaching, Zhang analyzed the parameters of computer technology in the theoretical model and the ecological teaching system and designed the ecological framework of the role of computer-assisted technology in college English teaching and the theoretical evaluation model of ecological teaching effects. A good learning environment for students with the concept of ecological teaching is created, and students' cross-cultural communication skills and professional English ability are cultivated [6]. Du analyzed the application optimization and teaching innovation of computer-aided design in gardening courses. Before learning computer-assisted courses, we should reasonably set up landscape professional courses, further strengthen the construction of professional basic courses, improve students' professional skills, and enable students to fully grasp the standards of garden planning and design [7]. However, in the research of the abovementioned related experts and scholars, the computer-assisted translation teaching course is not based on the current wireless communication background. Although it has been improved to a large extent compared with the traditional learning method, it is not without closely following the development of the times, there are also certain flaws in theory, which will not apply with the changes in the times.

Based on the consideration of traditional translation teaching courses, this article is based on the embedded microprocessor under wireless communication technology for computer-assisted translation classroom teaching. Students should be trained to be proficient in some basic skills, to be able to proficiently operate the translation-related tasks involved in the software provided by CAT software suppliers, to have a comprehensive understanding of the basic usage of CAT, to further master the use of at least one internationally accepted machine translation tool, and to be clear with the specific working mechanism of CAT and machine translation. Let students understand the principles of computer terminology management, combined with the basic technologies of wireless communication technology, and learn and use computer hardware systems under embedded microprocessors, which can effectively combine

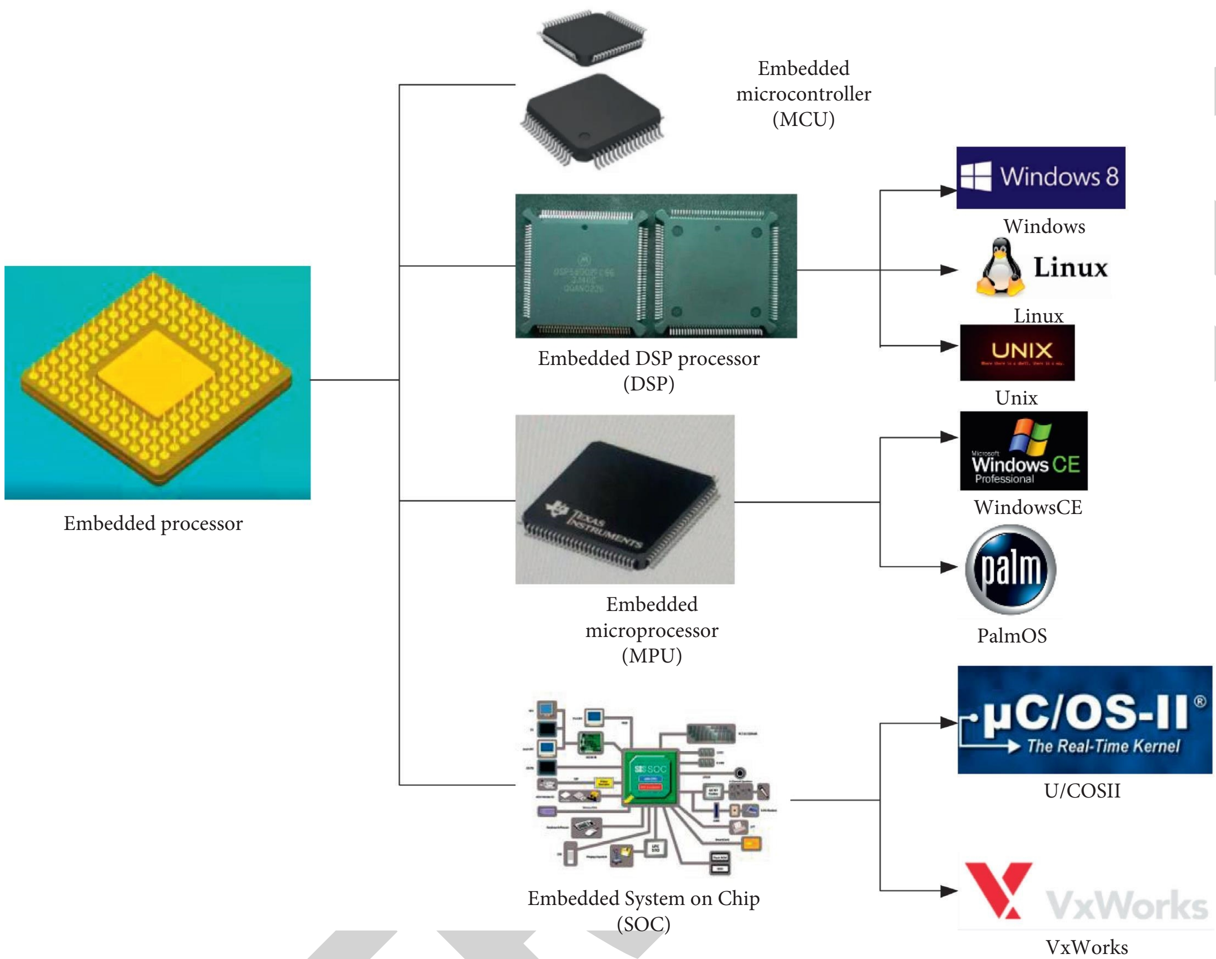


FIGURE 1: Microprocessor system structure and embedded system design.

these technologies and apply them in the design of daily translation courses.

2. Computer-Aided Research in the Context of Wireless Communication with Embedded Microprocessors

2.1. Embedded Microprocessor. The core of the embedded system is the embedded processor, which is a hardware unit including control and auxiliary system operation [8]. The scope is extremely wide, from the original 4 bit processor, the 8 bit single-chip microcomputer that is still in large-scale application to the 32 bit and 64 bit embedded CPU that is widely used now. Embedded processors include embedded microcontroller (MCU), embedded DSP processor (DSP), embedded microprocessor (MPU), and embedded system on chip (SOC), as shown in Figure 1 is the structure of the microprocessor system and embedded system design [9]. The biggest difference between these embedded microprocessors is the speed and real-time performance of digital signal processing operations. Since the advent of microprocessors, the development of embedded systems has been changing with each passing day. In the entire embedded system, the core is undoubtedly the embedded processor, which is related to the performance of the entire system [10]. The embedded microprocessors that are most popular to date will still be respected in the future for a long time.

Embedded microprocessors are mainly evolved from the core CPU in general-purpose computers [11]. Its characteristic is that it has a 32 bit or more processor, with excellent performance, but with it is the high price [12]. Microprocessor refers to the central processing unit (CPU) composed of one or a few large-scale integrated circuits. The CPU is a large-scale integrated circuit. However, unlike traditional computer processors, in actual embedded applications, only functional hardware closely related to embedded applications is retained, and other redundant functional parts are removed, so that embedded applications can be realized with the lowest power consumption and resources, the special requirements [13]. The core of the hardware layer of an embedded system is an embedded microprocessor. The biggest difference between an embedded microprocessor and a general-purpose CPU is that most of the embedded microprocessors work in systems specially designed for specific user groups. The completed tasks are integrated in the chip, which is conducive to the design of embedded systems tend to be miniaturized, while also having high efficiency and reliability [14]. Figure 2 shows an overview

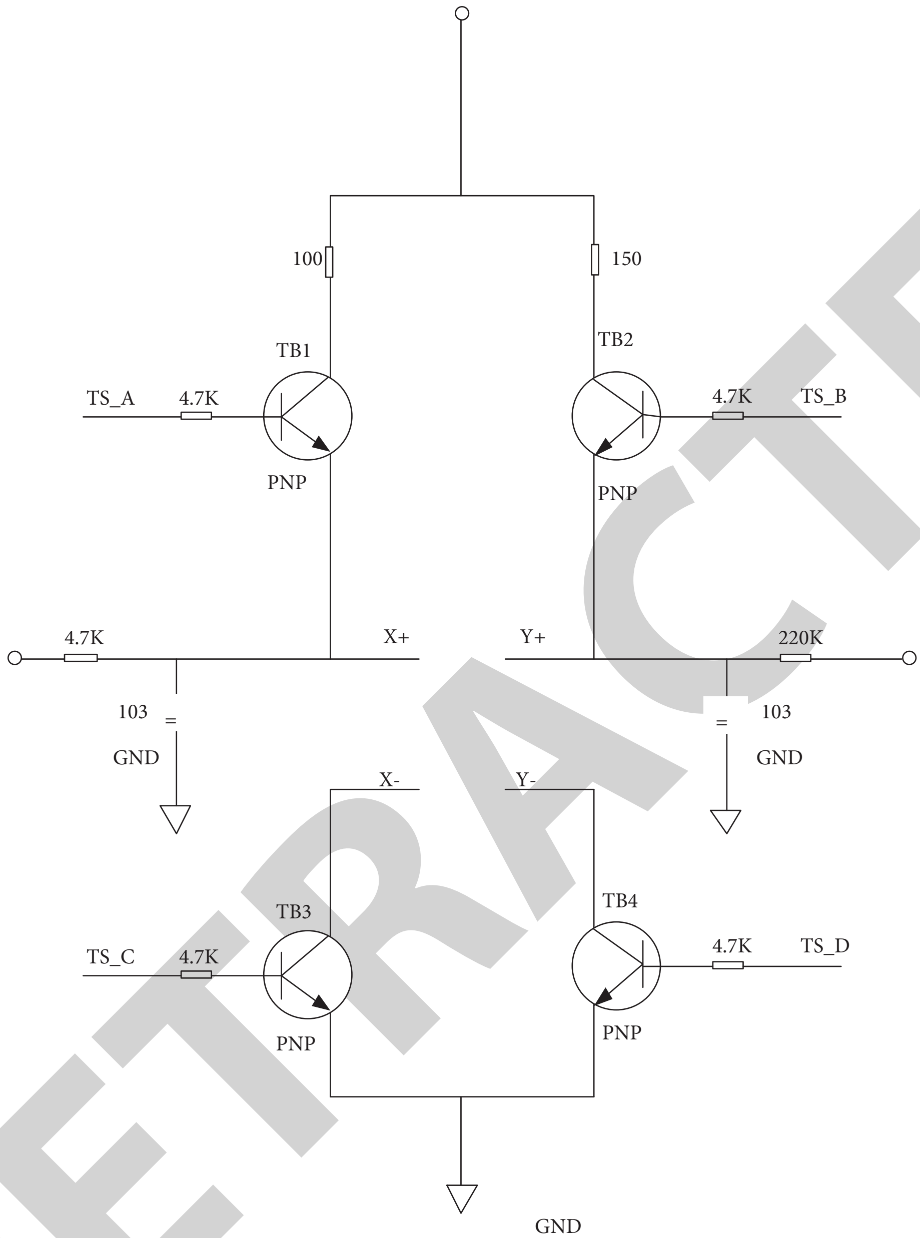


Figure 2: Overview of an embedded microprocessor.

diagram of an embedded microprocessor, which combines many functional blocks and integrates many functions on a small chip, which is a manifestation of the current technological advancement [15].

In the late 1970s, embedded microprocessors were evolved and they underwent four major development stages, namely SCM, MCU, networking, and software hardening [16]. The design of the embedded microprocessor is similar to the microprocessor design of the ordinary desktop computer, but the working stability is higher, the power consumption is lower, and the adaptability to the environment (such as temperature, humidity, electromagnetic field, vibration, etc.) is strong, smaller in size, and has more integrated functions [17]. In the field of desktop computers, the main indicator when comparing processors is computing speed. From a 386 computer at 33 MHz to a Pentium 4 processor at 3 GHz, the increase in speed is the change that users are most concerned about. The response speed of embedded microprocessors in different environments is not the same, and the internal processing system will have subtle changes. The choice of the embedded processor must be based on the design requirements, in the performance, power consumption, function, size and packaging form, SoC level, cost, commercial considerations, and many other factors to compromise [18].

2.2. Wireless Communication Technology. Wireless communication refers to the long-distance transmission

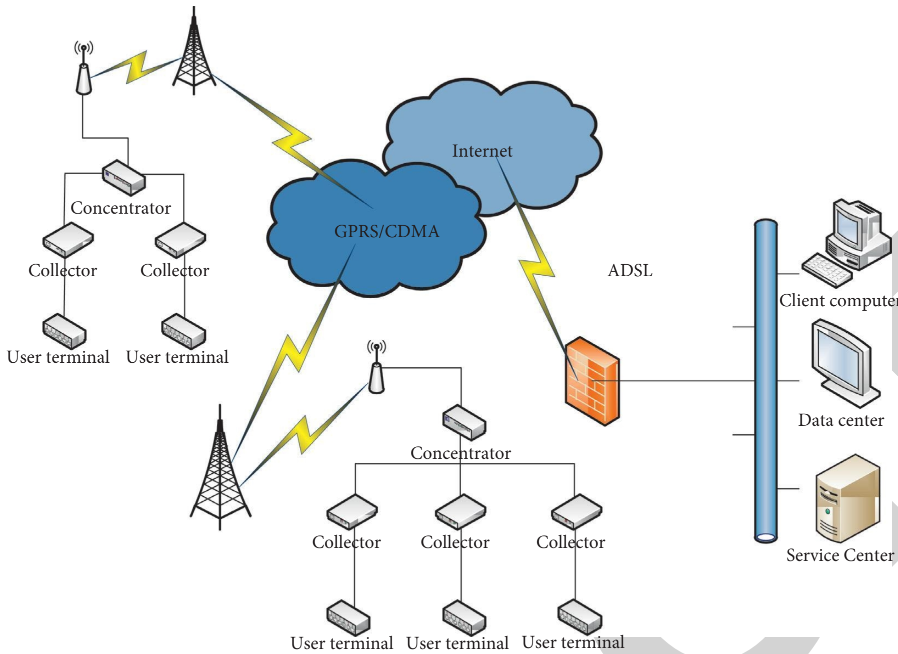


Figure 3: Transmission route map of wireless communication technology.

communication between multiple nodes without propagation through conductors or cables. Wireless communication can be carried out by radio as shown in Figure 3. Wireless communication includes a variety of fixed, mobile, and portable applications, such as two-way radios, mobile phones, personal digital assistants, and wireless networks [19]. Other examples of radio wireless communication include GPS, garage door remotes, and wireless mice. Most wireless communication technologies use radio, including Wi-Fi, which is only a few meters away, and deep space networks that communicate with Voyager 1 and have a distance of more than millions of kilometers. The difference between other electromagnetic wave wireless technology and wireless communication technology lies in whether the quality of information transmission can be guaranteed and the speed will be faster. However, some wireless communication technologies do not use radio, but use other electromagnetic wave wireless technologies, such as light, magnetic field, and electric field [20]. Nowadays, wireless communication technology has been well developed and is widely used in all walks of life. It is a technology that is widely used in industries and is also one of the foundations of current 5G, Internet of Things, and other technologies [21].

The CDMA communication system is one of the latest technologies in the context of wireless communication. It is widely used in all walks of life. It can achieve accurate and reliable wireless communication, can achieve spread-spectrum code capture (initial synchronization), and it can also achieve synchronous tracking of coding sequence (precise synchronization) [22]. CDMA is an advanced wireless spread spectrum communication technology used in digital cellular mobile communication. It can meet the demand of operators for large capacity, low cost, and high-quality mobile communication system in recent years. According to the phase difference between different information, the control signal can reduce the phase difference, and the phase of the control local sequence is consistent with the phase sequence at the time of transmission. The phase discriminator that can achieve this function has an S-shaped curve, which is realized by its own correlation characteristics [23].

Suppose the characteristic of $1/2T_C$ phase discriminating curve is $D_{T_C/2}(\tau)$, and the characteristic of T_C phase discriminating curve is $D_{T_C}(\tau)$, then

$$\begin{aligned} D_{T_C/2}(\tau) &= R_{PN}(\tau - 1/2T_C) - R_{PN}\left(\tau + \frac{1}{2}T_C\right), \\ D_{T_C}(\tau) &= R_{PN}(\tau - T_C) - R_{PN}(\tau + T_C). \end{aligned} \tag{1}$$

Using the code sequence synchronization tracking method formed by the phase discrimination characteristics of (1) and (2), the transmitted information can be controlled in real time in the wireless communication technology.

$$\begin{aligned} W_E(t) &= \sqrt{2P}PN(t-\tau_S).PN(t-T_C-\hat{\tau}_S) + n(t).PN(t-T_C-\hat{\tau}_S), \\ W_L(t) &= \sqrt{2P}PN(t-\tau_S).PN(t+T_C-\hat{\tau}_S) + n(t).PN(t+T_C-\hat{\tau}_S), \\ E(t) &= W_E(t) - W_L(t). \end{aligned} \tag{2}$$

Bring the above (3) and (4) into (5)

$$\begin{aligned} E(t) &= A\sqrt{2P}\triangle_{PN}(t-\hat{\tau}_S)PN(t-\hat{\tau}_S) + n(t)A\triangle_{PN}(t-\hat{\tau}_S), \\ \triangle_{PN}(t-\hat{\tau}_S) &= PN(\triangle_{PN}(t-T_C-\hat{\tau}_S) - PN(t+T_C-\hat{\tau}_S). \end{aligned} \tag{3}$$

When the related code sequence is synchronized, the code sequence related to the baseband has a very important role in synchronizing the tracking loop, and the phase detector used in the baseband tracking loop is a bit different from the previous one.

$$\begin{aligned} E(t) &= A\sqrt{2P}\triangle_{PN}(t-\hat{\tau}_S)PN(t-\hat{\tau}_S), \\ \triangle_{PN}(t-\hat{\tau}_S) &= PN\left(\triangle_{PN}\left(t-\frac{T_C}{2}-\hat{\tau}_S\right)-PN\left(t+\frac{T_C}{2}-\hat{\tau}_S\right).\right. \end{aligned} \tag{4}$$

According to the processing method for unlocking the buckle, the first item in $E(t)$ can be divided into average component and variable component and is expressed as follows:

$$\triangle_{PN}(t-\hat{\tau}_S)PN(t-\hat{\tau}_S) = E[\triangle_{PN}(t-\hat{\tau}_S)PN(t-\hat{\tau}_S) + n_s(t,\tau_e), \tag{5}$$

where

$$\begin{aligned} \tau_e &= \tau_s - \hat{\tau}_S, \\ n_s(t,\tau_e) &= \triangle_{PN}(t-\hat{\tau}_S)PN(t-\hat{\tau}_S) - D_{T_C/2}(\tau_e), \end{aligned} \tag{6}$$

where PN(t), $D_{T_C/2}(\tau_e)$, and $n_s(t,\tau_e)$ are all wireless communication signals with a period of T.

The second term of $E(t)$ is:

$$n_n(t) = n(t)\triangle_{PN}(t-\hat{\tau}_S)). \tag{7}$$

The related function is as follows:

$$R_{n_n}(\tau) = E(n_n(t)n_n(t-\tau)). \tag{8}$$

Simplifying $R_{n_n}(\tau)$ can get the following simplified formula:

$$R_{n_n}(\tau) = 2\frac{N+1}{N}.\frac{N_0}{2}.\sigma(\tau) \xrightarrow{F} T\, S_{n_n}(f). \tag{9}$$

In summary, the error output result of the baseband correlation synchronization tracking loop in the coding sequence of wireless communication technology is as follows:

$$E(t) = A\sqrt{2P}\left[D_{T_C/2}(\tau_e) + n_s(t,\tau_e) + \frac{1}{\sqrt{2P}}n_n(t)\right]. \tag{10}$$

This error signal passes through the loop low-pass filter ($F(P)$), and when it acts on the VCO, an estimate of the phase difference between the receiving and sending code sequences will be generated, and the phase of the local code sequence can be adjusted to a certain extent to implement synchronization tracking. The normalized phase is accurately estimated as follows:

$$\frac{\hat{\tau}_S}{T_C} = K_V E(t)\left(\frac{F(P)}{P}\right), \tag{11}$$

where K_V is the voltage control gain of the VCO and $F(P)$ is the transfer function of the loop LPF. For synchronous tracking in wireless communication technology, it has the following technical characteristics:

$$\begin{aligned} \frac{\hat{\tau}_S}{T_C} &= H(P)\left[\frac{\tau_S}{T_C} + \frac{N}{2(N+1)}\left(n_s(t,\tau_e) + \frac{1}{\sqrt{2P}}n_n(t)\right)\right], \\ H(P) &= \frac{KF(P)/P}{1+KF(P)/P}, \\ K &= 2A\sqrt{2P}K_V\frac{N+1}{N}. \end{aligned} \tag{12}$$

Wireless communication technology is the current trend in the times. A technological innovation under the current wireless communication background can be carried out when there is good environment and equipment. Now wireless communication technology mostly pursues high-speed data transmission and high-definition image transmission. This can meet the needs of different users. In addition, wireless communication technology has many advantages, such as high speed, flexibility, diversity, economy, etc. Wireless communication technology is characterised by high speed communication, and it is considered to be fast when compared to current traditional communication methods; wireless communication can help users to communicate anytime and anywhere and can quickly browse the web, play games, etc., which effectively guarantees the smoothness of data transmission and the clarity of images; diversity is mainly for value-added services. Compared with the current communication technology, the core technology of wireless communication technology is different in nature. It adopts orthogonal frequency multiplexing technology, which can provide diversified value-added services such as digital video broadcasting and digital audio broadcasting. Because of its own flexibility, the deployment process is simpler than traditional communication systems, and it can also be set up on different basic networks, so the cost is relatively low, even lower than the current system [24].

2.3. Computer-Aided Teaching Research. Computer-assisted teaching is a very popular new teaching system, where it introduces computer technology into teaching to provide teachers with a new teaching aid tool and at the same time provide students with a new learning mode. Because computer teaching cites big data, Internet, radio communication, and other technologies, it is carried out through a series of human-computer interaction activities, with interactive and individual teaching characteristics [25, 26]. Interaction refers to the communication between students and teachers, while personality refers to the characteristics of each student. There should be both commonness and individuality in flipped classroom. Interactivity can realize man-machine dialogue, feed back students' needs to the computer, and the computer will feed back the collected feedback to the students through data analysis, and individuality is the biggest advantage of computer-assisted teaching. In the context of wireless communication, the study of computer technology-assisted translation teaching courses embodies the

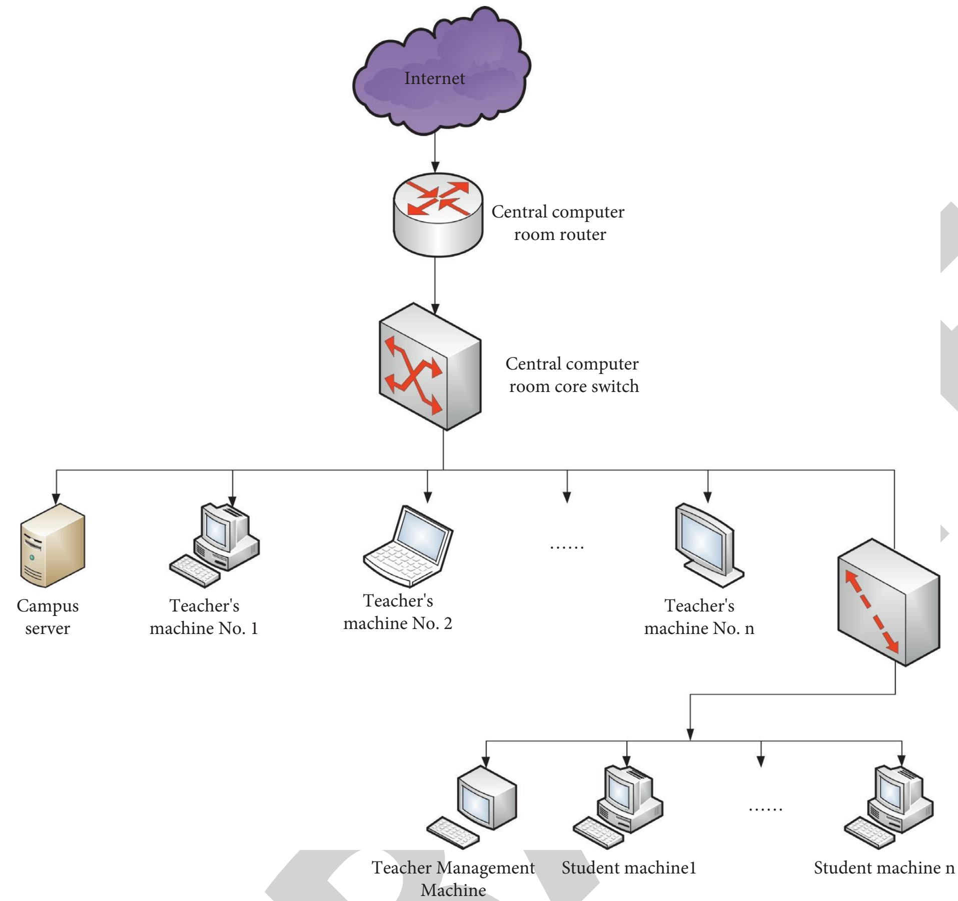


Figure 4: Schematic diagram of computer-assisted teaching.

characteristics of powerful computer functions, fast running speed, and multiple resources. Combined with the long-distance transmission functions of wireless communication technology, it can be well applied in translation teaching, greatly improve the learning efficiency of students. Figure 4 shows a specific schematic diagram of computer-assisted teaching [27–29].

3. Embedded Microprocessor and Wireless Communication Are Used for Computer-Assisted Teaching Experiment

3.1. Embedded Operating Logic of the Computer Hardware Experiment Microprocessor. Nowadays, all domestic colleges and universities use teacher education-oriented teaching mode in translation teaching. On this basis, the combination of microprocessor and computer-related technology has become an advanced experimental teaching method. In the prior art, the experimental device uses an independent console to control the operation of the experimental microprocessor. The console and the experimental microprocessor circuit are different chips. The experimenter generates various controls by operating the control console on the computer. The signal controls the operation of the experimental microprocessor. However, there is currently a lack of an effective operation control logic for controlling the operation of experimental microprocessors, which can be applied to microprogram control and hard-wired control microprocessors [30]. It has a comprehensive and efficient operation control method and can be well implemented and detailed translation. In teaching, in view of the limitations and deficiencies in the implementation of experimental microprocessor operation control of the computer hardware experiment device in the prior art, an embedded operation control logic for the experimental microprocessor in the computer hardware experiment is proposed, which can be very effective. A good solution to this problem. Figure 5 shows the structure block diagram of the embedded operation control logic of the proposed computer hardware experimental microprocessor.

With the rapid development of 5G, Internet of Things, and computer technology, all walks of life are now using these new technologies and gradually replacing labor, freeing people from heavy and trivial daily work. Education has been around since ancient times [31–33]. 4G networks are built for mobile phones, not optimized for the Internet of Things. 5G provides huge bandwidth for the Internet of things. Thousands of years ago, it has always been based on the model of teacher teaching and student learning. Now, with the more advanced equipment, the more tired, the more advanced equipment can make this work easier. In the case of computer-assisted teaching, people's learning time

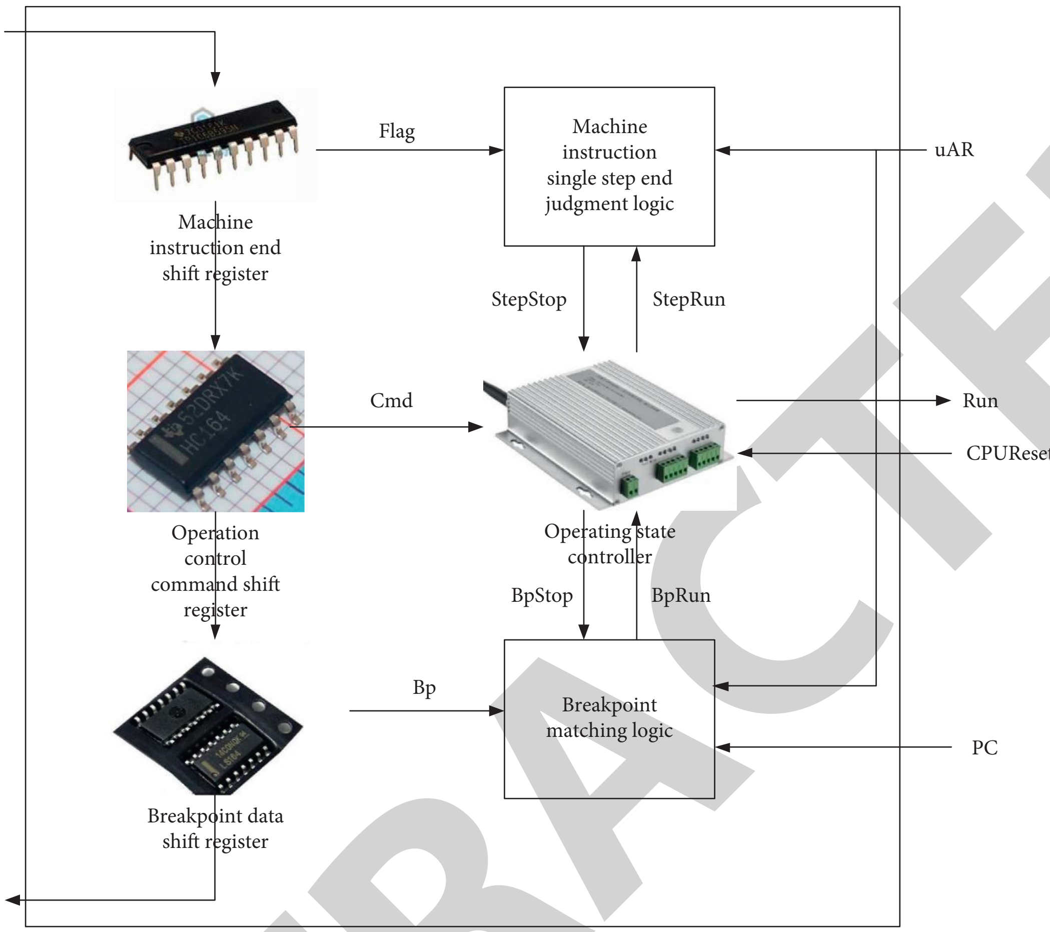


Figure 5: Embedded microprocessor used in computer.

and learning methods have changed in different ways. The application of embedded microprocessors in computer-assisted translation teaching is still rare in domestic and foreign research, but the technology of using embedded microprocessors has been experimented by many people in the past, and it has a great effect, as shown in Figure 6. It is the actual application situation of different embedded microprocessors.

3.2. Status Quo of Computer-Assisted Teaching under the Background of Wireless Communication. With the continuous development of the times, the wired era has left us, and now the most important means of communication is the realization of computer-related technologies under the background of wireless communication. Traditional wireless communication technology is affected by hardware devices, especially the connection speed and network bandwidth [34, 35]. In the past few years, China's wireless communication technology has rapidly spread and replaced it. The 3G and 4G construction processes have been superimposed, and the 5G construction has also begun to develop at a high speed, and the difficulty of maintaining the communication network has increased sharply, but it has brought a broader market. In terms of industry, China's 4G network is currently mature, and the construction of the "new infrastructure" representing 5G is accelerating, and the new communication network model has entered the construction cycle. Wireless communication technology has gradually begun to be widely used in all walks of life in our country and has produced great economic benefits. Figure 7 shows the specific development of wireless communication technology in China in recent years.

In recent years, with the rapid changes in information technology, wireless communication technology has accelerated the integration of new technologies such as the Internet, big data, and the Internet of Things, and information management and control, which has become the general trend in the industry. In the context of the geometric growth of data services, traditional communication technology service companies have many disadvantages such as decentralized management, extensive execution, long support chains, and slow response speed, making it increasingly difficult to meet customer needs. The application of wireless communication technology in computer-assisted translation teaching has not yet been implemented in our country. After all, the traditional education model of the education industry has always been accustomed to the public.

3.3. Computer-Aided Translation Teaching Experiment. The combination of computer and traditional teaching can improve students' enthusiasm in class and make learning resources can be shared. In the papers related to the teaching

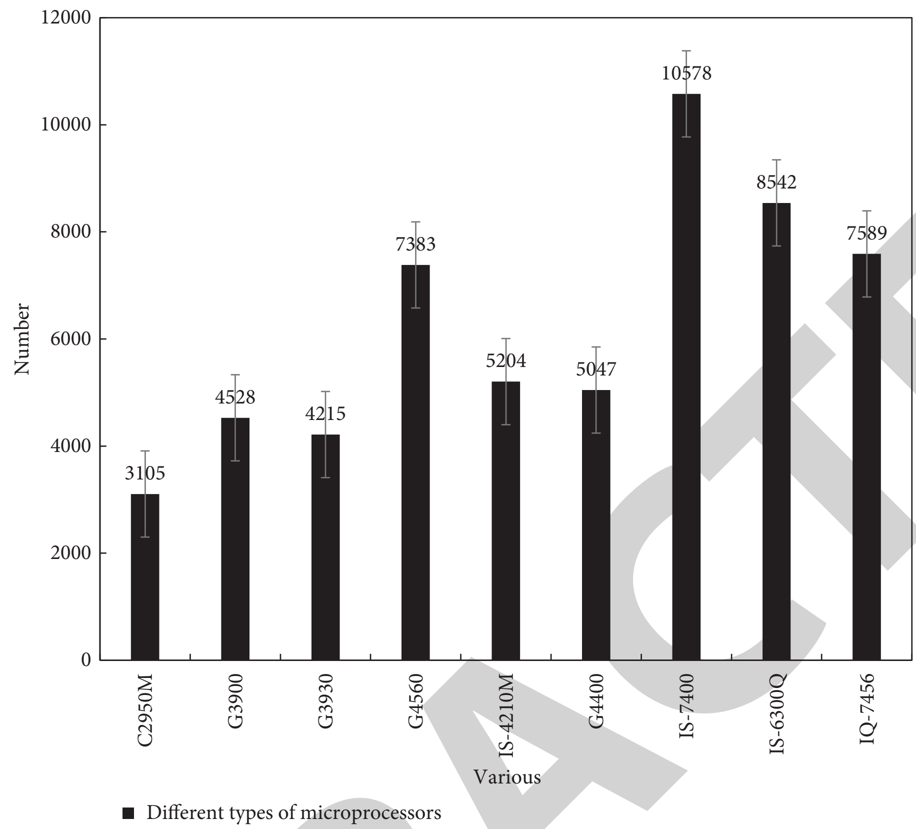


Figure 6: Application of different embedded microprocessors.

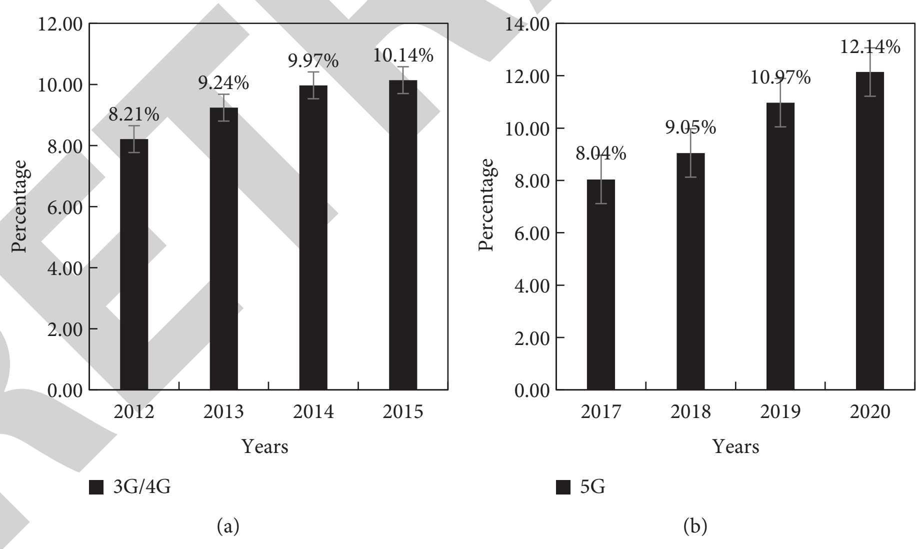


Figure 7: The development of China's wireless communication technology in recent years.

effect of computer teaching, most domestic and foreign research scholars are qualitative researches. Some scholars put forward suggestions and plans to improve the teaching effect, and some scholars combined computers with traditional teaching to improve the actual teaching effect, but they have been in a state of talking on paper. No actual experiment has been made for relevant verification, but a qualitative method is used to verify that computer teaching is better than traditional teaching in terms of effect.

The effects of traditional teaching and the use of computer-assisted teaching are compared in the translation classroom, and at the same time, it also explores the better learning knowledge of college students in the translation classroom and uses questionnaires to conduct related

Table 1: Reliability analysis of questionnaire.

Serial number	Feature element content	Each value of α	Overall value of α
1	Learning attitude	0.795	0.847
2	Learning interest	0.814	0.824
3	Learning motivation	0.809	0.827
4	Attention	0.817	0.834

Table 2: Correlation coefficient table of the score of each item and the total score of the questionnaire.

Question number	Total correlation coefficient	Question number	Total correlation coefficient	Question number	Total correlation coefficient
1	0.40	11	0.34	21	0.36
2	0.62	12	0.64	22	0.54
3	0.61	13	0.46	23	0.64
4	0.54	14	0.49	24	0.34
5	0.49	15	0.44	25	0.64
6	0.56	16	0.64	26	0.35
7	0.45	17	0.25	27	0.39
8	0.39	18	0.45	28	0.42
9	0.095	19	0.45	29	0.75
10	0.52	20	0.43	30	0.66

Table 3: About the actual situation of the questionnaires of the two groups A and B.

Category	Number of questionnaires issued	Number of questionnaires returned	Number of valid questionnaires	Recovery rate	Usage rate (%)
A	40	40	38	100	95
B	40	40	39	100	97.5
A	39	39	37	100	94.9
B	38	38	36	100	94.8

research. From the students' learning interests, learning motivations, and learning attitudes, we will explore in other aspects and compare which of the traditional teaching mode and the computer-assisted teaching mode has more advantages. Table 1 shows the reliability analysis of the questionnaire.

This self-made questionnaire is used as a test tool, with a certain university student as the research object, the questionnaire adopts closed questions, and relevant explanations are provided when the questionnaire is issued to help students understand the content of the questionnaire and make correct judgments. The quality of the questionnaire is ensured first and then the statistics and sorting of relevant data are carried out. In total, there are 30 questions in this questionnaire. The relationship between the questions and the total score of the questionnaire obtained through the relevant survey statistics is shown in Table 2, which can well reflect the current college students' views on computer-assisted teaching.

Randomly divide translation students from a certain university into groups A and B for experiments. Group A is the experimental group that uses computers for assisted teaching, and group B is the control group that uses traditional teaching methods. And the questionnaires were distributed between the two groups, and two questionnaires were conducted before and after the experiment to explore whether there were any changes in the psychology of the students in the two groups after the experiment. Table 3 shows the survey situation of the two groups A and B of the two questionnaires before and after.

After a period of teaching experiment observation, from the comparative observation of each class, it is found that the classroom learning situation of students in different groups is shown in Figure 8. There are obvious differences in performance. The specific effect is that the interest of students in the computer-assisted teaching group is generally higher than that of the interest of students in the regular teaching group lasts for a long time. About 90% of the students in the computer-assisted teaching group are concentrated, while only 70% of the students in the traditional teaching group are concentrated. The auxiliary teaching group is 20% higher than the traditional teaching group. Students in the computer-assisted teaching group are less likely to use mobile phones, talk, travel, and do tasks unrelated to the content in the classroom. Most of the students expressed their willingness to participate in the course content.

After one semester of experiments, I found that both the computer-assisted teaching group (group A) and the traditional teaching method group (group B) have had great changes in their learning attitudes, and they love learning more than before. However, the degree of seriousness of the computer-assisted teaching group is still greater than that of the traditional teaching group, and the students' self-

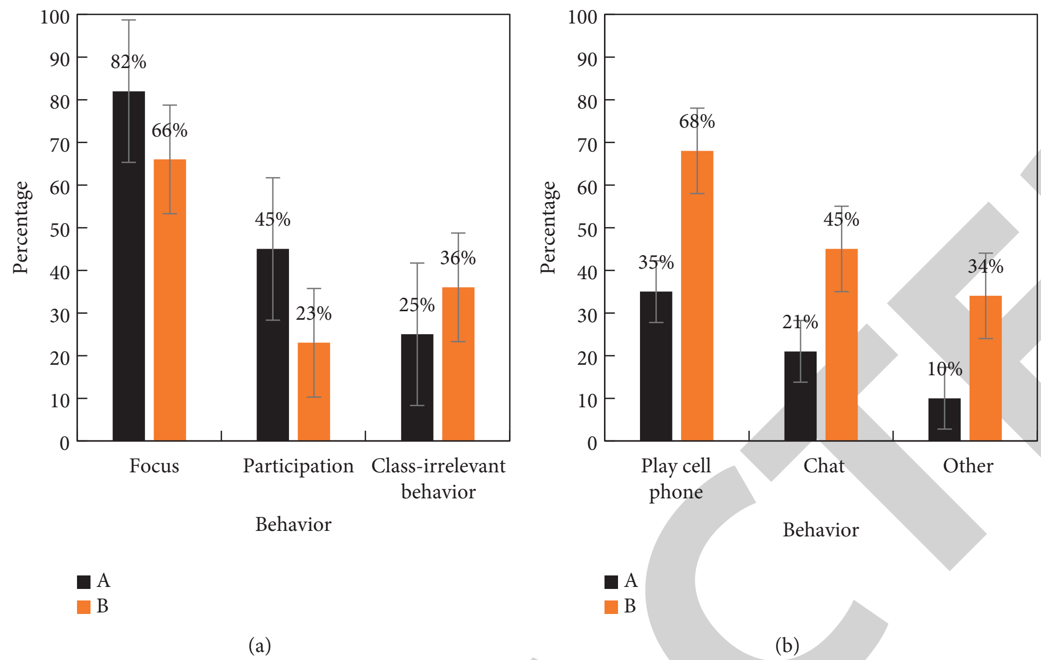


Figure 8: Groups A and B on the proportion of classroom performance.

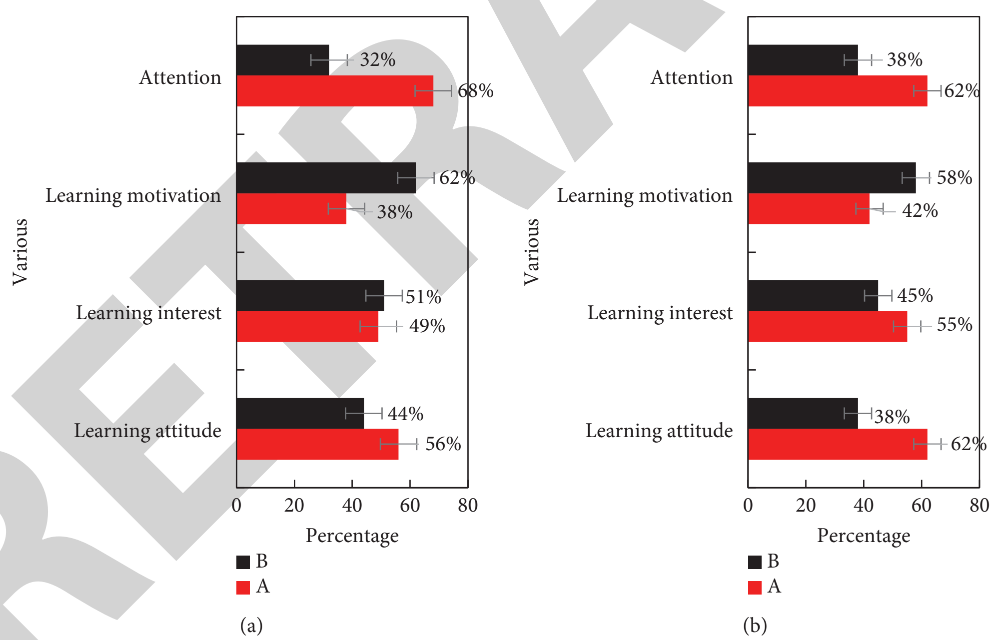


Figure 9: Changes in groups A and B after one semester.

consciousness is higher. Compared with the lazy learning attitude before, there has been a very big change. The specific situation is shown in Figure 9.

In the preexperiment test, the first batch of questionnaires was collected and the SPSS18.0 software was used to conduct independent sample T-test on the four dimensions of the questionnaire. After testing, according to Table 4, it can be concluded that the computer-assisted teaching group (i.e., group A)) and the traditional teaching group (group B) in the four dimensions of learning motivation, learning interest, learning attitude, and attention ($P > 0.05$), there is no significant difference. It shows that the experimental subjects have no difference in these four dimensions and have good homogeneity. They are relatively good experimental samples and can be used for follow-up experiments.

After a semester of teaching comparative experiment, after the test, the same questionnaire was distributed to the same group of students in the computer-assisted teaching group (i.e., group A) and the traditional teaching group (i.e., group B), and the questionnaires were recovered and used

Table 4: Preexperiment test of A and B on the four dimensions.

Variable	Group	M	SD	T	P
Learning attitude	A	27.7354	4.0157	−1.624	0.134
	B	28.9713	3.9478		
Learning interest	A	27.8951	3.4217	−1.573	0.099
	B	30.7529	3.1347		
Learning motivation	A	28.9754	3.4875	0.614	0.549
	B	29.5478	3.5741		
Attention	A	9.2472	2.9875	−0.497	0.591
	B	9.1348	3.0478		

Table 5: Postexperiment test of A and B on the four dimensions.

Variable	Group	M	SD	T	P
Learning attitude	A	32.0478	3.5175	2.217	0.048
	B	29.5178	4.3271		
Learning interest	A	35.0478	4.4573	3.195	0.201
	B	31.6478	4.1578		
Learning motivation	A	31.4298	3.4647	0.847	0.650
	B	31.4200	3.3478		
Attention	A	8.0417	2.6354	−2.415	0.035
	B	9.0475	3.5647		

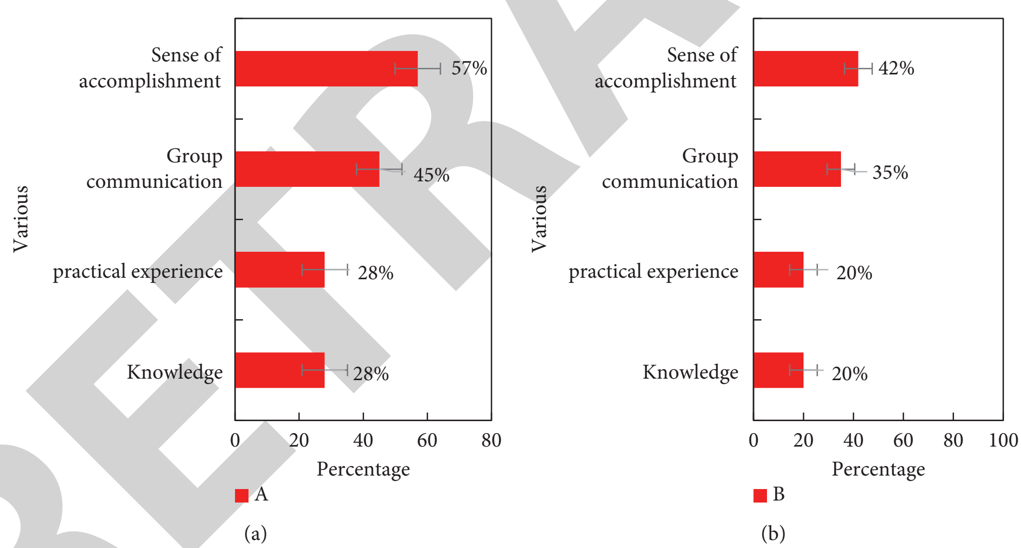


Figure 10: Comparison of the proportion of students' classroom performance in the two teaching modes.

SPSS 18.0 for independence. Sample T-test, after testing, according to Table 5, there are significant differences between the two classes in the three dimensions of learning attitude, learning interest, and attention ($P < 0.05$), and there is a very significant difference in learning interest. This shows that after teaching experiments, the computer-assisted teaching group and the traditional teaching group have differences in the three dimensions of learning motivation, learning interest, and attention. There is no difference in learning motivation between the two classes ($P > 0.05$), indicating that after a semester of teaching comparative experiment, there is no difference in learning motivation between the computer-assisted teaching group and the traditional teaching group, and the translation teaching effect comparison experiment has no learning motivation.

As shown in Figure 10, the sense of success in the acquisition of knowledge, real experience, exchange of experience, and computer-assisted teaching translation classroom is much higher than that of traditional translation teaching groups. In terms of knowledge acquisition, traditional teaching accounts for about 20% and computer-assisted teaching accounts for about 28%. In terms of practical experience, traditional teaching teams account for about 20%, while computer-assisted teaching accounts for about 28%. But in terms of the success rate of group communication, the traditional teaching group accounted for 35% and the computer-assisted teaching group accounted for 45%. In terms of students' sense of accomplishment, 42% in the traditional teaching group and 57% in the computer-assisted teaching group. The above data all show that computer-assisted teaching is generally better than traditional teaching in terms of student classroom performance.

4. Discussion

The analysis of the computer-assisted teaching intention questionnaire shows that compared with the traditional translation teaching in colleges and universities, most students understand computer-related operations better and prefer the influence and skill development of computer-assisted teaching. This part of the questionnaire reflects the students' personal feel. Computer-assisted teaching is very useful for the complete and practical application of translation knowledge. Regarding the results of the relevant test score data analysis in class and after class, it can be intuitively seen through the independent sample *T*-test that the two groups with no obvious difference show significantly more differences in test scores. Among them, the computer-assisted teaching increased performance in the group significantly faster. This is done to verify the hypothesis put forward before the experiment, that is, the influence of computer-assisted teaching on the professional development of translation students is more obvious. In terms of classroom efficiency, student participation increases, the attention spans longer, the sense of accomplishment became higher, and there is a reduction in their irrelevant behavior. This information often allows teachers to learn more about student performance.

5. Conclusions

In today's society, talents are produced in large numbers, and talents from various 985 and 211 colleges and universities abound. At this time, companies pay particular attention to the specific abilities of recruiters. Therefore, this issue should be paid attention to when training in schools. There is no difference between the vocational training and professional characteristics of major colleges and universities, and the CAT curriculum format suitable for the times should be created based on the discipline advantages of colleges and universities , integrate translation assistance software into independent classroom teaching and independent subject generation system, and expand school-enterprise industry-university-research interaction. It will provide students with more translation education, teaching, and practical opportunities. This article is based on the research of computer-assisted translation teaching courses under the background of embedded microprocessor wireless communication. I want to explore the current translation teaching mode, integrate the current advanced computers into it, and gradually play a leading role. Now all major universities have been in trying things, this will be of great benefit to enhancing the professional ability of college students and increasing the professional competitiveness of graduates.

Data Availability

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Conflicts of Interest

The authors state that this article has no conflicts of interest.

Acknowledgments

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

[1] D-H. Li, H.-Y. Li, J. Wei, E. Guo, and L. Li, "Application of flipped classroom based on the Rain Classroom in the teaching of computer-aided landscape design," *Computer Applications in Engineering Education*, vol. 28, no. 2, pp. 357–366, 2020.

[2] Y. Li, "Teaching innovation of environmental art design specialty based on computer aided," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 20, pp. 548–555, 2017.

[3] N. Zhang, "Research on the application of computer aided Design in clothing Design teaching in higher vocational colleges," *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, vol. 12, no. 3, pp. 4817–4821, 2021.

[4] J. Su, Y. Feng, and L. Liu, "Research on the influence of computer aided intelligent tutoring system on teacher's self-efficacy," *Journal of Intelligent and Fuzzy Systems*, vol. 35, no. 3, pp. 2749–2759, 2018.

[5] L. Ma and K. Miao, "Computer aided application and research on the process of physical education teaching," *Boletin Tecnico/technical Bulletin*, vol. 55, no. 4, pp. 313–321, 2017.

[6] S. Zhang, "A research on the construction of computer aided college English teaching system based on ecological teaching," *Revista de la Facultad de Ingenieria*, vol. 32, no. 11, pp. 359–364, 2017.

[7] Q. Du, "Application optimization and teaching mode innovation of computer aided design in landscape gardening course," *Revista de la Facultad de Ingenieria*, vol. 32, no. 12, pp. 284–289, 2017.

[8] Y. Wang, Y. Liu, C. Wang et al., "Storage-less and converter-less photovoltaic energy harvesting with maximum power point tracking for Internet of things," *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, vol. 35, no. 2, pp. 173–186, 2016.

[9] F. Khalid, S. R. Hasan, S. Zia, O. Hasan, F. Awwad, and M. Shafique, "MacLeR: machine learning-based runtime hardware trojan detection in resource-constrained IoT edge devices," *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, vol. 39, no. 11, pp. 3748–3761, 2020.

[10] X. Wang, Q. Zhou, Y. Cai, and G. Qu, "Toward a formal and quantitative evaluation framework for circuit obfuscation methods," *IEEE Transactions on Computer-Aided Design of*

Hindawi
Scientific Programming
Volume 2022, Article ID 4378765, 11 pages
https://doi.org/10.1155/2022/4378765

Research Article

The Development Status and Trend of Urban Smart Tourism Based on Internet of Things Technology

Yi Zhang and Qi Li

Department of Tourism and Health Care, Qinhuangdao 066000, Hebei, China

Correspondence should be addressed to Qi Li; liqi@hbiibe.edu.cn

Received 11 February 2022; Revised 1 April 2022; Accepted 11 April 2022; Published 28 April 2022

Academic Editor: Ahmed Farouk

The rapid economic development and the improvement of people's living standards have prompted the rapid development of tourism. And in the era of big data, it is inevitable for economic and technological development to apply IoT technology to various industries. The application of Internet of Things technology in the tourism industry conforms to the development of the times, promotes the upgrading of the industry, and also promotes the emergence and development of smart tourism. At present, the development of smart tourism provides convenient and timely services for people's travel and also improves the management level and reception capacity of tourist destinations. Therefore, this paper conducts an in-depth discussion on the urban smart tourism based on the Internet of Things technology and summarizes the development status of urban tourism. And based on the current development situation to predict the future development trend of urban smart tourism and the future development plan of smart tourism, this paper discusses the current problems of smart tourism in order to promote the healthy and sustainable development of urban smart tourism. The research in this paper has great reference significance and practical guiding significance for the healthy and stable development of smart tourism in the future.

1. Introduction

At present, the development of modernization, informatization, and internationalization brings opportunities for the operation of traditional tourism. The new tourism industry changes its operation and management mode through informatization, innovates the concept of tourism service through modernization, and expands tourism methods and development channels and service modes through cloud computing and Internet of Things technology [1]. However, the phenomenon of "smart tourism" outweighs the actual effect. The country's high attention has made tourism companies embark on the reform of "smart tourism". However, it did not conduct too much market research and also deeply understand the needs of tourists for tourism. The "smart tourism" project that does not meet the needs of tourists not only does not make tourists feel convenient but also makes it difficult for tourist attractions to complete their own transformation and upgrading [2]. Of course, as an advanced science and technology, the application of Internet of Things technology in the development of tourism has a great role in promoting the development of tourism, and the development space of smart tourism is even greater.

Due to the vigorous development of tourism and its existing problems, many scholars have studied the problems and solutions in tourism. At the same time, the development of smart tourism has also attracted the attention of scholars, who have studied the development of smart tourism and are looking for ways to reform and innovate tourism. Among them, ATB demonstrates the potential value that spatial and semantic analysis of social media information can provide to smart tourism ecosystems. He found that social media analytics can capture spatial patterns in cities related to user presence, context, and topic engagement. He also outlines how these models can serve as inputs for smart city tourism value creation [3]. Although his research has a certain reference value for the innovation and reform of the tourism industry, there is no relevant technical support. Romao J conducts a structural modeling analysis of the performance determinants of urban attractiveness from the perspective of the residential population and international tourism demand. The analysis revealed a precarious balance between liveability, environment, population, visitor numbers, and growth [4]. Although Romao's research analyzes the development of tourism in combination with the city's attractiveness, it lacks actual demonstration data. García-Hernández combines a compilation of information on initiatives and measures from public tourism planning documents with semistructured interviews with those responsible for managing smart city strategies and sustainable development projects. The results show that a growing number of destinations are challenged with the need to generate knowledge useful for managing tourist overload [5]. Although his research has practical significance, it rarely involves the transformation and upgrading of tourism. Mozghovyi studied the main characteristics of smart destination development. Its findings can be used to plan the further development of smart tourism destinations and the corresponding adjustment of tourism innovation policies [6]. Although his research has certain reference significance for the reform and upgrading of smart tourism, he has not conducted in-depth discussions on the development of smart tourism. Although their research has shortcomings, it has certain reference value for the upgrading of traditional tourism and the long-term and sustainable development of smart tourism.

This paper studies the development status and development trend of smart tourism. This paper can deeply analyze the problems existing in the current development of the tourism industry and provide convenience for tourists to travel with the intelligent technology of information technology. But the application of high technology to the tourism industry has to be implemented in the end. The research on smart tourism in this paper can prevent the entry of smart tourism from being kidnapped by technology and money and liberate the development of smart tourism from the kidnapping of the core concepts of traditional tourism. It promotes the need for tourists to become a guide for the development of smart tourism. Considering the individual needs of tourists to further promote the improvement and perfection of the smart tourism industry chain, this paper makes the development of smart tourism expand in a larger scope and in more aspects to seek improvement [7]. It can promote the healthy and sustainable development of smart tourism and achieve a two-way balance between tourism's economic benefits and environmental benefits.

This paper also has the following innovations in the research on smart tourism: (1) Improve the original tourism industry chain with the Internet of Things information technology, thereby improving the efficiency of tourism management, the quality of tourism products, and the satisfaction and experience of tourists. (2) Using the Internet of Things technology to intelligentize the infrastructure of the tourism industry, promote the service capability and service quality of the scenic spot, realize the sharing of tourism resources, and expand the tourist source base of the scenic spot. (3) The development status of smart tourism is monitored by the Internet of Things technology. This paper ensures a two-way balance between its development and environmental protection. At this time, the balanced development of smart tourism not only ensures economic benefits but also ensures environmental benefits.

2. Methods to Analyze the Current Situation and Trends of Urban Smart Tourism Development

2.1. IoT Technology. IoT technology is the third revolution of information technology, including sensor technology, embedded system technology, RFID technology, intelligent technology, nanotechnology, and other key technologies, as shown in Figure 1.

The Internet of Things technology plays an important role in the industrial upgrading of the tourism industry. Especially in the role of building a travel online service platform, basically, all service systems will involve the Internet of Things technology, including the travel information on the platform that needs to be stored through the communication network. Therefore, the Internet of Things technology plays a key role in the development of smart tourism, especially sensor technology, intelligent technology, and embedded system technology [8, 9]. The application of sensors in smart tourism is generally used for ticket checking and ticketing. We need to check tickets when we travel to tourist areas every day. The application of sensors in this area saves us a lot of time [10].

Generally, there is more than one ticket gate in a scenic spot; that is, if there are multiple ticket gates, multiple sensors are required, so the sensing technology applied by the sensing device is the same [11]. We set the wireless sensor network to have N nodes distributed in a square detection area of length M. The nodes of each sensing device transmit the detected tickets to the identified router node X through multiple nodes. Then, it will be forwarded by the D router nodes and finally passed to the identification system in the overall IoT platform to identify the validity and correctness of the ticket, and at the same time, it can also record the amount of passenger flow through the ticket gate. The internal network structure of the sensor device is shown in Figure 2.

The nodes in the sensor can adjust their own maximum communication distance S according to the range of the communication network [12, 13]. If the geometric distance d between node i and node j is smaller than S, there is an edge between node i and node j. The statistical process of the passenger flow of the IoT platform is as follows:

$$
\begin{aligned}
D_3 &= \frac{N_3}{X_3} * \varphi, \\
D_1 &= \frac{N_1}{X_1} * \varphi, \\
D_2 &= \frac{N_2}{X_2} * \varphi.
\end{aligned}
\tag{1}
$$

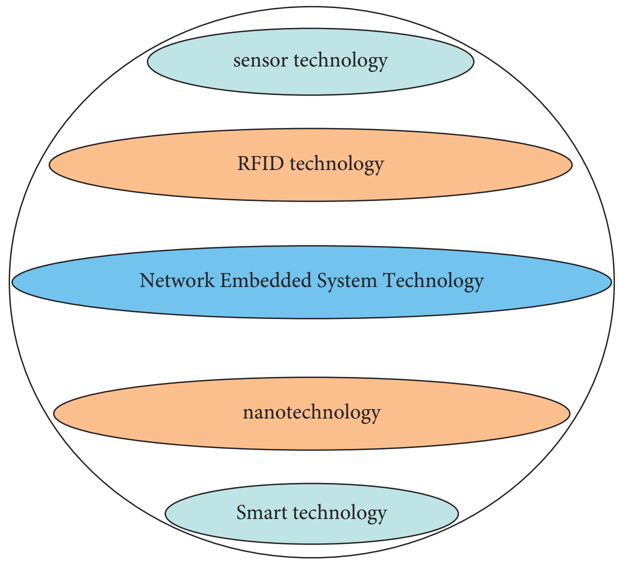


Figure 1: IoT technology.

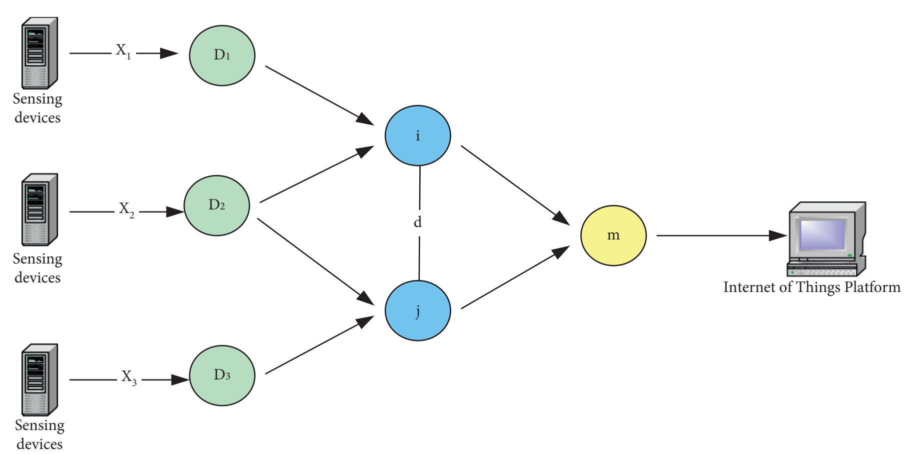


Figure 2: The internal network structure of the sensor device.

Each sensor device will have tourists checking tickets to enter the tourist area, so it is necessary to calculate the number of tickets in each sensor. In the following formula, φ is a parallel matrix, and its form is as follows:

$$\varphi = \begin{bmatrix} M & M \\ M & M \end{bmatrix}. \tag{2}$$

This matrix represents a communication range of the monitoring area. After calculating the ticket checking quantity of each sensor ticket checking equipment, it needs to be aggregated to the transmission nodes i and j of the third layer, and then, the formula for calculating the quantity Q of the aggregated nodes i and j is as follows:

$$\begin{aligned} Q_i &= \left(D_1 + \frac{1}{2}D_2\right) * \int_v^t S, \\ Q_j &= \left(\frac{1}{2}D_2 + D_3\right) * \int_v^t S, \end{aligned} \tag{3}$$

where t represents the transmission time of the number of tickets, and v represents the transmission speed of the information. Then, the total amount of ticket checking information is calculated as follows:

$$Q_m = \sum_v^t \left(Q_i + Q_j\right) * \frac{1}{2} * \int S. \tag{4}$$

In this way, the Internet of Things platform can be used to record the daily passenger flow of the scenic spot, and the environmental capacity of the scenic spot can be predicted. It promotes the balanced development of the scenic area's ecology and the sustainable green development of the scenic area, so as to achieve the balanced development of the environment and economy. Of course, if there are many tourists, the scenic spot needs to increase the ticket checking equipment; that is to say, the sensor technology will newly add node b in the square communication area of length M. The additional sensing devices will select the communication route with the best signal to connect. Then, the probability of node b selection depends on the number N of nodes, the speed of information transmission, and the time of information transmission, and the following rules are followed.

$$\prod(b) = \frac{N_X Q_m}{\sum_v^t d} * \varpi. \tag{5}$$

Among them, the form of ϖ is as follows:

$$\varpi = \begin{Bmatrix} M & t & M \\ D_1 & Q & D_3 \\ M & v & M \end{Bmatrix}. \tag{6}$$

In the Internet of Things, there is also an application of embedded technology. Embedded system technology is application-centric and computer-based. We can see that many scenic spots will develop WeChat public accounts or other IoT platforms to announce the dynamics of scenic spots in real time and do a good job in publicity. Embedded technology makes the infrastructure of the scenic spot more and more intelligent, so the embedded system needs to be installed on the equipment of the scenic spot, and then, to run the system, it is necessary to set up a program to automatically identify the information. Embedded systems need to input a lot of scenic information and command programs. Since the equipment in the scenic area will have subequipment and general equipment, the function of the subequipment is to summarize the obtained information into the general equipment. The principle of how to implant the command program into the embedded system is as follows:

$$\begin{aligned} x_{\text{demand}} &= \sum_v^t d * (Q * M) * \int_r^i S, \\ x_{\text{demand}} &\longrightarrow x_{1(\text{accept})}, \end{aligned} \tag{7}$$

where t is the transmission time of the wireless network, $v$is the network speed of the wireless network, d is the geometric distance between the devices, i is the weight generated by the system during command transmission, r is the threshold in the system, and S is the maximum communication distance of the equipment in the scenic area. Because the command is transmitted from the main device to the subdevice, the mapping principle is used to achieve the function of successful command transmission. To gradually introduce information into the system, it is necessary to sort out the information into the system in layers. Generally, the information is digitized into three paths in the embedded system, and the quantity transmitted by each path is different, which needs to be determined according to the location where the equipment in the scenic spot is placed. Then, the calculation of the information amount U of these three paths is as follows:

$$\begin{aligned} U_1 &= \frac{\prod_v^t Q}{d_1} * i_1 * r * \psi, \\ U_2 &= \frac{\prod_v^t Q}{d_2} * i_2 * r * \psi, \\ U_3 &= \frac{\prod_v^t Q}{d_3} * i_3 * r * \psi *. \end{aligned} \tag{8}$$

In the formula, ψ is a parallel matrix with the following form:

$$\psi = \begin{Bmatrix} 1 & i \\ r & 2 \end{Bmatrix}. \tag{9}$$

This matrix is to prevent information from being lost during transmission and to ensure the integrity of the information. Then, the amount of information transmitted from the subdevice information to the total system is

$$U = (U_1 + U_2 + U_3)^2 * i * r. \tag{10}$$

The information input in the embedded system can process the information in the system according to the instruction. The final generated information can be used for reference by the staff of the scenic spot while formulating the related matters of the scenic spot and using the Internet of Things technology can promote the long-term development of the scenic spot.

2.2. Development Status of Urban Smart Tourism. There are different folk customs and natural scenery all over the world, and different history and culture have created a variety of tourism resources, which are the basis for the development of tourism and the resource base for the development of smart tourism [14]. At present, with the rapid development of modern tourism and the increasingly perfect infrastructure, coupled with the combined effects of science and technology, tourism resources, geographical location, and natural environment, compared with other tourist destinations, urban tourism has shown relative comparative advantages in the competition of various elements of tourism [15]. The advantages of tourism development are shown in Figure 3.

Urban transportation is an important foundation for the development of the urban tourism industry, and it is also the basic condition for the implementation of the online functions of the smart tourism industry, which directly determines the development level of the smart tourism industry [16]. At present, the transportation infrastructure is becoming more and more perfect. High-speed rail, plane, urban subway, highway, etc. have greatly shortened the distance between home and tourist destinations. It facilitates people's travel and provides a transportation infrastructure foundation for the development of tourism. People's enthusiasm for tourism has also promoted the rise of tourism enterprises, which has made tourism enterprises around the world show a prosperous and vigorous development trend, and the growth of tourism enterprises has provided a stronger market theme support for the development of urban smart tourism [17]. And under the downward pressure of the world economy and the gradual slowdown in the growth rate of the world economy, the world tourism market is still hot, and the strong market has laid an excellent foundation for the development of smart tourism. In order to promote the development of smart tourism, it is very necessary to use the development of Internet of Things technology. The development of various smart platforms

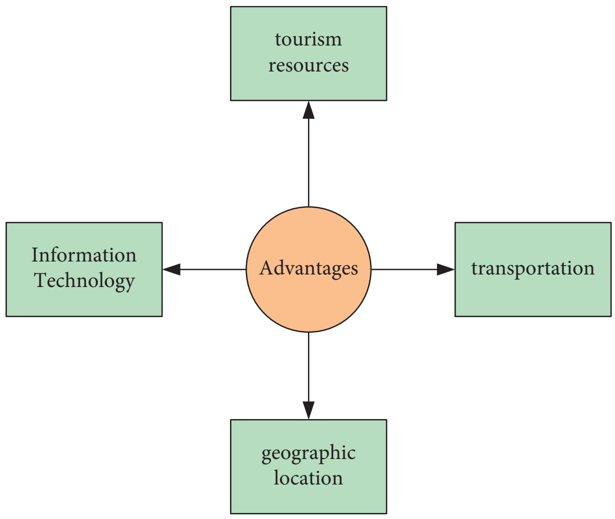


Figure 3: Advantages of tourism development.

provides technical support for the development of smart tourism. And the development of tourism is inseparable from the source of tourists, and the development of the economy provides the economic foundation for people's tourism [18].

But smart tourism is a high-investment information infrastructure construction. At present, the use of IoT technology to build a smart tourism platform requires a lot of capital investment, but the similarities and differences in the understanding and acceptance of smart tourism in various places have led to an extreme imbalance in the development of smart tourism in various cities and towns. It shows the phenomenon that tourist attractions with strong comprehensive strength develop fast, while those with weak comprehensive strength develop slowly. Therefore, people's cognition of the development of smart tourism still needs to be improved [19]. Although the development of smart tourism started late and started quickly, and with the continuous improvement of the informatization of the tourism industry, the enthusiasm for the development of smart tourism has gradually been ignited around the world, showing a great development momentum [20]. With the continuous injection of capital and the continuous increase of smart tourism projects, the development of smart tourism in cities and towns is in full swing, and the continuous improvement of the infrastructure of smart tourism also promotes the industrial upgrading of the tourism industry, the application of Internet of Things technology, and also makes the service equipment of the scenic spot more intelligent. Although the level of intelligence continues to improve, there are still many problems that have hindered the development of smart tourism. Because of the late start of smart tourism, the level of informatization is relatively low. People's understanding of smart tourism is not comprehensive enough, and there is no unified smart tourism development plan, which makes the information systems in various places independent of each other, and the distribution of resources is extremely unbalanced. A larger data and information sharing platform cannot be formed on regional platforms, which reduces the development quality of smart tourism [21]. Although the current smart tourism still has many development problems, the development of smart tourism is still moving towards a more intelligent and standardized direction. The development trend of smart tourism is shown in Figure 4.

The overall development of intelligent tourism is moving forward. Although there are still some problems in the current development, it still occupies a great development advantage. Policies, capital, technology, and resources are all advantages of urban smart tourism, so there is great potential to promote the development of smart tourism [22]. The development of smart tourism is specific as the measurement indicators in Table 1.

2.3. Smart Tourism Based on IoT Technology. At present, the development of Internet of Things technology has promoted the industrial upgrading of the tourism industry and, to a certain extent, the intelligentization of the tourism industry. By using the smart tourism platform constructed by the Internet of Things technology, the tourism resources can be integrated by using technology. Through the use of mobile communication networks for publicity and dissemination, for example, we can learn about tourist attractions anytime and anywhere on mobile smart devices, and we can see many classic promotional videos on TV, which are all with the help of Internet of Things technology [23]. The development of the tourism industry with the help of IoT technology can promote the strength and breadth of its promotion. The smart tourism IoT platform services are shown in Figure 5.

In Figure 5, the Internet of Things can provide various detailed introductions of tourist attractions, such as cultural introductions of scenic spots and recommendations of scenic spots near scenic spots, and it is convenient for tourists to plan travel routes and places to visit in advance. Of course, it is also possible to intelligently recommend travel routes and travel hotel restaurants, so that tourists can more easily find their foothold in the tourist destination. Therefore, smart tourism provides tourists with more convenient services and understands tourists' preferences in a timely manner, so smart tourism attracts a large number of tourists [24]. And the tourism public service platform includes the system as shown in Figure 6.

The tourism service management platform system as shown in Figure 6 mainly includes a ticket sales system, an integrated management system, a tour guide system, a public transportation system, and the like. At the same time, it can also provide a platform for tourists to express their travel thoughts and share their travel thoughts with others. It provides a practical and effective reference for other people's travel strategies, and tourists can plan their own travel routes more intelligently, effectively enrich their travel experience, and meet their own travel needs. The ticketing system effectively reduces the work of the tourist service station, greatly improves the work efficiency, and also saves a lot of unnecessary wasted time for tourists.

At the same time, smart tourism based on the Internet of Things technology has made the management of tourist attractions intelligent. Scenic area managers can use the Internet of Things technology to build a comprehensive

Tourism information

Figure 4: Development trend of smart tourism.

Table 1: Measurement metrics.

Influence factors	Measurement.
Policy	The government supports capital investment in smart tourism
Capital	GDP The per capita urban disposable income Total investment in urban tourism Number of smart tourism projects
Tourist communications	Tourist traffic command center Tourist highway kilometres
Human resource	Tourism employment Number of foreign language tour guides
Level of technological progress	Investment in smart tourism research and development Smart tourism r&d personnel
Intelligent service level	Travel agency personalized service level Number of hotels with reservation service

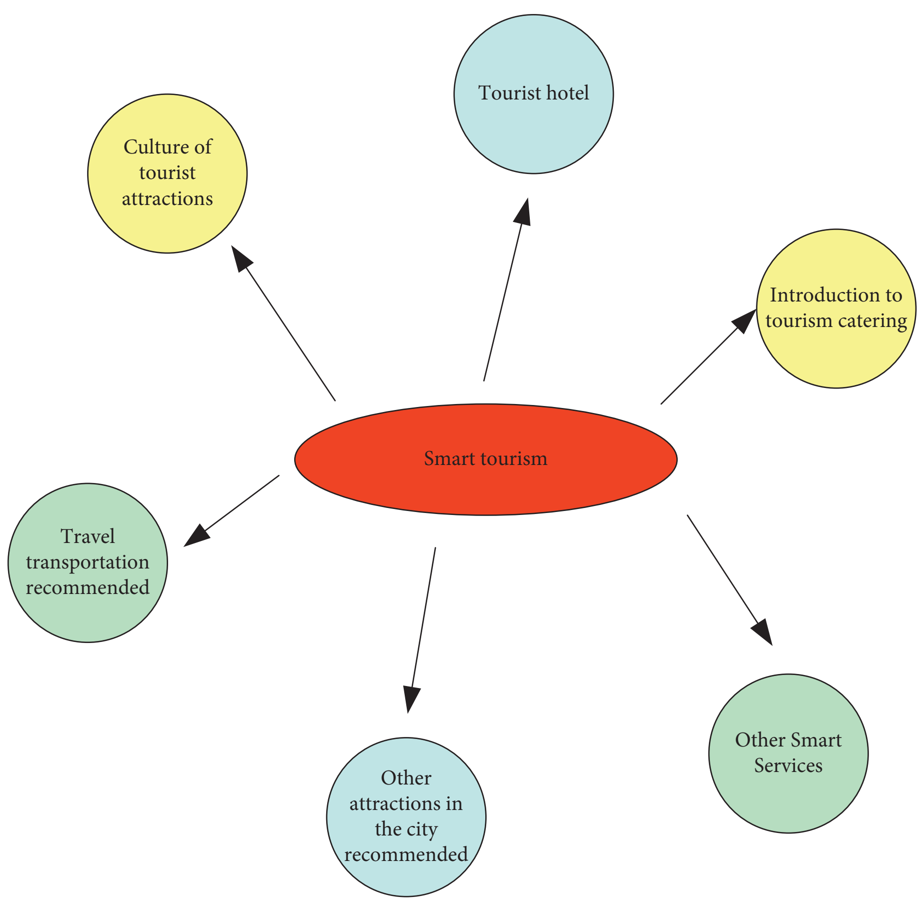


Figure 5: IoT platform services.

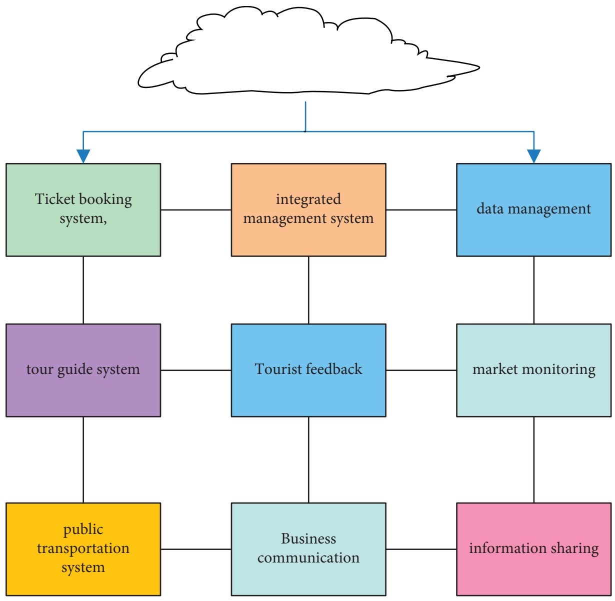


Figure 6: Tourism public service platform system.

monitoring network to facilitate the effective management of tourist attractions [25]. With the help of IoT technology, managers can effectively understand the tourist reception capacity of scenic spots. It promotes the sound development and protection of the scenic environment and infrastructure, grasps the passenger flow in a timely manner, improves the management level of the scenic spot, and provides tourists with a more relaxed and comfortable play experience. In addition, the Internet of Things technology center can also be used to build a tourism information platform to provide tourists with more convenient information services in various aspects such as food, housing, shopping, travel, and entertainment. It makes the related service business of the tourism industry more closely, so as to truly promote the economic development of the tourism industry in an all-round way. In the urban smart tourism, the town itself has a large population, so it is necessary to consider the population carrying capacity of the town to ensure the environmental construction of the town. It promotes the healthy and green development of the urban environment but also promotes the healthy development of tourism and the improvement of urban infrastructure. In a word, the development prospect of urban smart tourism based on Internet of Things technology is very broad, and the improvement of economic level and the improvement of life quality provide a solid foundation for the development of smart tourism.

3. Experiment and Analysis on the Current Situation and Trend of Urban Smart Tourism Development

3.1. The Current Situation of Urban Smart Tourism Development. In recent years, the development of economic level and the improvement of people's quality of life have provided a financial basis for people to travel abroad, and the number of scenic spots is increasing every year. Table 2 shows the number of A-level scenic spots in China in 2020, and Figure 7 shows the statistical changes in the number of A-level scenic spots in China from 2017 to 2020.

It can be clearly seen from Table 2 and Figure 7 that the number of A-level scenic spots in China is increasing every year, and the number of A-level scenic spots in 2020 has reached 13,332. Among them, the number of 5A-level scenic spots is also increasing year by year, which shows the rapid development of tourism. There are tens of thousands of A-level scenic spots, and the number of other scenic spots has increased. The annual 5A-level scenic spots are also growing. It can see in the broken line in Figure 7, and it can be seen that new 5A-level scenic spots appear every year. It can be said that the abundance of tourism resources has provided a solid resource foundation for the development of smart tourism. And in recent years, the development of smart tourism has reduced the difficulty of travel itinerary planning for independent users and the information barriers of tourist areas and has prompted individualized needs to be met accordingly. The growth of the number of independent travelers and the transaction volume of online travel relying on the development of smart tourism are shown in Figure 8.

It can be seen from Figure 8(a) that the number of self-guided marches is increasing year by year, and especially in 2020, the number of self-guided walks will reach about 10 billion. According to Figure 8(b), the online transaction volume is also increasing year by year, indicating that the development of smart tourism is becoming more and more mature, and it has gradually entered people's field of vision. Its customer base is also getting wider and wider, and it has a solid customer base. At present, the development of smart tourism is still thriving. Although there are a series of problems, it is far from the convenience brought by the development of smart tourism to tourists, and tourists can get a better travel experience.

3.2. The Development Trend of Urban Smart Tourism. Tourism is inseparable from the economic foundation, so the development of tourism depends on the development of the economic level. To analyze the development trend of smart tourism, it is necessary to understand the economy of the country and the people, as well as the popularization speed of electronic products and people's understanding of smart tourism, so as to promote the industrialization and resource integration of smart tourism. Then, China's domestic GDP and growth rate are shown in Figure 9, and the per capita GDP of some provinces and cities is shown in Table 3.

It can be seen from the figure that China's GDP has increased year by year, and although the growth rate is sometimes fast and sometimes slow, the overall economy is developing upwards, so the economic development of the country can drive the development of tourism, and the development of tourism can also promote the economic development of the country, and the two promote each other. Therefore, the national economy maintains a stable operation, and the development of tourism will also push forward the development. And the state's capital investment in smart tourism is shown in Figure 10.

Table 2: Number of A-level scenic spots in China in 2020.

Levels	Amount
Number of A-level scenic spots	13332
Number of 2A and 1A tourist attractions	2069
Number of 3A-level scenic spots	6931
Number of 4A-level scenic spots	4030
Number of 5A scenic spots	302

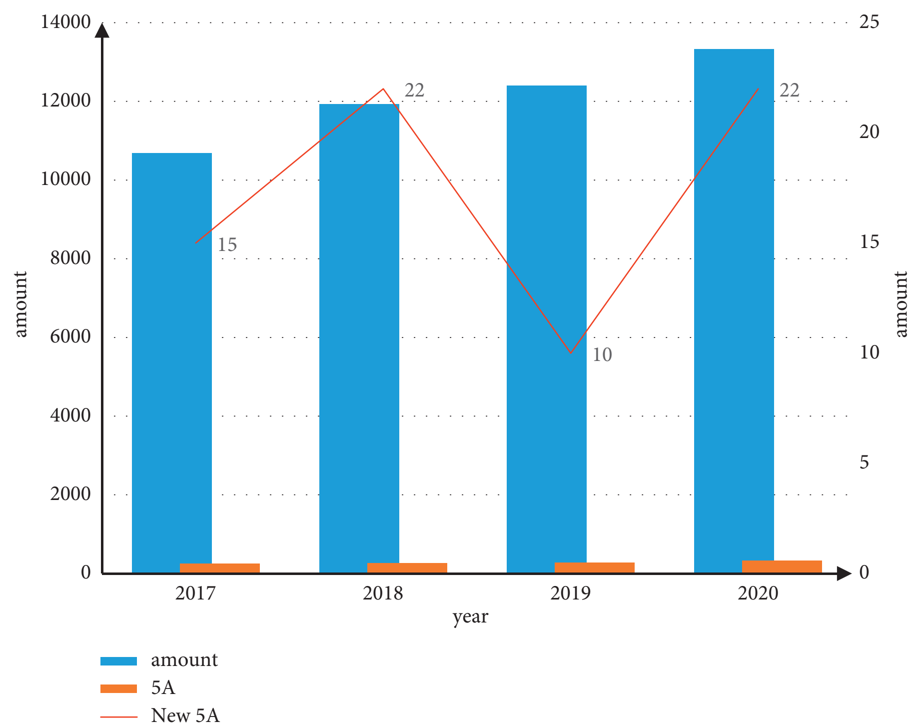


Figure 7: Number of A-level scenic spots in China from 2017 to 2020.

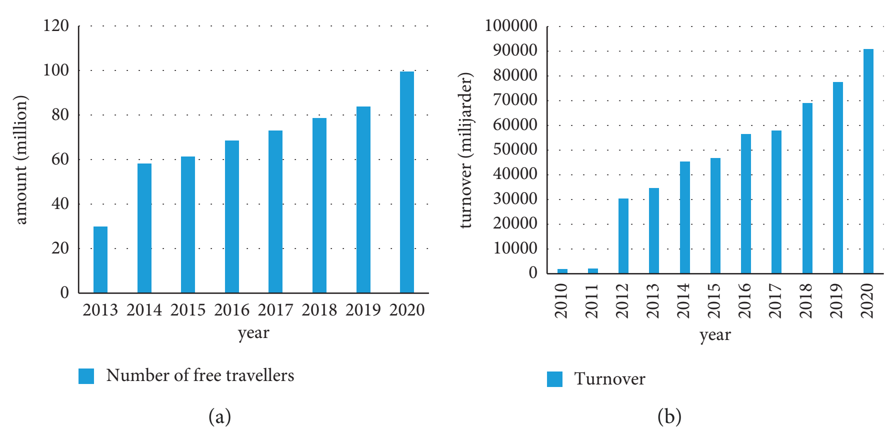


Figure 8: Development of smart tourism platforms. (a) Growth in the number of independent travelers. (b) Online travel transactions.

As can be seen from Figure 10, the country invests capital in the development of smart tourism every year, especially in 2017, when the capital invested 1.2 billion yuan, vigorously promoting the development of urban smart tourism. And every year, funds are invested in the development of the self-contained tourism industry.

3.3. Summary of Experiments and Analysis. From the analysis of the development status of smart tourism, it can be found that the development of smart tourism is not only supported by the Internet of Things technology but also has a large and rich resource base, a base of tourists, and an extremely wide tourism market. The use of smart tourism

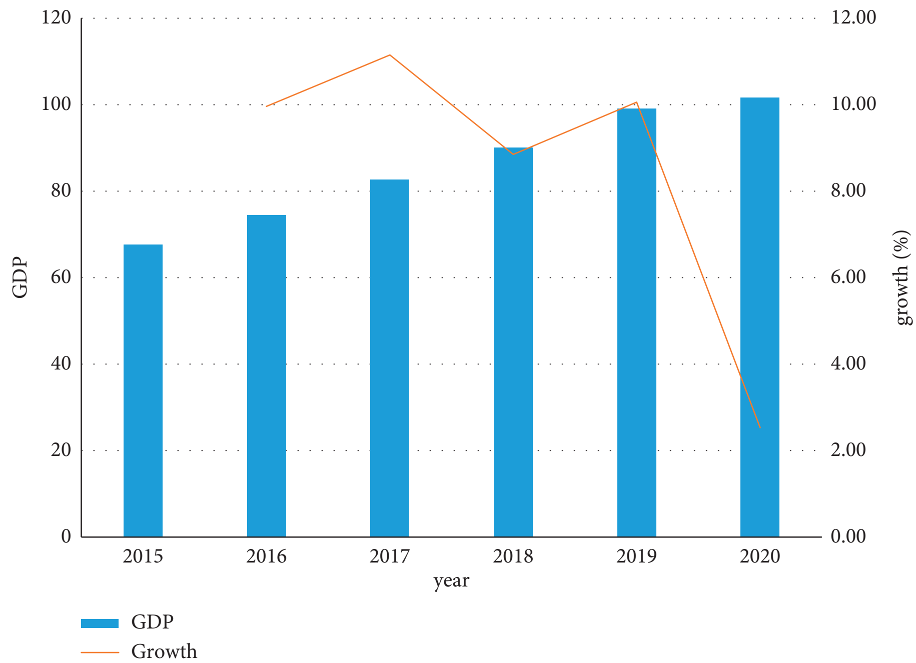


Figure 9: China's domestic GDP and growth rate.

Table 3: GDP per capita in some provinces and cities.

Provinces	Per capital GDP
Beijing	174904
Yunnan	51943
Jilin	51141
Guizhou	46228
Shanghai	155606
Anhui	63383
Jiangxi	56854
Guangdong	87897

service platforms by tourists is also increasing, and the online transaction volume is also increasing year by year. Although the current smart tourism service platform still has some problems, it also provides great convenience for tourists. And the growth of the national economy and the growth of personal GDP also provide an economic foundation for people to travel. It also promotes the development of smart tourism. From the analysis of the development trend of smart tourism, it can be found that although the development of smart tourism has been limited to a certain extent, the state still has the support of policy and funds for the development of smart tourism, coupled with the continuous development of the economy, the progress of science and technology, and the gradual improvement of the online tourism service platform. The development trend of smart tourism based on the Internet of Things technology is accelerating, and the development of scenic infrastructure is very promising and is developing in the direction of smart, green, and sustainable development.

4. Discussion

This article first expounds the Internet of Things technology. At present, the application of the Internet of Things technology is very extensive. The application of the Internet of Things technology in tourist attractions can help the management of scenic spots and the construction of infrastructure. In the traditional tourism industry, it is very difficult to calculate the passenger flow of scenic spots. However, with the development of smart tourism, it is very convenient to know the passenger flow of the scenic spot, and at the same time, it can accurately measure the carrying capacity of the scenic environment. The Internet of Things technology has a great role in promoting the industrial upgrading of the tourism industry. It can promote the intelligentization of the infrastructure of the scenic spot, monitor the environmental changes of the scenic spot in time to make relevant policy adjustments, and ensure the sustainable development of the scenic environment. At the same time, it can also use the Internet of Things technology to promote tourist attractions, so as to promote the popularity and influence of the scenic spots. Tourists can leave their feelings about the scenic spot on the Internet to promote resource sharing and expand the tourist source market of the scenic spot.

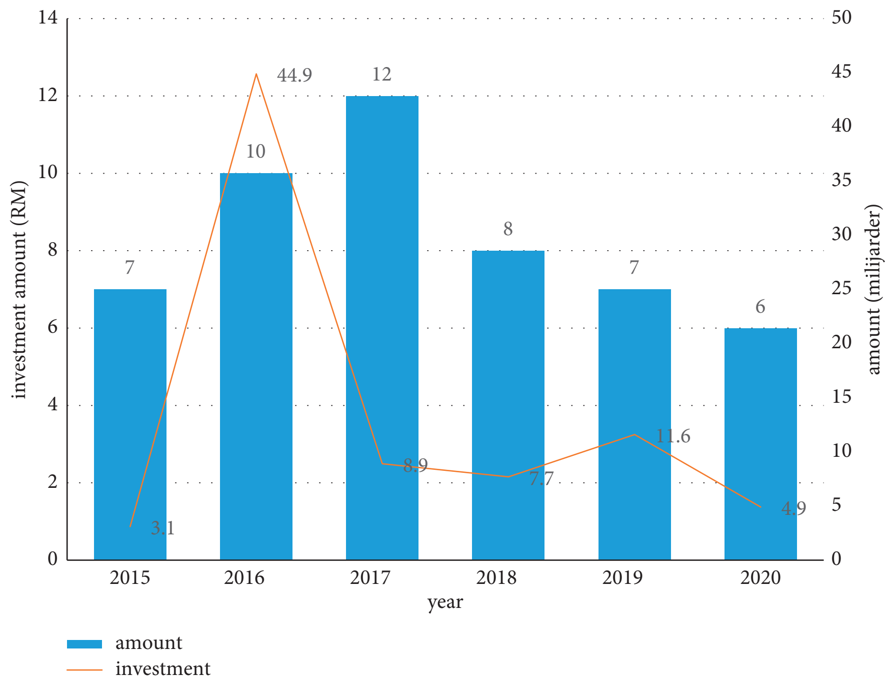


Figure 10: National capital investment in smart tourism.

This paper analyzes the development status of smart tourism and finds that the development of smart tourism is extremely fast, but there are also many problems in the process of rapid development. Therefore, we need to effectively control the development of smart tourism, and at the same time, we need to understand the concept of smart tourism. Do not rush to see its earnings growth, only by grasping the concept of "wisdom" well and then building the brand development of smart tourism can promote the long-term development of smart tourism. The existing development problems of smart tourism, such as imperfect infrastructure and false propaganda, are solved. Various tourist information service systems in scenic spots are improved to promote more intelligent online services. At the same time, let people know about smart tourism projects, gradually promote smart tourism into life, make it normalized, and promote the healthy and sustainable development of smart tourism.

This paper analyzes the development trend of smart tourism. According to the country's GDP growth and per capita GDP growth, the increase in people's income also provides the possibility of tourism, and the upward development of the national economy can naturally promote the development of smart tourism. And the economy is an important pillar of the development of tourism. Only when people's living standards improve, there may be funds to travel, so the development of smart tourism will be faster. And smart tourism is an industrial upgrade of traditional tourism. With the support of national policies and capital investment, the development of smart tourism will get better and better. The development of smart tourism is not only supported by the base of tourists but also by funds and national policies. Of course, under the premise of rapid development, it is still necessary to monitor and control its development with the help of Internet of Things technology to ensure that smart tourism develops in a good trend.

5. Conclusions

The smart tourism industry with IoT technology discussed in this paper is an emerging industry. It is produced with the current industrial upgrading and technological development, and it is also an upgrade of traditional tourism, which can ensure the healthy and sustainable development of tourism. At present, the rapid development of smart tourism has brought great economic benefits and can provide more convenient services for tourists, so smart tourism is widely respected. However, in the case of its rapid development, some problems have also appeared, resulting in an extremely unbalanced development. Therefore, under the premise of the development of smart tourism in the future, it is necessary to use the Internet of Things technology to control it, which is a more balanced development of smart tourism. With the support of funds and policies, the development of smart tourism is in full swing, and its development will be more perfect and more sustainable in the future, achieving a two-way balance between development and the environment. Of course, the analysis of the current development status of smart tourism in this paper is not very comprehensive. It is hoped that later research on smart tourism can analyze it better and more comprehensively and promote the healthy and stable development of smart tourism.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] T. Bobo, T. P. Mudombi, and E. Gopo, "Unlocking urban tourism through city branding," *International Journal of Urban Planning and Smart Cities*, vol. 2, no. 1, pp. 45–58, 2021.

[2] I. V. Gukalova, "Dubai phenomenon of smart urban development: another world or an example for implementation?" *Geography And Tourism*, no. 49, pp. 109–124, 2019.

[3] T. Brandt, J. Bendler, and D. Neumann, "Social media analytics and value creation in urban smart tourism ecosystems," *Information & Management*, vol. 54, no. 6, pp. 703–713, 2017.

[4] J. Romão, K. Kourtit, B. Neuts, and P. Nijkamp, "The smart city as a common place for tourists and residents: a structural analysis of the determinants of urban attractiveness," *Cities*, vol. 78, pp. 67–75, 2018.

[5] M. G. Hernández, I. J. Baidal, and S. M. D. Miguel, "Overtourism in urban destinations: the myth of smart solutions," *Boletín de la Asociación de Geógrafos Españoles*, vol. 7, no. 83, pp. 1–38, 2019.

[6] A. Mozghovyi and A. Sebta, "The role of smart tourism destination as A tool for sustainable development of urban tourism," *Geography And Tourism*, no. 53, pp. 3–8, 2019.

[7] M. Sepe, "Softly smart: experiencing place identity," *Proceedings-Institution of Civil Engineers*, vol. 170, pp. 231–243, 2017.

[8] F. Bouchon and M. Rauscher, "Cities and tourism, a love and hate story; towards a conceptual framework for urban overtourism management," *International Journal of Tourism Cities*, vol. 5, no. 4, pp. 598–619, 2019.

[9] F. Xiao, "Multi-sensor data fusion based on the belief divergence measure of evidences and the belief entropy," *Information Fusion*, vol. 46, pp. 23–32, 2019.

[10] O. I. Khalaf and G. M. Abdulsahib, "Optimized dynamic storage of data (ODSD) in IoT based on blockchain for wireless sensor networks," *Peer-to-Peer Netw. Appl*, vol. 14, no. 2, pp. 1–16, 2021.

[11] C. Irazábal, "Coastal urban planning in the "green republic": tourism development and the nature-infrastructure paradox in Costa Rica," *International Journal of Urban and Regional Research*, vol. 42, no. 5, pp. 882–913, 2018.

[12] I. Osamah, O. I. Khalaf, and G. M. Abdulsahib, "Energy efficient routing and reliable data transmission protocol in WSN," *International Journal of Advances in Soft Computing and Its Applications*, vol. 12, no. 3, pp. 45–53, 2020.

[13] G. M. Abdulsahib and O. I. Khalaf, "Accurate and effective data collection with minimum energy path selection in wireless sensor networks using mobile sinks," *Journal of Information Technology Management*, vol. 13, no. 2, pp. 139–153, 2021.

[14] J. Raun, N. Shoval, and M. Tiru, "Gateways for intra-national tourism flows: measured using two types of tracking technologies," *International Journal of Tourism Cities*, vol. 6, no. 2, pp. 261–278, 2020.

[15] A. Komninos, J. Besharat, D. Ferreira, J. Garofalakis, and V. Kostakos, "Where's everybody? Comparing the use of heatmaps to uncover cities' tacit social context in smartphones and pervasive displays," *Information Technology & Tourism*, vol. 17, no. 4, pp. 1–29, 2017.

[16] H. Leung, W. M. To, A. Chung, and D. H. K. Hung, "Smart city development and sound planning in Macao," *Technical Acoustics*, vol. 39, no. 5, pp. 622–626, 2020.

[17] J. Liu and C. Cao, "The application of old city planning based on the concept of smart cities: a case study of wanli district, nanchang," *Journal of Landscape Research*, vol. 10, no. 6, pp. 20–23, 2018.

[18] R. FISTOLA and R. A. L. A ROCCA, "Driving functions for urban sustainability: the double-edged nature of urban tourism," *International Journal of Sustainable Development and Planning: Encouraging the unified approach to achieve sustainability*, vol. 12, no. 3, pp. 425–434, 2017.

[19] Y. Qin, "Analysis of key elements for smart tourist city construction with G1-Entrophy methods," *Revista de la Facultad de Ingenieria*, vol. 32, no. 11, pp. 759–763, 2017.

[20] L. Belli, A. Cilfone, L. Davoli et al., "IoT-enabled smart sustainable cities: challenges and approaches," *Smart Cities*, vol. 3, no. 3, pp. 1039–1071, 2020.

[21] B. Dutta and S. M, "Online tourist behaviour: an evaluation of the tourism industry of India," *Atna - Journal of Tourism Studies*, vol. 13, no. 1, pp. 19–28, 2018.

[22] O. L. Jong, "Pursuit of a sustainable tourism policy by connecting historical sites and ancient conventions in Seoul," *Advances in Social Sciences Research Journal*, vol. 6, no. 11, pp. 45–64, 2019.

[23] A. Dąbrowska, "dabrowska@uw.edu.plDepartment of Local Development and Policy, Faculty of Geography and Regional Studies,University of Warsaw,Poland. Traditional sectors-based on natural resources – a blessing or a curse for less developed regions? A case study of Podlaskie Voivodeship," *Miscellanea Geographica*, vol. 21, no. 3, pp. 89–95, 2017.

[24] D. Sónia and A. V. Alves, "Alvesestoril higher Institute for tourism and hotel Studies,Estoril,PortugalEstoril higher Institute for tourism and hotel Studies,Estoril,Portugal. Impact of mobile applications in changing the tourist experience," *European Journal of Tourism, Hospitality and Recreation*, vol. 11, no. 1, pp. 113–120, 2021.

[25] Z. L. Xu, X. M. Liu, and D. X. Liu, "The analysis of the trend and status of research & development in the upstream industry technology of rare earth-based on the perspective of patent measurement," *Chinese Rare Earths*, vol. 39, no. 3, pp. 138–148, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 3755257, 9 pages
https://doi.org/10.1155/2022/3755257

Research Article

Analysis and Evaluation of the Relationship between Teaching Pressure and Self-Efficacy of College Teachers Based on Artificial Neural Network

Songjiao Wu

Chongqing University of Arts and Sciences, Chongqing 402160, China

Correspondence should be addressed to Songjiao Wu; 20060076@cqwu.edu.cn

Received 20 January 2022; Revised 1 April 2022; Accepted 4 April 2022; Published 28 April 2022

Academic Editor: Ahmed Farouk

With the reform of the education system, the society today raises higher requirements for college teachers, which cause immense psychological stress among them. To enhance the quality of teachers, it is important to analyze the relationship between teaching pressure and self-efficacy. Therefore, this paper tries to analyze and evaluate the relationship between teaching pressure and self-efficacy of college teachers based on artificial neural network. Firstly, a grey correlation analysis (GRA) model was established for the teaching pressure and self-efficacy of college teachers, and the analysis procedure was detailed. Then, the possible multicollinearity of the GRA model was tested. In addition, a linear regression model was established based on Lasso variable selection model and ridge regression variable selection model, aiming to eliminate the multicollinearity between various teaching pressure factors in the GRA model. Finally, a multilabel learning algorithm was proposed based on neural network and label correlation. In this way, the correlations between the various teaching pressure factors and teachers' self-efficacy were mined automatically. The proposed model proved valid through experiments.

1. Introduction

With the reform of the education system, the society today raises higher requirements for college teachers: a college teacher needs to play multiple roles at the same time, namely, knowledge imparter, students' psychological tutor, class leader, and pioneer of advanced teaching method [1–5]. Many college teachers find it difficult to strike the balance between being an ordinary person and acting as a role model, and thus face an immense psychological stress [6–10]. Survey results show that college teachers of the same level, although faced with the same pressure in the same period, could be optimistic or pessimistic. When a teacher perceives a low teaching pressure, he/she will work actively, have a high self-efficacy, and improve his/her qualities rapidly. Therefore, it is important to analyze the relationship between teaching pressure and self-efficacy [11–13].

Chung and Chen [14] compared the self-efficacy, job satisfaction, and pressure of teachers in application-oriented colleges in Fujian and Taiwan and discussed the role of self-efficacy in this context. Considering the importance of science and educational psychology in education system, Kuo et al. [15] treated learning motivation as the predictor variable and self-efficacy as the evidence variable and tried to discover the important correlation of the learning motivation and self-efficacy of teachers and students with the principle of educational psychology. Hamedi [16] pointed out that education informatization is an inevitable trend of higher education reform; identified teachers as the key to advancing and applying information education; attributed the psychological stress of college teachers to subjective and objective sources under education informatization; and suggested that teachers should adjust their cognition, emotions, will, and behaviors to meet the needs of education. Wang and Wang [17] revised the technology acceptance model to focus on three individual differences (self-efficacy, personal innovation ability, and sensitivity to environmental pressure).

The above is a brief review of the research into the teaching pressure and self-efficacy of college teachers. It can be seen that the studies at home and abroad have achieved a lot of results, but some defects are yet to be solved. In terms of research contents, the relevant research is immature, failing to fully consider the various indices of teaching pressure. In terms of research methods, most studies rely on questionnaire survey and qualitative research. The scientific level and rigor must be improved by introducing artificial intelligence (AI) strategies. Therefore, this paper tries to analyze and evaluate the relationship between teaching pressure and self-efficacy of college teachers based on artificial neural network [18–20]. Section 2 establishes a grey correlation analysis (GRA) model for the teaching pressure and self-efficacy of college teachers and details the analysis procedure. Besides, the possible multicollinearity of the GRA model was tested with Pearson correlation coefficient and variance inflation factor (VIF). Then, a linear regression model was established based on Lasso variable selection model and ridge regression variable selection model, aiming to eliminate the multicollinearity between various teaching pressure factors in the GRA model. Section 3 proposes a multilabel learning algorithm based on neural network and label correlation and relies on the algorithm to automatically mine the correlations between the various teaching pressure factors and teachers' self-efficacy. The proposed model proved valid through experiments.

2. Multifactor Correlation Analysis Model

2.1. Model Construction. In recent years, domestic and foreign scholars have achieved fruitful results on the correlation analysis of different variables. The main tools used for correlation analysis are GRA, least squares regression, etc.

The foreign research of self-efficacy began with the American psychologist Albert Bandura, who created the concept of self-efficacy in 1977. Seven years later, he defined self-efficacy from the angle of social cognitive theory as an individual's belief in their capacity to execute behaviors necessary to produce specific performance attainments. The self-efficacy is mainly influenced by six factors: performance experience, vicarious experience, imaginal experience, social persuasion, physical arousal, and psychological state. To derive the correlation between college teachers' teaching pressure and self-efficacy, it is important to exclude the unimportant factors and sort the influencing factors by the degree of correlation. For this purpose, the study constructs a GRA model. The analysis procedure of the proposed model is as follows.

Step 1. To reflect the systematic correlations and fully consider the possible multicollinearity, it is necessary to set up the reference series and comparative series for correlation analysis. This paper takes the quantified self-efficacy of teachers as the reference series Q and the quantified values of teaching pressure factors as the comparative series W_i. Let l be the calculation moment and i be the number of rows of influencing factors. Then, the reference series and comparative series can be, respectively, expressed as

$$\begin{cases} Q = Q(l)\, l = 1, 2, \ldots, m, \\ W = W_i(l)\, l = 1, 2, \ldots, m, i = 1, 2, \ldots n. \end{cases} \quad (1)$$

Step 2. Preprocess the collected sample data; i.e., take the average of the series data of each teaching pressure factor:

$$w_i(l)' = \frac{w_i(l)}{\overline{w_i}}. \quad (2)$$

Let $\tau \in [0, 1]$ be the resolution coefficient that determines the difference of correlation coefficients. Then, the correlation coefficient between self-efficacy of college teachers and each teaching pressure factor can be calculated by

$$\delta_i(l) = \frac{(\min/i)(\min/l)\left|w_0(l) - w_i(l)\right| + \tau(\max/i)(\max/l)\left|w_0(l) - w_i(l)\right|}{\left|w_0(l) - w_i(l)\right| + \tau(\max/\mathrm{i})(\max/l)\left|w_0(l) - w_i(l)\right|}. \quad (3)$$

Step 3. Compute the correlation degree between self-efficacy of college teachers and each teaching pressure factor. Here, correlation coefficient is introduced to measure the degree of correlation between the two concepts. The correlation coefficient has various values, which correspond to the influencing factors. To reduce the effects of dispersion of sample data on overall correlation comparison, this paper takes the average of the correlation coefficients corresponding to different influencing factors at different moments. The correlation degree can be calculated by

$$e_i = \frac{1}{n}\sum_{l=1}^{n} \delta_i(l). \quad (4)$$

When the correlation degree e falls in [0, 0.25], teachers' self-efficacy has a low correlation with teaching pressure factors. When e falls in [0.25, 0.5], teachers' self-efficacy has a medium correlation with teaching pressure factors. When e falls in [0.5, 0.75], teachers' self-efficacy has a relatively strong correlation with teaching pressure factors. When e falls in [0.75, 1], teachers' self-efficacy has a highly strong correlation with teaching pressure factors.

Step 4. After computing the correlation degree of each teaching pressure factor, rank the various factors by the correlation degree with teachers' self-efficacy.

To test the possible multicollinearity of the GRA model, the teaching pressure factors selected by the model were tested based on Pearson correlation coefficient.

The author firstly calculated the covariance $XF(w, q) = HO(W,Q)\text{-}HO(W)HO(Q)$ between each influencing factor and teachers' self-efficacy and then computed the standard deviation ε_w of the influencing factors and that ε_q of teachers' self-efficacy. Let HO be the expectation. Then, the Pearson correlation coefficient φ_{wq} between each teaching pressure factor and teachers' self-efficacy can be calculated by

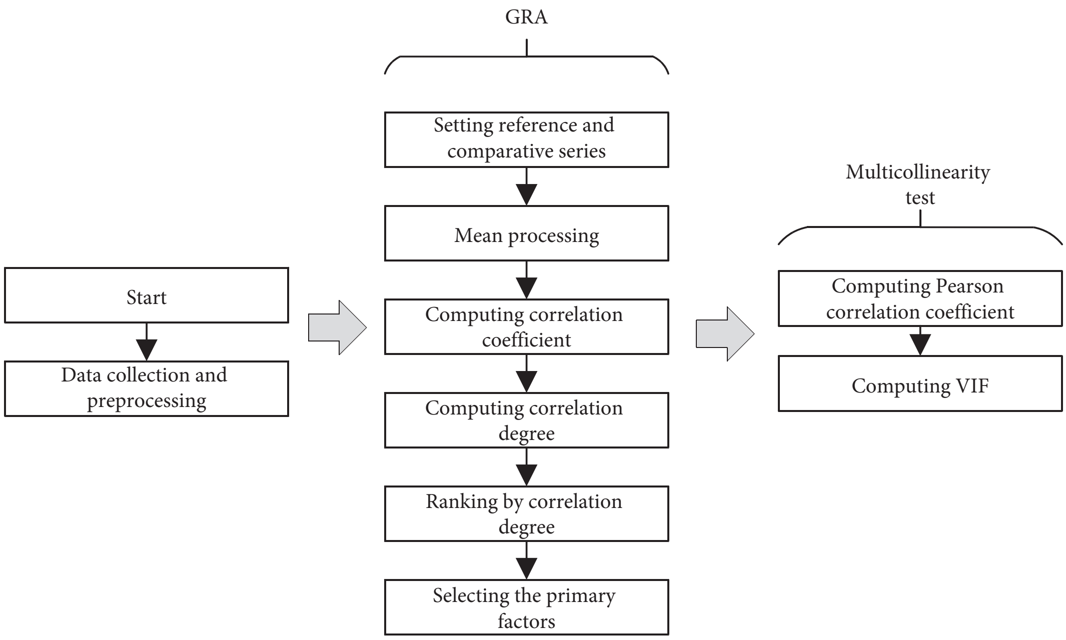


Figure 1: Model flow.

$$\varphi_{wq} = \frac{XF(w,q)}{\varepsilon_w \varepsilon_q} = \frac{HO\left[(w-\lambda_w)(q-\lambda_q)\right]}{\varepsilon_w \varepsilon_q}. \tag{5}$$

If $\varphi_{wq} = 0$, the teaching pressure factor is not linearly correlated with teachers' self-efficacy; if $\varphi_{wq} > 0$, the two have a positively correlation; if $\varphi_{wq} < 0$, the two have a negative correlation; if $\varphi_{wq} > 0.8$, the two have a very strong linear correlation.

Next, the VIFs were calculated for the teaching pressure factors. The first step is to compute the coefficient of multiple determination E_i^2 of the current teaching pressure factor relative to the other influencing factors. The VIF can be calculated by

$$\text{VIF} = \frac{1}{1-E_i^2}. \tag{6}$$

If the VIF > 100, the GRA model faces a severe multicollinearity between the various teaching pressure factors. If the VIF is greater than 10 and smaller than 100, the model factors have a relatively strong multicollinearity. If the VIF is greater than 0 and smaller than 10, the model factors have a negligible multicollinearity. Figure 1 shows the execution flow of the multifactor correlation analysis model, which consists of model construction and multicollinearity test.

2.2. Variable Selection. Our regression model was constructed based on Lasso variable selection model, aiming to eliminate the multicollinearity between the various teaching pressure factors of the GRA model.

Let Q be teachers' self-efficacy, W be the matrix of teaching pressure factors, α be the parameter to be estimated, and σ be the error term. For a general linear regression model, there is $Q = W\alpha + \sigma$. After centralizing Q and normalizing W, the least squares estimation can be expressed as

$$\min\left[\sum_{i=1}^{m}\left(q_i - \sum_{j=1}^{n}\alpha w_{ij}\right)^2\right]. \tag{7}$$

The parameter to be estimated satisfies

$$\widehat{\alpha}_{LAS} = \left(W^T W\right)^{-1} W^T q. \tag{8}$$

Under the constraint $\sum^n|\alpha| \leq p$, the Lasso regression can be derived from formula (7):

$$\begin{cases} \widehat{\alpha}_{\text{lasso}} = \operatorname{argmin}\left[\sum_{i=1}^{m}\left(q_i - \sum_{j=1}^{n}\alpha w_{ij}\right)^2\right], \\ \text{s.t.} \sum_{j=1}^{n}|\alpha| \leq p. \end{cases} \tag{9}$$

Let μ be a positive penalty parameter controlling the number of influencing factors. The value of this parameter can be computed through cross validation. Based on Lagrangian duality, the above formula can be converted into

$$\widehat{\alpha}_{\text{lasso}} = \operatorname{argmin}\left[\sum_{i=1}^{m}\left(q_i - \sum_{j=1}^{n}\beta w_{ij}\right)^2 + \mu\sum_{j=1}^{n}|\alpha|\right]. \tag{10}$$

The greater than penalty parameter, the closer the regression coefficient of teaching pressure parameters to zero.

This paper also constructs a ridge regression variable selection model, aiming to eliminate the multicollinearity between influencing factors and form a contrast against Lasso variable selection model. For a general linear regression model, there is

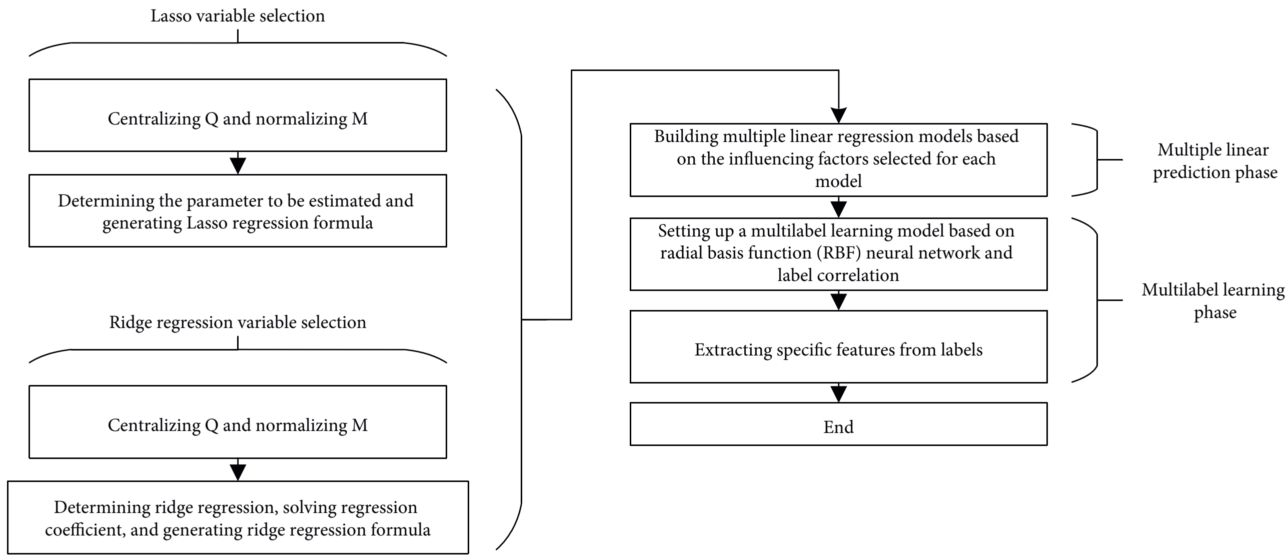


Figure 2: Flow of variable selection and linear regression.

$$Q = W\alpha + \sigma. \tag{11}$$

By least squares method, the regression coefficient α can be estimated as

$$\alpha = \left(W^T W\right)^{-1} W^T W. \tag{12}$$

The regression coefficient of ridge regression can be solved by

$$\alpha = \left(W^T W + lJ\right)^{-1} W^T Q. \tag{13}$$

Let $l \in [0,\ 1]$ be the ridge regression coefficient. The greater the value of l, the smaller the stability of the regression parameter to be affected by the multicollinearity between influencing factors, and the larger the variance of the predicted correlation. To mitigate the influence of variable dimensionality on predicted correlation, the teaching pressure factors of the model must be normalized before ridge regression. Let o_{ij} and e_{ij} be the values of original and normalized factors, respectively, and λ_j and ε_j be the arithmetic mean and standard deviation of variable j, respectively. Then, we have

$$e_{ij} = \frac{o_{ij} - \lambda_j}{\varepsilon_j}. \tag{14}$$

Figure 2 shows the flow of constructing linear variable regression models based on Lasso variable selection model and ridge regression variable selection model.

3. Multilabel Correlation Analysis

To automatically mine the correlations between teaching pressure factors and teachers' self-efficacy, this paper proposes a multilabel learning algorithm based on neural network and label correlation. The algorithm design mainly includes making reasonable use of the underlying correlation between teaching pressure factors, pruning additional features, exploring the correlation degree of the labels corresponding to the influencing factors, and reconstructing the feature set of factor attributes. Figure 3 shows the flow of the multilabel learning algorithm.

During the training of the learning algorithm, a binary classifier is firstly trained for the label corresponding to each influencing factor, to obtain the predicted label $B_i'(1 \le i \le x)$ of each sample. Then, B_i' is combined with each sample feature to form the augmented feature sets of training samples and test samples (C_{TR}^{AF} and C_{TE}^{AF}). Based on C_{TR}^{AF}, the class $A_i(1 \le i \le y)$ is obtained through label training. Finally, label $B_i'(1 \le i \le x)$ is predicted for C_{TE}^{AF} based on A_i. The additional feature information of each label can be expressed as

$$R_j = B - \left\{b_j\right\}. \tag{15}$$

The additional feature information of each influencing factor is pruned to lower the probability of noise of the additional information, reduce the dimensionality of label information, and simplify the entire algorithm. Figure 4 shows the flow of pruning. Out of the 249 teachers selected for this research, 205 provided effective responses.

Firstly, the original training samples are divided into a training set C^{TR} and a verification set C^{VE} in a ratio of 8 : 2. Next, a binary classifier is trained on the training set C^{TR}, and the binary classifier corresponding to the label k_j of the j-th factor is denoted as A_j. Then, the label set of C^{VE} is verified. F1 is introduced to measure the hardness of the label:

$$F_1 = \frac{2 \cdot PR}{PR + RE}. \tag{16}$$

This paper adopts the following pruning formula to judge whether the label is prone to prediction failure:

$$b^d = \left\{k_j | F_1\left(A_j, C^{VE}\right) \ge \Psi, 1 \le j \le y\right\}. \tag{17}$$

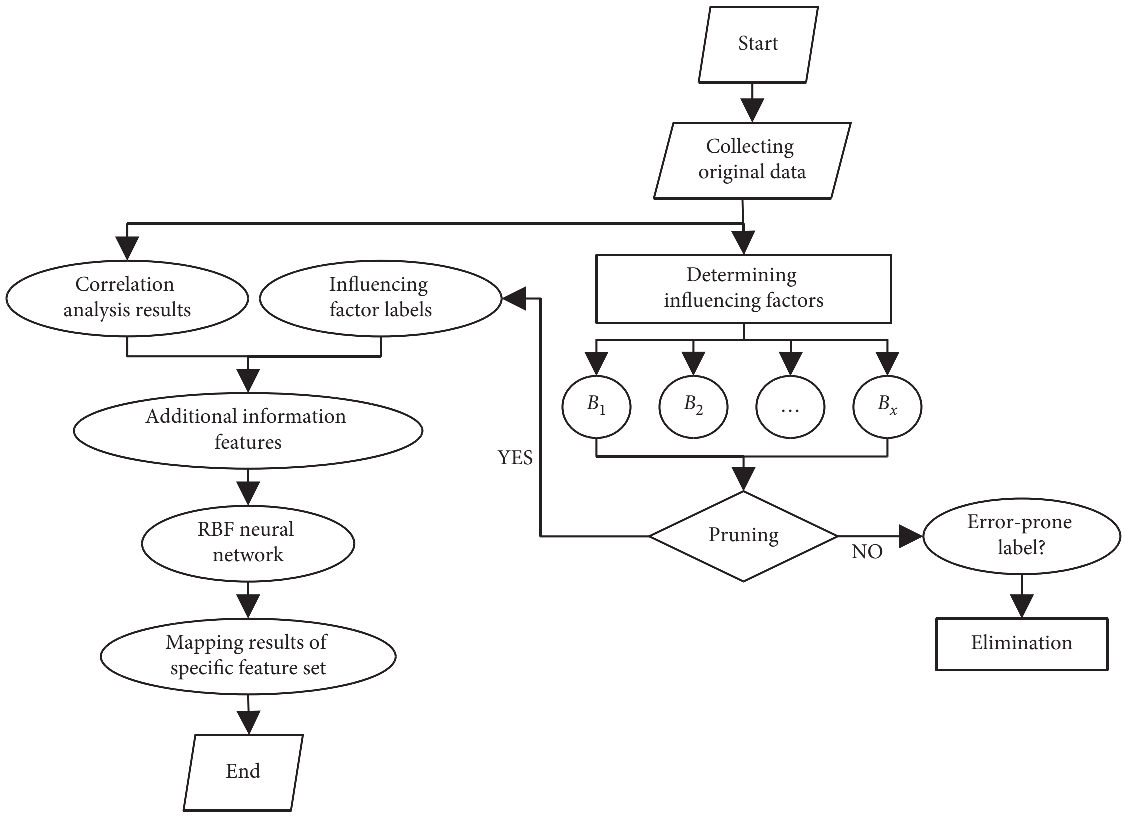


Figure 3: Flow of multilabel learning algorithm.

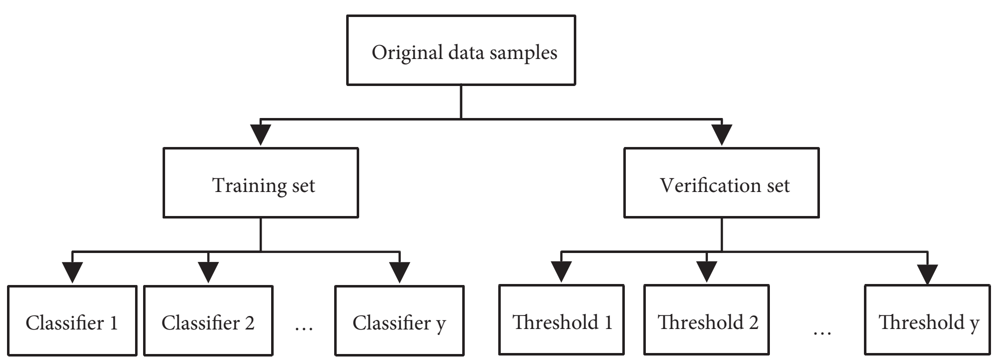


Figure 4: Flow of pruning.

Let Ψ be the preset threshold of F_1; $F(A_j,, C^{VE})$ be the F_1 of k_j; and Ψ_j be the threshold. If $\Psi_i > \Psi_j$, the label k_j of the j-th factor has a high confidence; if $\Psi_i < \Psi_j$, k_j is error-prone and should not be adopted as additional information.

Considering the inconsistency between the labels corresponding to different factors, this paper directly uses the predicted labels of these factors to train the label learning algorithm. The additional feature set of the influencing factors is constructed on RBF neural network.

As shown in Figure 5, the RBF neural network contains three layers: an input layer, a hidden layer, and an output layer. The hidden layer is activated by an RBF. Let o and ω be the center and expansion constant of the RBF, respectively. Then, the main forms of the RBF can be expressed as

$$\psi(a_t) = \exp\left(-\frac{1}{2\omega^2}g^2\right), \tag{18}$$

$$\psi(a_t) = \frac{1}{1 + \exp\left(g^2/\omega^2\right)}, \tag{19}$$

$$\psi(a_t) = \frac{1}{\sqrt{g^2 + \omega^2}}. \tag{20}$$

Formulas (18)–(20) are Gaussian function, inverse sigmoid function, and quasi-multi-quadratic function, respectively. Note that $g = ||a_t\text{-}o||$; the smaller the value of ω, the narrower the function, and the higher the selectivity.

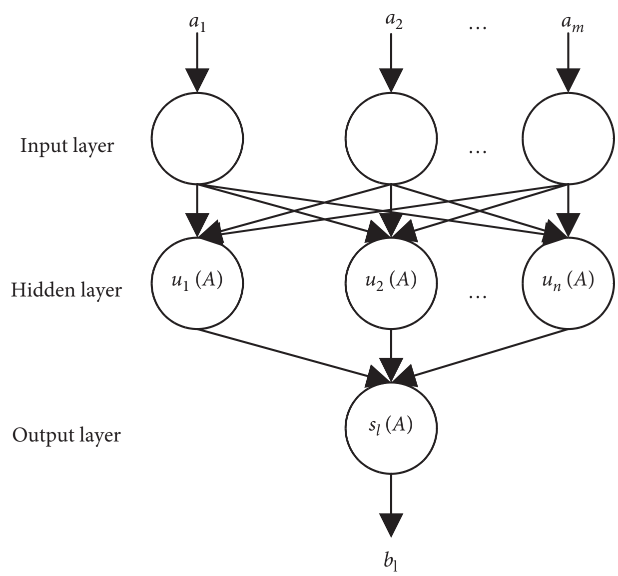


Figure 5: Structure of RBF neural network.

Training a multilabel learning model requires a lot of distinguishable information. To acquire more distinguishable information, the feature set containing the label attribute of each factor needs to be reconstructed, and the essential attributes of each label should be extracted from the original data on the corresponding teaching pressure factor. Fully considering the binary features of factor labels, this paper denotes the sample instances belonging to label b_l as H_w and those not belonging to that label as X_l. Then, H_l can be defined as

$$H_l = \{a_i | (a_i, B_i) \in C, b_l \in B_i\}. \tag{21}$$

X_l can be defined as

$$X_l = \{a_i | (a_i, B_i) \in C, b_l \notin B_i\}. \tag{22}$$

Next, k-means clustering is adopted to capture the attributes of H_l and X_l. H_l is divided into f'_l nonintersecting clusters with the cluster heads of $\{h^l_1, h^l_2, \ldots, h^l_f\}$, while X_l is divided into f''_l nonintersecting clusters with the cluster heads of $\{x^l_1, x^l_2, \ldots, h^l_{f'}\}$. Among the multilabel learning samples of teaching pressure factors, $|X_l| << |H_l|$ normally holds. This leads to the imbalance between positive and negative labels among the learning samples. To solve the problem, it is assumed that the number of positive labels equals that of negative labels:

$$f_l = f'_l = f''_l. \tag{23}$$

Let $\eta \in [0, 1]$ be the ratio parameter controlling the number of clusters. Then, the number of clusters of H_l and X_l can be configured by

$$f_l = \left[\eta \cdot \min\left(|H_l|, |X_l|\right)\right]. \tag{24}$$

The augmented feature sets C^{AF}_{TR} and C^{AF}_{TE} are imported to the neural network. The number of nodes on the hidden layer is set to $2f_l$. The original vector of the basis function for label y_k is denoted as $D_l = \{h^l_1, h^l_2, \ldots, h^l_{f+}, x^l_1, x^l_2, \ldots, h^l_{f'}\}$, i.e., the center of radial basis. Let $DIS(A\text{-}D_l)$ be the Euclidean distance from the eigenvector to the original vector. By taking Gaussian function as the activation function, the activation function of the hidden layer can be expressed as

$$u(A) = \exp\left(-\frac{\mathrm{DIS}(A - D_l)^2}{2\Phi_j^2}\right). \tag{25}$$

The formula of the expansion parameter $\Phi_j (k \le k \le y)$ can be rewritten as

$$\Phi = \left(\frac{2 \cdot \sum_{i=1}^{y-1} \sum_{j=i+1}^{y} DIS\left(D_i, D_j\right)}{y(y-1)}\right). \tag{26}$$

Formula (26) shows that Φ_j is the mean distance between the original vectors of two basis functions. Thus, the mapping from the additional feature set of the original influencing factors to the feature set of labels can be determined, once the center and the expansion parameter of the radial basis are confirmed. Let RV^i_l be the true value of the i-th sample A_i on label b_k. Then, the mapping from a specific feature set to the output layer can be given by

$$s_l(A) = \sum_{l=1}^{f_l} v_l u_l(A), \tag{27}$$

where $V = [v_1, v_2, \ldots, v_{fl}]$ is the weight matrix calculated by the minimum quadratic sum of squares:

$$GQ = \frac{1}{2} \sum_{i=1}^{f} \sum_{l=1}^{f_l} \left(s_l(A_i) - RV^i_l\right)^2. \tag{28}$$

If $RV^i_l = 1$, A_i belongs to label b_l; if $RV^i_l = 0$, A_i does not belong to label b_l.

4. Experiments and Result Analysis

To facilitate subsequent modeling and data description, this paper defines nine independent variables for teaching pressure: overload pressure W_1, working duration pressure W_2, further education pressure W_3, title evaluation pressure W_4, pressure of changing teaching method W_5, pressure of conflict between personal life and work W_6, interpersonal interaction pressure W_7, pressure from personal quality defects W_8, and student management pressure W_9.

The nine teaching pressure factors were organized into a comparative series, and the quantified values B of teachers' self-efficacy were grouped into a reference series. By the averaging method, the sample data on the teaching pressure and self-efficacy in a fixed period were nondimensionalized, to facilitate comparison and eliminate the influence of dimensionality. Table 1 shows the difference series between reference and comparative series. Further, the correlation coefficient and correlation degree between the two series were computed. The maximum and minimum absolute differences of the matrix were 0.513 and 0.003, respectively. Table 2 ranks the correlation degrees.

Table 1: Difference series between reference and comparative series.

Year	2008	2009	2010	2011	2012	2013	2014
W_1	0.1358	0.0265	0.1254	0.0956	0.2561	0.0524	0.0365
W_2	−0.3254	−0.3325	−0.4251	−0.3126	−0.3265	−0.3142	−0.3326
W_3	0.1325	0.1246	0.0352	0.1264	0.1052	0.0562	0.0751
W_4	−0.185	−0.172	−0.212	−0.118	−0.105	−0.106	−0.145
W_5	−0.3625	−0.4526	−0.2514	−0.3625	−0.3514	−0.2875	−0.2956
W_6	−0.362	−0.195	−0.254	−0.324	−0.156	−0.236	−0.152
W_7	−0.3625	−0.1542	−0.5214	−0.3261	−0.2517	−0.3625	−0.4582
W_8	−0.3625	−0.3624	−0.1652	−0.2547	−0.3185	−0.2674	−0.2854
W_9	0.2145	0.3614	0.1247	0.2851	0.0147	0.1504	0.0536
Year	2015	2016	2017	2018	2019	2020	2021
W_1	0.0395	0.1625	0.1524	0.1326	0.1254	0.1145	0.1025
W_2	−0.2315	−0.1958	−0.1625	−0.0325	0.0254	0.2685	0.3965
W_3	0.0856	0.0625	0.1132	0.1052	0.2514	0.3251	0.1025
W_4	−0.131	−0.102	−0.045	−0.006	0.028	0.165	0.153
W_5	−0.2415	−0.1958	−0.1925	−0.1746	0.1634	0.2135	0.0195
W_6	−0.241	−0.362	−0.251	−0.162	0.125	0.256	0.482
W_7	−0.1362	−0.2574	−0.3615	−0.1625	0.1254	0.2856	0.3471
W_8	−0.3846	−0.1824	−0.2851	0.1358	0.3541	0.1254	0.2614
W_9	0.0471	0.0851	0.1246	0.0258	0.0214	0.0254	0.0362

Table 2: Correlation degree ranking.

Factor	W_1	W_2	W_3	W_4	W_5
Correlation degree	0.7528	0.5712	0.8124	0.7846	0.8328
Ranking	5	8	2	3	1
Factor	W_6	W_7	W_8	W_9	
Correlation degree	0.7656	0.6943	0.5482	0.6814	
Ranking	4	6	9	7	

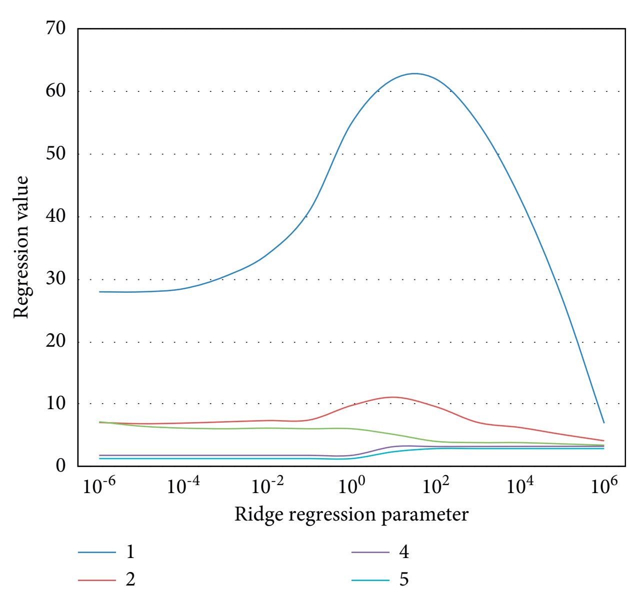


Figure 6: Ridge traces of main influencing factors.

When the correlation degree is greater than 0.8, the teaching pressure factor is very highly correlated with self-efficacy; when the correlation degree is between 0.8 and 0.75, the two have a relatively high degree of correlation; when the correlation degree is between 0.75 and 0.7, the two have a general degree of correlation; when the correlation degree is between 0.7 and 0.65, the two are barely correlated; when the correlation degree is smaller than 0.65, the two are weakly correlated. As shown in Table 2, W_5, W_3, W_4, W_6, and W_1 are main influencing factors, while W_2, W_7, W_8, and W_9 are barely correlated factors.

The ridge variable selection model was constructed by ridge trace method and cross validation. Figure 6 presents the ridge traces of main influencing factors. From top to bottom, the five curves represent the regression curves of W_5, W_3, W_4, W_6, and W_1 generated with different values of the ridge regression parameter. As the parameter increased continuously from zero, the regression linearity of W_5 increased temporarily and then declined continuously, while the regression curves of W_3, W_4, W_6, and W_1 remained stable. The standard regression coefficient only oscillated very slightly.

The correlation degree between teaching pressure factors and teachers' self-efficacy was predicted by the constructed model, with the data samples of 2014–2017 being the training set and those of 2018–2021 being the testing set. Tables 3 and 4 present the correlation analysis results based on multiple linear regression and RBF neural network, respectively. The two tables display the error, relative error, and MRE between the training set results and the test set results.

Table 3: Correlation analysis results based on multiple linear regression.

Year	2014	2015	2016	2017
True value	5887.2	6025.2	5986.1	5968.4
Predicted value	5748.5824	5864.2548	5896.2547	5869.3251
Error	−28.2	−235.1	−96.2	−149.2
Relative error (%)	0.5	3.6	1.7	2.3
MRE (%)	2.2			
MAE	125			
RMSE	148			

Note. MRE: mean relative error, MAE: mean absolute error, RMSE: root mean square error.

Table 4: Correlation analysis results based on RBF neural network.

Year	2018	2019	2020	2021
True value	6652	6694	—	—
Predicted value	6724	6958	7223	7452
Error	74	253	—	—
Relative error (%)	1.2	4.2	—	—
MRE (%)	2.56		—	—

Table 5: Simulation results of different models.

Algorithm number	*A*	*B*	*C*	*D*	*E*
1	0.201	0.345	0.452	0.162	0.674
2	0.202	0225	0.452	0.172	0.758
3	0.203	0.225	0.554	0.254	0.721
4	0.208	0.255	0.462	0.185	0.754
5	0.198	0.275	0.465	0.185	0.752
6	0.185	0.265	0.462	0.178	0.756
7	0.195	0.254	0.462	0.162	0.758

Table 6: Runtime before and after pruning.

Dataset number	1	2	3	4	5
After	10.7524	6.5241	5.2682	0.3527	96.2548
Before	31.0214	13.2547	12.5846	1.0245	231.5648
Ratio	2.95861	2.04562	2.32641	3.01542	2.52162

To verify its effectiveness, our model was compared with six other multilabel learning algorithms through simulation, namely, binary relevance, classifier chains, calibrated label ranking, random k-labelsets, machine learning–k-nearest neighbors (ML-KNN), and machine learning–decision tree (ML-DT). The performance was evaluated by five metrics: A: ratio of difference; B: error ratio of top-ranking label; C: mean distance between predicted label set and actual label set; D: error ratio of the ranking of error-prone labels; E: correct ratio of the ranking of high confidence labels. The simulation results of different models are displayed in Table 5. It can be seen that our model performed better than the 6 contrastive algorithms on all five metrics. Hence, the algorithm performance can be improved by fully utilizing the label correlations corresponding to the influencing factors.

Table 6 compares the runtime before and after pruning. Before the operation, the algorithm was highly complex. After the operation, the runtime was greatly shortened and was linearly correlated with the scale of the labels corresponding to the influencing factors. Because of the rising prediction accuracy of correlation degree, the proposed algorithm has an ideal overhead of time complexity.

5. Conclusions

This paper mainly analyzes and evaluates the relationship between teaching pressure and self-efficacy of college teachers based on artificial neural network. Firstly, the author created a GRA model for the teaching pressure and self-efficacy of college teachers and detailed the analysis procedure. Next, the possible multicollinearity of the GRA model was tested in two steps: computing the Pearson correlation coefficient and calculating the VIF. Then, a linear regression model was established based on Lasso variable selection model and ridge regression variable selection model and used to eliminate the multicollinearity between various teaching pressure factors in the GRA model. Finally, a multilabel learning algorithm was developed based on neural network and label correlation to automatically mine the correlations between the various teaching pressure factors and teachers' self-efficacy.

Through experiments, the difference series between reference and comparative series, as well as correlation degree ranking, were obtained. The results show that overload pressure W_1, further education pressure W_3, title evaluation pressure W_4, pressure of changing teaching method W_5, and pressure of conflict between personal life and work W_6 are the main influencing factors, while working duration pressure W_2, interpersonal interaction pressure W_7, pressure from personal quality defects W_8, and student management pressure W_9 are barely correlated factors. After that, the ridge traces were plotted for the main influencing factors. The correlation analysis results were obtained based on multiple linear regression and RBF neural network. Moreover, the error, relative error, and MRE between the training set results and the test set results were displayed, and the runtime before and after pruning was summarized. The experimental results fully demonstrate the effectiveness of our model.

Data Availability

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

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] N. A. Razak, H. Ab Jalil, and I. A. Ismail, "Challenges in ICT integration among Malaysian public primary education teachers: the roles of leaders and stakeholders," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 14, no. 24, pp. 184–205, 2019.

[2] Y. Sun and F. Gao, "Exploring the roles of school leaders and teachers in a school-wide adoption of flipped classroom: school dynamics and institutional cultures," *British Journal of Educational Technology*, vol. 50, no. 3, pp. 1241–1259, 2019.

[3] C. N. Chu, "Bring independent practice technology to after-school: preliminary results from the mixed roles of teachers and parents study to explore children effects in Chinese characters learning," in *Proceedings of the International Conference on Frontier Computing*, pp. 841–845, Tokyo, Japan, June, 2016.

[4] B. Wang, "Study on changes of college English teaching method and redefinition of teachers' roles in the computer network environment," *International Journal of Emerging Technologies in Learning*, vol. 12, no. 8, pp. 137–145, 2017.

[5] H.-L. Chou and J. C.-Y. Sun, "The moderating roles of gender and social norms on the relationship between protection motivation and risky online behavior among in-service teachers," *Computers & Education*, vol. 112, pp. 83–96, 2017.

[6] O. Kwon, K. Choi, and M. Kim, "User acceptance of context-aware services: self-efficacy, user innovativeness and perceived sensitivity on contextual pressure," *Behaviour & Information Technology*, vol. 26, no. 6, pp. 483–498, 2007.

[7] S. N. Hu and D. Chen, "Investigation on the present situation of university teachers' scientific research pressure under the background of information," in *Proceedings of the 2020 International Conference On Artificial Intelligence And Education (ICAIE)*, pp. 249–252, Tianjin, China, June, 2020.

[8] J. Pereira, A. Teixeira, and H. Simões, "Effect of Occupational Activity on Ambulatory Blood Pressure Behavior in university Teachers," *Occupational Safety and Hygiene V*, vol. 2, pp. 563–566, 2017.

[9] P. Dondon, J. M. Duprat, and C. Delesse, "Yoga practice: a modern tool against new kind of pressure for teachers and researchers in scientific engineering schools," in *Proceedings of the 7th WSEAS International Conference On Engineering Education*, pp. 58–65, Corfu Island, Greece, July, 2010.

[10] N. Canpolat, T. Pinarbasi, and M. Sözbilir, "Prospective teachers' misconceptions of vaporization and vapor pressure," *Journal of Chemical Education*, vol. 83, no. 8, pp. 1237–1242, 2006.

[11] B. Standl and N. Schlomske-Bodenstein, "Investigating teacher's empathy and its impact on pre-service teachers' self-efficacy in programming tasks," *the 16th Workshop in Primary and Secondary Computing Education*," *Virtual Event, Germany*, vol. 1-2, 2021.

[12] S. Latifah, N. E. Susilowati, K. Khoiriyah, and R. Rahayu, "Self-efficacy: its correlation to the scientific-literacy of prospective physics teacher," *Journal of Physics: Conference Series*, vol. 1155, no. 1, Article ID 012015, 2019.

[13] A. A. Rogers, J. J. Rogers, and J. C. Baygents, "A longitudinal evaluation of an AP type, dual-enrollment introduction to engineering course: examining teacher effect on student self-efficacy and interest in engineering (evaluation)," in *Proceedings of the 2019 ASEE Annual Conference & Exposition*, Tampa, United States, June, 2019.

[14] T.-Y. Chung and Y.-L. Chen, "Exchanging social support on online teacher groups: relation to teacher self-efficacy," *Telematics and Informatics*, vol. 35, no. 5, pp. 1542–1552, 2018.

[15] P. Kuo, J. Huang, Q. Ji, L. Lin, Z. Chen, and K. Chen, "Comparison of self-efficacy, job stress and satisfaction of application-oriented university teachers in Fujian and Taiwan," in *Proceedings of the 2019 IEEE Eurasia Conference on IOT, Communication and Engineering (ECICE)*, pp. 109–112, Yunlin, Taiwan, October, 2019.

[16] M. A. Hamedi, "The relationship between educational psychology and academic motivation and self-efficacy and minor training skills of teachers," *Research Journal of Applied Sciences, Engineering and Technology*, vol. 4, no. 23, pp. 5188–5192, 2012.

[17] X. Wang and L. Wang, "The Reason and Self-Adjustment of College Teachers' Psychological Pressure under the Background of IT in Education," in *Proceedings of the 2011 IEEE International Symposium on IT in Medicine and Education*, pp. 264–266, Cuangzhou, China, December, 2011.

[18] Y. Xie, S. Zhang, and Y. Liu, "Abnormal behavior recognition in classroom pose estimation of college students based on spatiotemporal representation learning," *Traitement du Signal*, vol. 38, no. 1, pp. 89–95, 2021.

[19] Y. Zhao, W. Ren, and Z. Li, "Prediction of English scores of college students based on multi-source data fusion and social behavior analysis," *Revue d'Intelligence Artificielle*, vol. 34, no. 4, pp. 465–470, 2020.

[20] Q. Guo, "Detection of head raising rate of students in classroom based on head posture recognition," *Traitement du Signal*, vol. 37, no. 5, pp. 823–830, 2020.

Hindawi
Scientific Programming
Volume 2022, Article ID 7596991, 12 pages
https://doi.org/10.1155/2022/7596991

Research Article

Application of Traditional Culture in Intelligent Advertising Design System in the Internet Era

Dan Sun

School of Art & Design, Dalian Polytechnic University, Dalian 116000, Liaoning, China

Correspondence should be addressed to Dan Sun; sundan@dlpu.edu.cn

Received 24 January 2022; Revised 1 April 2022; Accepted 5 April 2022; Published 27 April 2022

Academic Editor: Ahmed Farouk

This paper focuses on the application of traditional culture in the intelligent advertising design system in the internet era. The existence form of traditional culture is abstract and vivid. It is extremely charming when used in advertising design. It is unique and subtle and has the beauty of holding a pipa half-covered. The classic colors reveal the splendor of history, which is fascinating, and it seems to want people to integrate into it and appreciate its beauty. This paper, firstly, introduces the background of traditional culture and intelligent advertising design and discusses its significance and innovation. Combined with the research methods and experiments put forward by the related work, the advertising system model is, firstly, proposed. The process of ad request processing, system hardware topology, and ad real-time bidding process are introduced. It will talk about the feature association algorithm in advertising design, explain the linear logistic regression and nonlinear algorithms, and describe the GBDT feature processing process. It combines stochastic gradient descent, decision trees, etc., to calculate ad click-through rates. It also explained the allocation algorithm of traffic and quality and market competition in advertising design. It is guided by a probabilistic filtering mechanism that tests ad spend, bidding, and market competition. Finally, the effect evaluation experiment of intelligent advertising system based on traditional culture fusion is carried out. It displays the application of traditional culture, such as Dunhuang Feitian and blue and white porcelain, Huizhou architecture, and Miao embroidery. It uses pictures to show its beauty, and it compares the advertising situation in the perspective of traditional culture and modern fashion. It is concluded that the introduction of traditional culture into advertisements is more attractive. Through the establishment of an outdoor advertising evaluation system based on face gesture recognition to calculate the pedestrian parking viewing rate, it is concluded that the system has a very high accuracy rate and a very small error, only 3.76%, which can be effectively applied to actual scenarios.

1. Introduction

The traditional culture seal engraves the history in human thought. Even in today's environment, where various cultures are bursting out, traditional culture is unique in the world by virtue of its wide range of subjects, long history, and profound connotations. Because of this, the international communication and influence of traditional culture has become more far-reaching. In the form of cultural pluralism and cultural globalization, the phenomenon of the integration of traditional culture and advertising is a natural occurrence. The combination of advertising and traditional culture makes it more characteristic and disseminated. The combination of the two not only allows advertising to play its own promotional role but also can spread and promote traditional culture and its value. In addition to expressing the phenomenon of the combination of advertising and traditional culture, traditional culture is not limited to tradition. The reason why it can be so active and full of vitality in modern society is inseparable from its variability and inclusiveness. The progress of the times and society has also promoted the transformation and innovation of traditional culture. Therefore, in modern society, traditional culture has more possibilities and more tenacious vitality [1]. In the process of combining advertising and traditional culture, various questions will be encountered. Advertising, as a commercial culture, cannot be separated from the heritage of the nation and country. The injection of traditional culture makes each component of the advertisement more attractive. Concise and meaningful advertising words, culturally rich copywriting, etc., make advertising out of the original limited structure and expression. The rhythm of ancient poetry in traditional culture has brought far-reaching influence to advertising. Under the smudge of traditional culture, the mode of communication and the form of expression are more worthy of appreciation. Advertising and traditional culture are integrated with each other and influence each other. The addition of traditional culture makes advertising more oriental and more oriental.

The innovation of this paper is to substitute random forest into the advertising design system so that it has more accurate testing ability and can reduce errors. For imbalanced datasets, random forest can balance the error. When there is a classification imbalance, random forest can provide an effective method to balance the error of the dataset. The traditional culture is integrated into the advertisement, and the product is promoted in a more subtle and tactful way of expression so that it has a unique temperament and an endless aftertaste. The designed system is used to test the interest of pedestrians in advertisements, which can better design and adjust advertisements, which is of great practical significance.

2. Related Work

Advertising design has always been an object of great enthusiasm for new media. Ding et al. designed and implemented a blockchain-based digital advertising media system (B2DAM) with Hyperledger as the implementation platform. The B2DAM system integrates distributed ledgers, multichain, smart contracts, and consensus mechanisms to ensure the decentralization and multiparty maintenance of immutable data [2]. Dong et al. proposed an efficient random forest-based detector for metric learning, called the random forest metric learning (RFML) algorithm. It combines semimultiple metrics with random forests to better separate the desired target and background. Experimental results show that the proposed method outperforms state-of-the-art object detection algorithms and other classical metric learning methods [3]. Xia et al. proposed a new ensemble method called rotation random forest by kernel principal component analysis (RoRF-KPCA). Specifically, the original feature space is, firstly, randomly split into several subsets, and KPCA is performed on each subset to extract high-order statistics [4]. Papathomas proved that assigning a g-prior (or mixture of g-prior) to the parameters of some log-linear model specifies the g-prior (or mixture of g-prior) of the parameters of the corresponding logistic regression. By deriving asymptotic results and numerical descriptions, this correspondence extends to the posterior distribution of model parameters when g-prior is employed [5]. HudaS uses multiple linear regression and p-values for each individual API feature to select the least relevant and most important features. It reduces the dimensionality of large malware data and ensures that there is no multicollinearity. Then, a stepwise logistic regression method is employed to test the importance of individual malware features against the corresponding Wald statistic, and a binary decision model is constructed [6]. Baneshi et al. constructed a tree-based model using the Gini index as a homogeneity criterion and also applied a complementary discrimination analysis. The variables that helped build the tree were stressful life events, mental disorders, family support, and religious beliefs [7]. Although these studies have certain guiding significance, there are insufficient demonstrations, which can be further improved.

3. Advertising System Model and Related Algorithms

3.1. Advertising System Model. Before designing the advertising publishing system, it is necessary to comprehensively consider many requirements, such as users' needs for business updates and related services [8]. Only by adding these important requirements into the design of the system in advance can we finally provide users with a stable, efficient, practical, and reliable advertising publishing system [9]. In terms of humanization, it is necessary to add support in many aspects, such as system scalability, security, etc. Under the ever-changing situation of advertising in the future, the system can expand different functions with different advertising needs. At the same time, it is necessary to take adequate protection in terms of data security to effectively prevent data leakage [10]. The business processing flow of each subsystem in the advertising publishing system is shown in Figure 1.

On the premise of the nonfunctional requirements of the system, the hardware topology is defined according to the relevant functional definitions of the subsystems of the system [11]. Its system topology is shown in Figure 2.

The structure of the server-side subsystem is shown in the figure. It is not difficult to see that the advertisement management system, the advertisement delivery system, the advertisement display system, and the data analysis system have corresponding servers. A server and a server node constitute the database server [12]. In the above-mentioned corresponding servers, both the ad delivery server and the ad display server are composed of one server to achieve a balanced load [13]. The advertisement management background is generally deployed on a separate server node. Because the function of the background is single, this deployment can improve reliability and security. At the same time, it can improve the efficiency of advertisement display and delivery, reduce the impact on advertisements as much as possible, and further reduce the risk of overall system downtime [14]. The responsibility of the statistical analysis server is to be responsible for the statistics and calculation of a large amount of data.

The data management platform can summarize and process the user's information. The main purpose is to process the collected user data and make it available for use in advertising systems and markets. The data management platform usually collects users' browsing records, identifies users' preferences, and reasonably categorizes different users. These obtained data are sold to DSP, etc., who can orient the data more precisely [15]. DSP is a system and an online advertising platform. It can make it easier and more

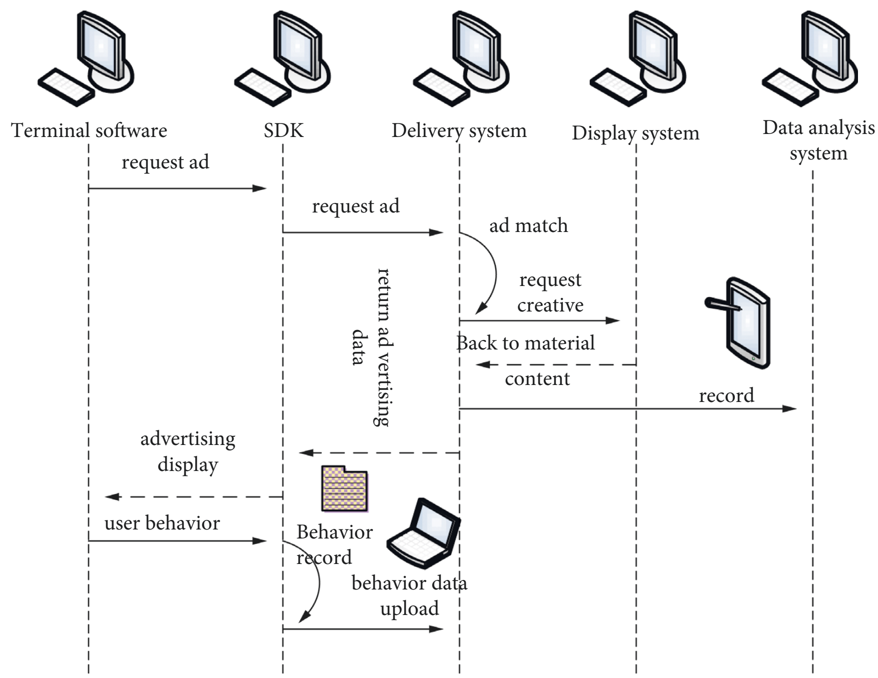


Figure 1: Ad request processing flow.

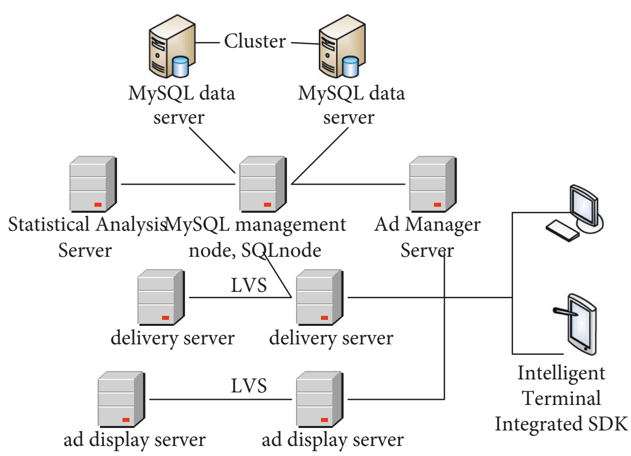


Figure 2: Topology.

convenient for advertisers to follow a unified bidding and feedback method. It purchases high-quality ad inventory in real time at reasonable prices for online ads located on multiple ad exchanges. These data have a decisive influence on the level of quotations in the real-time bidding process. The advertising real-time bidding process is shown in Figure 3.

3.2. Feature Association Algorithm in Advertising Design. Linear logistic regression has a relatively simple learning ability when learning attribute features. It can only learn a single feature or a single attribute. For example, it can only learn the type of advertisement that can get more click-through rate or the type of product advertisement that is more popular with consumers [16]. In the collected data, each component can be regarded as a characteristic data. Each feature corresponds to at least one unknown parameter, thus forming a linear model function. However, linear logistic regression cannot learn effectively when multiple features or multiple attributes are interleaved, for example, which sports enthusiasts prefer between health products and sports equipment, and which type of product advertisement has higher attention than the advertisement of the same product. These situations are not faced by linear logistic regression [17]. In simple terms, it is actually a combination of multiple features or multiple attributes to get more features or attributes. At the same time, it can also analyze the impact of more aspects or dimensions. Essentially, it is a case of polynomial regression. The maximum depth is set in advance, each branch is probed with a step-by-step strategy, and the entire process is processed continuously. It is transformed into a binary discrete attribute, and at the same time, it learns and trains the relationship between each feature or attribute so that the output can obtain appropriate enhanced attributes [18]. Considering the base attribute and the enhancement attribute as a feature vector, we can have the advantages of both. Basic attributes are used to obtain basic click trends, and enhancement attributes are used to improve the accuracy of final click prediction [19]. Figure 4 shows the GBDT feature processing.

The proportion of positive samples in the original dataset has a great impact on the learning of the model. In the ad network, there are a huge number of ad requests every day, and these ad requests make the number of learning samples increase accordingly. In the offline state, training the model consumes more resources. At the same time, the data used needs to be updated continuously. Hence, the feasibility of this training method is very low [20]. Therefore, according to the actual needs, the proportion of positive samples is adjusted, and the negative samples are used by sampling. In

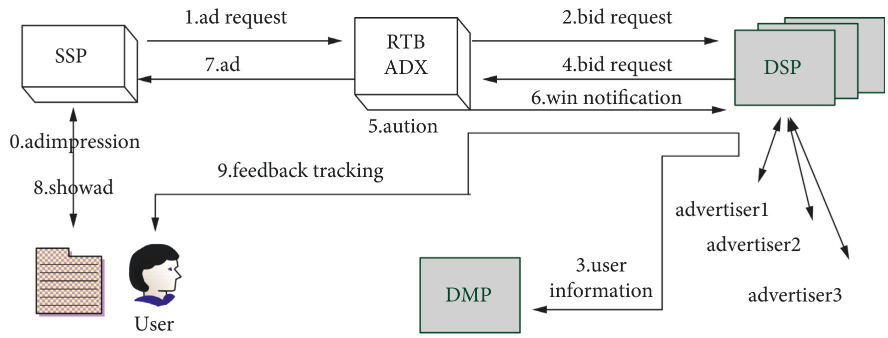


Figure 3: Ad real-time bidding process.

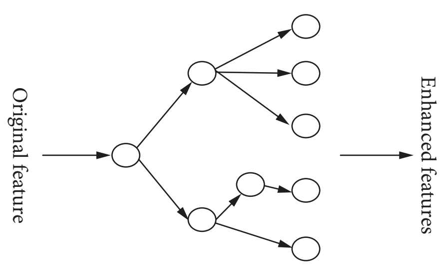


Figure 4: GBDT feature processing.

this environment, the model can perform more training and learning on positive samples, thereby reducing the overall computational cost [21]. There are far fewer positive examples than negative examples, and the original data has a serious class imbalance problem. There is a huge challenge for training to learn useful patterns. Hence, the data is negatively sampled.

CTR prediction models are generally divided into two types: linear and nonlinear. Among them, logistic regression is one of the most commonly used linear CTR prediction models. When the raw data is processed, it is modeled and solved. The linear logistic regression model regards the information in each request as a feature vector m, and the function click rate $\phi(m)$ of the feature vector m can be expressed as follows:

$$\phi(m) = \text{sigmoid}(f(m)). \tag{1}$$

The linear sum of the features can be expressed as follows:

$$f(m) = \mu_0 + \sum_{k=1}^{N} \mu_k m_k. \tag{2}$$

Then, the logistic function and the s-type function are as follows:

$$\text{sigmoid}(s) = \frac{1}{1+e^{-s}}. \tag{3}$$

$f(m)$ is the linearly weighted sum of the eigenvectors that wraps them to [0, 1] via the sigmoid function. At this time, when the weighted sum wireless approaches infinity, $\phi(m)$ approaches 1 infinitely. When the weighted sum infinitely approaches negative infinity, $\phi(m)$ infinitely approaches 0. At this time, upon combining the probability density of a, m and the predicted value of $\phi(m)$, the likelihood function of the data sample with the amount of data as x is solved. The class label and feature vector of the k sample instance are represented by $a^{(k)}$ and $m^{(k)}$, and the logarithmic result is as follows:

$$\text{Log}W(\mu) = \sum_{k=1}^{x} \left\{ a^{(k)} \log \phi\left(m^{(k)}\right) + \left(1 - a^{(k)}\right) \log\left(1 - \phi\left(m^{(k)}\right)\right) \right\}. \tag{4}$$

It can be seen that the negative logarithm of the likelihood function can be used as its cross entropy or logarithmic loss function. Then, the iterative rule for calculating the weight is controlled by maximizing the gradient direction and step size of the likelihood function value. At this time, for the i^{th} weight value of the dimension feature vector b, there are,

$$\mu_i \longleftarrow \mu_i + \lambda\left(a^{(k)} - \phi\left(m^{(k)}\right)\right) m_i^{(k)}, \quad i = 1, 2, \ldots, b. \tag{5}$$

Stochastic gradient descent is named because the overall process resembles a random descent route. The stochastic gradient descent method uses only one sample to iterate at a time, and the training speed is very fast. In the whole optimization process, the optimization of this method is not an all-encompassing optimal solution. However, by this method, all the weight values can be updated directly with the error between the obtained predicted value and the actual value. If it is necessary to further shorten the training time and obtain better convergence performance, the Newton-Raphson method can be used. The resulting error is actually a maximum likelihood estimate that fits a Gaussian distribution. Hence, it is equivalent to solving least squares. Because the least squares of linear logistic regression is not a convex function, it is difficult to obtain the global optimal value by stochastic gradient descent. At this time, through the method of logarithmic loss function and the corresponding target formula are established, and the regular term is used to prevent parameter overfitting.

$$\min \sum_{k=1}^{x} \left\{ a^{(k)} \log \phi\left(m^{(k)}\right) + \left(1 - a^{(k)}\right) \log\left(1 - \phi\left(m^{(k)}\right)\right) + \frac{\lambda}{2}\|\mu\|^2 \right\}. \tag{6}$$

In addition to using linear models to predict click-through rates, common click-through rate prediction methods are gradient boosted decision trees. The decision tree construction process is feature selection, decision tree generation, and pruning (reducing the size of the tree structure and alleviating overfitting). Unlike linear models, gradient-boosted decision trees are nonlinear models. Therefore, this method will only leave the best and most powerful features and attributes, and the rest will be discarded. Compared with linear models, decision trees are nonlinear models that can directly use continuous attributes. At the same time, when preprocessing data, its requirements are also lower than linear models. In linear models, the high sparseness of feature vectors is generally caused by the binary encoding in the features. Therefore, using a linear model in the normal flow at this time will adversely affect training. It improves the summation of linear logistic regression by decomposing the model.

$$f(m) = \mu_0 + \sum_{k=1}^{N} \mu_k m_k + \sum_{k=1}^{N} \sum_{i=1}^{N} \langle v_k, v_i \rangle m_k m_i, \tag{7}$$

where $v \in R^{N\times Q}$ and Q are the size of the latent space.

$$\langle v_k, v_i \rangle = \sum_{f=1}^{Q} v_{k,i} \cdot v_{i,f}. \tag{8}$$

This mode can better understand the interaction between the eigenvalues of the sparse vector and improve the shortcomings of the original linear model.

3.3. Allocation Algorithm of Traffic, Quality, and Market Competition in Advertising Design. Since the proposed scheme is guided by a probabilistic filtering mechanism, the probabilistic filtering value in it is called the step rate. The step rate can be defined as a function of time s. The reason why advertising campaigns are limited is because different advertising campaigns target different groups. At the same time, its effects under the influence of different factors are also different. Therefore, it is necessary to design its own distribution plan for different types of advertising campaigns, which can be used as a reference for similar advertising campaigns. In general, it is not appropriate to process $w(s)$ as a continuous function, and a more practical method is to process time in segments. It divides the total length of the day into S segments on average. Assuming that the estimated cost in a certain time period is 1, the total budget for the day is $\{q_1, q_2, \ldots, q_S\}$. At the same time, the number of ad requests m from ADX in this time period s is $\{x_1^s, x_2^s, \ldots, x_m^s\}$, and the corresponding function is $req(s)$. After $w(s)$, the ad requests are screened, and the first qualified ad request is $\{c_1^s, c_2^s, \ldots, c_m^s\}, c_n^s \in \{0, 1\}$. 0 means inappropriate, 1 means qualified, and the step rate is as follows:

$$w^{a\ dc}(s) = \frac{\sum_{i=0}^{i=m} c_i^s}{m}. \tag{9}$$

After bidding, the ad request sequence that wins the bid under the calculation of the advertising exchange market is $\{a_1^s, a_2^s, \ldots, a_m^s\}, a_n^s \in \{0, 1\}$, 1 is the chance to win the advertising exhibition, and the probability of winning the bid is as follows:

$$kt^{a\ dc}(s) = \frac{\sum_{i=0}^{i=m} a_i^s}{m}. \tag{10}$$

In the actual RTB environment, the data corresponding to the unqualified ad request is missing. As a result, the data corresponding to the qualified line price is missing, which further affects the optimization of the qualification rate prediction and the establishment of the qualified price prediction model. To effectively improve the prediction accuracy, linear regression and censored regression methods are used to build the model. The final cost sequence for the above ad requests is $\{c_1, c_2, \ldots, c_S\}$, and the cost sequence for ineligible ad requests is 0. Therefore, it can be concluded that in a certain period of time, the smaller the gap between the actual cost and the predicted cost, the better the effect, namely $|q_s - \sum_{i=1}^{m} b_i^s| \leq \varepsilon$. The average impression price during this time period s is as follows:

$$bwn(s) = \frac{\sum_{i=0}^{i=m} b_i^s}{\sum_{i=0}^{i=m} a_i^s}. \tag{11}$$

The quality of ad impressions is affected by many factors, for example, the number of clicks in different time periods, the purchase behavior of consumers in different time periods, etc. The performance of the data of these factors can intuitively show the quality of an advertisement. With this data, it is possible to more accurately increase the budget during the time period when the ad quality is high, thereby increasing the impact of the ad. As much of the budget as possible should be placed in high-quality time periods. The ad display quality metric defined in this article reflects the difference between the display quality and the average quality in a certain period, and it can be expressed as follows:

$$\phi(s) = \frac{iwa(s) - \text{avg}(iwa)}{\text{avg}(iwa)}. \tag{12}$$

$\phi(s)$ is the change of advertisement quality. When its performance is average, the calculated result is 0, and the high quality value is a positive number, otherwise, it is a negative number. It controls the value between 0 and 1 and uses the mapping function to control the quality factor. The mapping function used to control the quality factor at this time may be a logistic function. At this time, the quality factor function is as follows:

$$qf(s) = f^{\phi}(\phi(s)). \tag{13}$$

ϕ controls the speed of change in ad quality and can be set to 1 when its display quality is close to average. On any given day, the numerical changes of the traffic of a certain ad and the number of buyers participating in the bidding are different. At the same time, the winning rate is affected by a variety of factors, such as market trading mechanism, bidding strategy, etc. The change of winning the bid rate is determined by the change of these factors. However, the specific value of the winning rate cannot intuitively show the real situation of the competition level. The difference between the transaction price in a certain period of time and the average transaction price in that day is defined as follows:

$$\lambda(s) = \frac{bwn(s) - \operatorname{avg}(bwn)}{\operatorname{avg}(bwn)}. \tag{14}$$

Then, it takes the mean of the squares of $\phi(s)$ and $\lambda(s)$.

$$\begin{aligned} \overline{\phi} &= \sqrt{\frac{\sum_{s=1}^{S} \phi(s)^2}{S}}, \\ \overline{\lambda} &= \sqrt{\frac{\sum_{s=1}^{S} \lambda(s)^2}{S}}. \end{aligned} \tag{15}$$

$(\overline{\phi}/\overline{\lambda})\lambda(s) - \phi(s)$ is the competition degree of period s, and the competition degree coefficient can be obtained as follows:

$$bf(s) = f^{\lambda}\left(-\frac{\overline{\phi}}{\overline{\lambda}}\lambda(s) + \phi(s)\right). \tag{16}$$

The distribution probability of the campaign in period s is as follows:

$$w^{a\ dc}(s) = b^{a\ dc} \cdot pf(s) \cdot bf(s), \quad w^{a\ dc}(s) \le 1. \tag{17}$$

The average distribution probability at this time is as follows:

$$\operatorname{avg}\left(w^{a\ dc}\right) = \frac{1}{S}\sum_{s=1}^{S} w^{a\ dc}(s). \tag{18}$$

The relationship between its total budget and each indicator is as follows:

$$BGT^{a\ dc} = \sum_{s=1}^{S} \operatorname{req}(s) \cdot b^{a\ dc} \cdot pf(s) \cdot bf(s) \cdot er^{a\ dc}(s) \cdot bwn(t), \text{s.t.} \sum_{s=1}^{S} \operatorname{req}(s) \ge \frac{BGT^{a\ dc}}{\operatorname{avg}(bwn)}. \tag{19}$$

The adaptive ad distribution strategy proposed in this paper is based on calculated theoretical distribution probabilities. At the same time, the actual distribution probability is continuously adjusted according to the actual situation. In practice, real-time bidding mostly sells the remaining traffic of the media. It is usually difficult for users to have enough favorable impression on it, and the user's click behavior has great randomness. It is not to mention the instability of the predictor effect caused by the sparse click behavior. Assuming that the actual spending budget in a certain time period s is $V^{a\ dc}(s)$, the actual distribution ratio in the next time period should be adjusted to the following:

$$p^{a\ dc}(s+1) = w^{a\ dc}(s+1) \cdot \frac{BGT^{a\ dc} - \sum_{a=1}^{s} v^{a\ dc}(a)}{\sum_{j=s+1}^{S} \operatorname{req}(j) \cdot w^{a\ dc}(j) \cdot er^{a\ dc}(j) \cdot bwn(j)}. \tag{20}$$

Its continuous analogy ensures the progress of budget allocation.

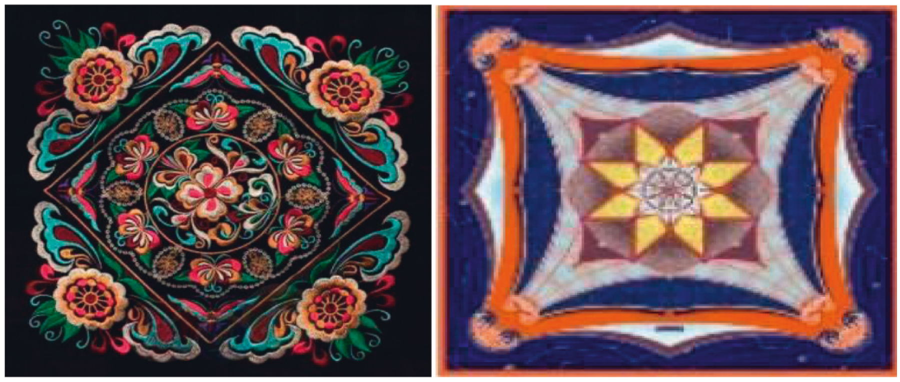
4. The Effect Evaluation Experiment of Intelligent Advertising System Based on the Integration of Traditional Culture

4.1. Application of Traditional Culture in Real Life and Advertising. Chinese traditional culture is like nectar and jade liquid. It is beautiful and unique. It walks into modern times with a long-standing history and shocks the world. Traditional culture includes thought, writing, language, followed by six arts, i.e., ritual, music, archery, imperialism, calligraphy, and numbers. Then, there are calligraphy, music, martial arts, quyi, chess, festivals, folk customs, etc., derived from the rich life. Designers will apply various characteristic elements of traditional Chinese culture to their own works, such as the Miao embroidered silk scarves designed and produced by Hermes. The emergence of Chinese elements makes the advertising system not only limited to a single design but also makes the products full of Chinese charm and vivid life rhythm. The emergence of Chinese elements makes the design of the advertising system more diversified. Figure 5 shows the design of traditional cultural elements in the product.

The colors of Hui style architecture seem to be natural, and the ancient rhyme is solemn. It is like a fine brush and ink, with white walls and black tiles as the main color, which not only highlights the overall color but also integrates with the surrounding natural environment and coexists in harmony. It is what the design says to be in harmony with nature. Hui style buildings use brick, wood, and stone as raw materials, and they mainly use wood frame. The beam frame is mostly made of huge materials and pays attention to decoration. Brick, wood, and stone carvings are also widely used, showing a superb level of decorative art. Huizhou architecture well-reconciles traditional culture and natural environment, making the overall picture tend to be harmonious. It is shown in Figure 6.

In advertising design, the beauty of traditional culture is everywhere, for example, the Dunhuang Feitian designed by the game characters, holding a pipa in silky ribbons, with a good posture like a fairy. The shades of blue and purple are resplendent with aura, and the contrasting colors have a great visual impact. In the advertising design of the pen holder, blue and white porcelain and brushes are used, which is very beautiful. Just like the cheongsam woman in the alley in the south of the Yangtze River came slowly, ethereal and clear. It is shown in Figure 7.

The beauty of traditional culture is polished by time. It is beautiful in the charm of the old and time-honored brand,



Miao Embroidery Hermes scarf

Figure 5: Design of traditional cultural elements in products.

neat aesthetics messy aesthetic

Figure 6: Huizhou architecture in traditional culture.

game advertisement Pen holder advertisement

Figure 7: Application design of traditional cultural elements in advertising.

and it is even more attractive after it is integrated into the advertising design. Of course, it is difficult to obtain evidence just by saying it out of thin air, and it is more convincing to cooperate with the experiment.

4.2. Comparative Experiment of Advertising in the Perspective of Traditional Culture and Modern Fashion. This experiment ran ads with traditional cultural elements on three different platforms. We call it k1, and different ads with modern elements. We call them k2 and k3. Judging the details of the ad in terms of duration control, screen rotation, color tone, endorsement, and delivery time. 200 people were randomly selected to judge the three kinds of advertisements, and then different people were selected to test, and 5 favorite tests were carried out, respectively. The full score is 1, it can score decimals, it can like two or three ads at the same time, or it can like one or neither. To evaluate the purchase intention, the three platforms are platform 1, platform 2, and platform 3, and the data obtained are shown in Figure 8.

From Figure 8, i.e., customer preferences and purchase intentions on platform 1, it can be seen that the public is fonder of advertisements with traditional culture implantation and has a higher purchase intention. Compared with

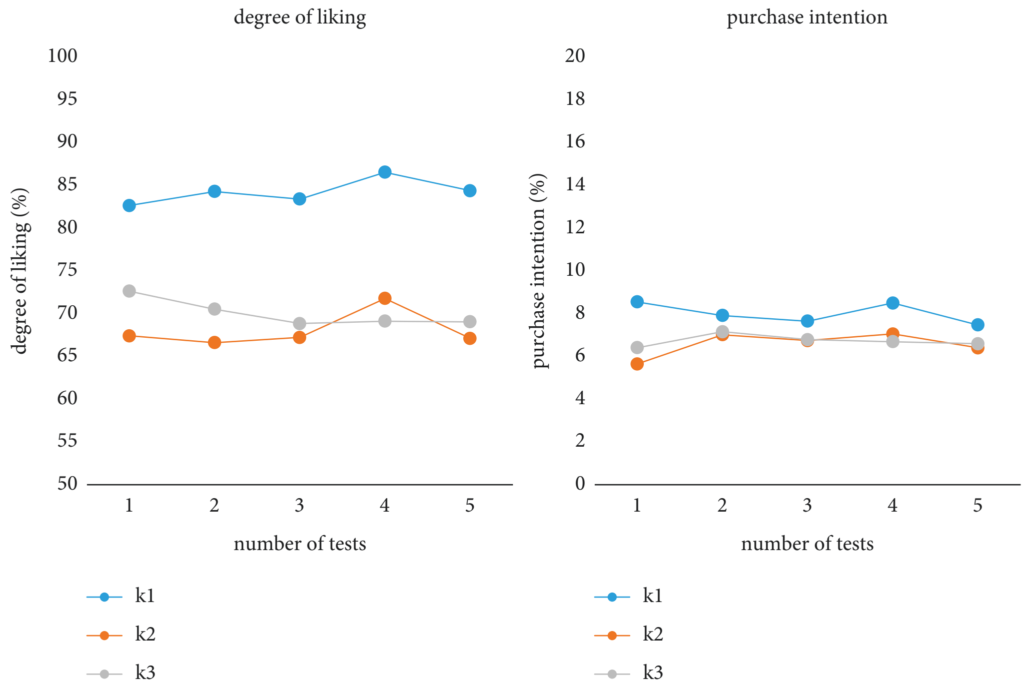


Figure 8: Test customer preference and purchase intention on platform 1.

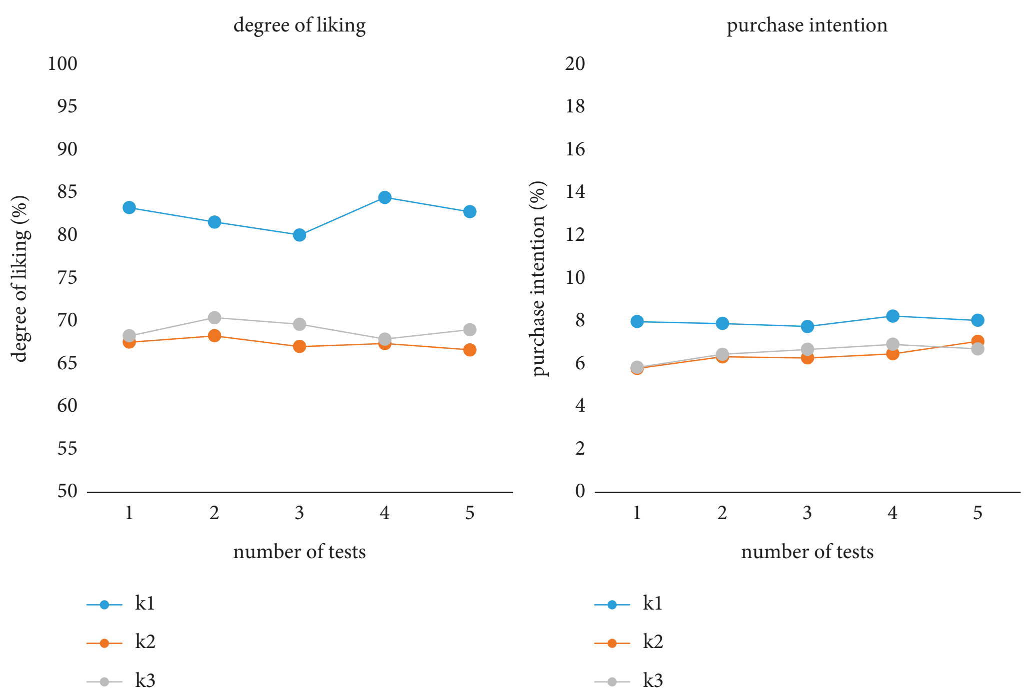


Figure 9: Test customer preference and purchase intention on platform 2.

the other two pure modern elements, the ad likeness increased by about 17%, and the purchase intention increased by about 1.4%.

From Figure 9, i.e., customer preferences and purchase intentions on platform 2, it can be seen that the public is fonder of advertisements with traditional culture implantation and has a higher purchase intention. Compared with the other two pure modern elements, the ad likeness increased by about 15%, and the purchase intention increased by about 1.7%.

From Figure 10, i.e., customer preferences and purchase intentions on platform 3, it can be seen that the public is fonder of advertisements with traditional culture implantation and has a higher purchase intention. Compared with the other two pure modern elements, the ad likeness increased by about 11%, and the purchase intention increased

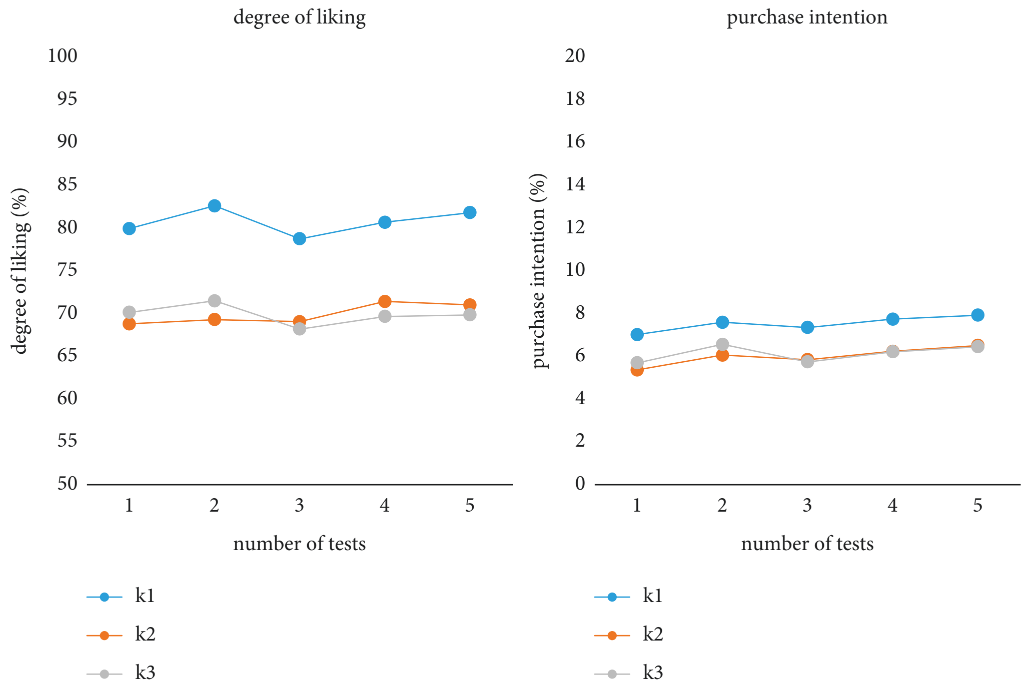


Figure 10: Test customer preference and purchase intention on platform 3.

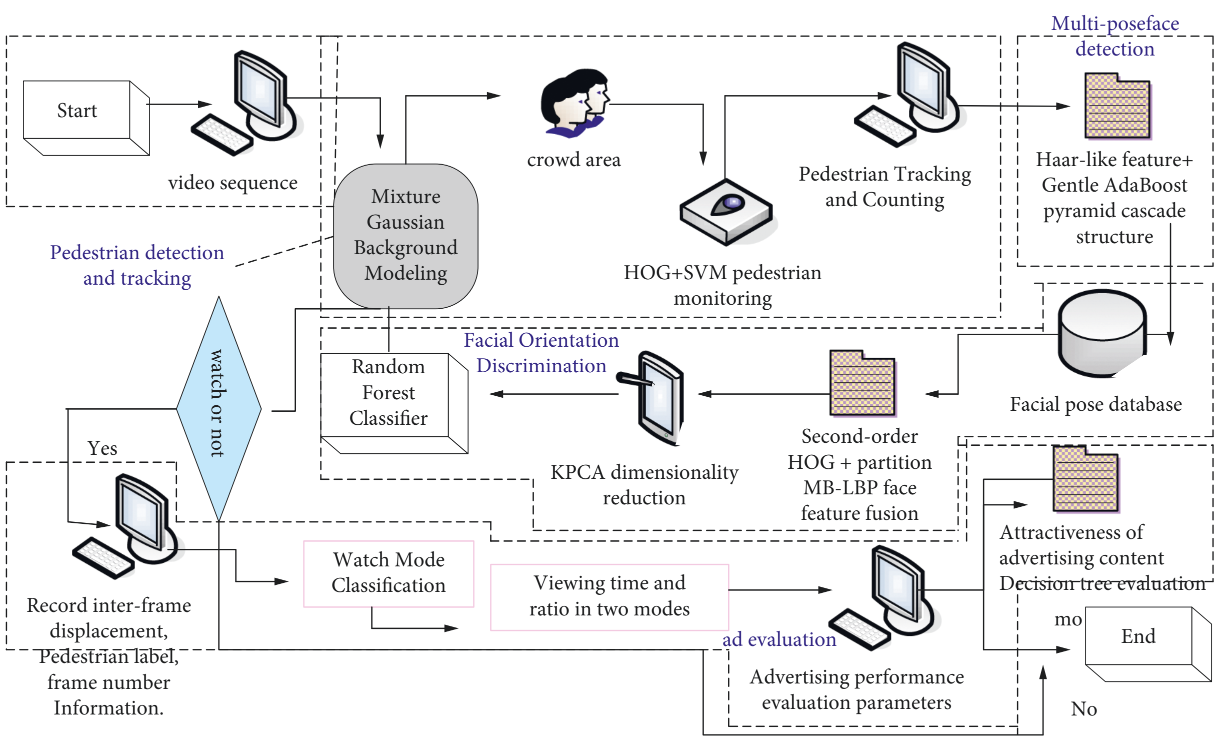


Figure 11: Outdoor advertising effect evaluation system.

by about 1.5%. Therefore, on the whole, people have a high degree of acceptance and love for traditional cultural input into smart advertisements. It tends to be a visual feast with traditional colors, and is also willing to consume it.

4.3. Evaluation System of Facial Gesture Recognition Effect Based on Outdoor Advertising. After placing the billboards, the staff will set up surveillance cameras at suitable locations nearby. Through existing mature technologies, such as face recognition, dynamic tracking, and behavior recognition, it can identify pedestrians who pay attention to the content of billboards and obtain effective data, i.e., the evaluation parameters that can automatically and independently obtain the advertising effect can be realized. With a sufficient data

Table 1: Statistics of advertising effect evaluation system.

Number of times	Statistical methods	Human traffic	Stop and watch	Walking and watching	Viewing ratio (%)	Stop and watch the ratio (%)	Look at the proportions (%)
1	System statistics	24	6	8	58.33	25.00	33.33
2		19	5	6	57.89	26.32	31.58
3		16	5	3	50.00	31.25	18.75
4		20	6	6	60.00	30.00	30.00
5		26	7	7	53.85	26.92	26.92
6		23	7	9	69.57	30.43	39.13
7		24	6	7	54.17	25.00	29.17
8		19	6	4	52.63	31.58	21.05

Table 2: Manual calculation results of advertising effect evaluation.

Number of times	Statistical methods	Human traffic	Stop and watch	Walking and watching	Viewing ratio (%)	Stop and watch the ratio (%)	Look at the proportions (%)
1	Manual statistics	24	6	7	54.17	25.00	29.17
2		16	5	5	62.50	31.25	31.25
3		16	5	3	50.00	31.25	18.75
4		20	5	5	50.00	25.00	25.00
5		24	7	5	50.00	29.17	20.83
6		23	7	7	60.87	30.43	30.43
7		26	7	5	46.15	26.92	19.23
8		21	6	4	47.62	28.57	19.05

base, an evaluation model for the attention of advertising content can be established. The model can carry out a thorough and effective analysis and processing of the advertising effect evaluation parameters so that the overall evaluation effect of the advertisement can be improved more. The overall algorithm of the intelligent analysis advertising effect evaluation system used in this paper is shown in Figure 11.

Random forest repeatedly selects n samples randomly from the original training sample set N to generate a new training sample set to train a decision tree. Then, follow the above steps to generate m decision trees to form a random forest. The classification result of the new data is determined by the score formed by the votes of the classification tree.

It places surveillance cameras on the 9 m-high roof and randomly selects a certain number of advertising viewers. These people are guided back and forth within the range that the surveillance cameras can detect in this way to simulate actual pedestrians passing by to watch the advertisement. The time to watch back and forth is about 4 minutes, for a total of 8 back and forth viewings. Statistics are made according to the above data, as shown in Tables 1 and 2. The experimental data counts the number of people who stopped to watch, the flow of people, and the number of people who watched while walking. At the same time, the viewing ratio corresponding to these data was counted, and the data detected by the surveillance camera was compared with the manually counted data.

The 8 groups of data obtained from the above experiments were compared with the manually obtained data. From this, it can be concluded that, to a certain extent, the monitoring and detection system is more sensitive to the recognition and evaluation of pedestrians watching advertisements, although there may be certain errors. However, on the whole, the number of people who have watched the advertisement detected by the monitoring and detection system is significantly higher than the number of people who have been manually counted. According to the further calculation of the obtained data, it can be obtained that the monitoring accuracy rate of the monitoring and detection system for the pedestrian viewing ratio is 96.7%. Therefore, the corresponding error is 3.3%, and the system can meet the qualified standard in practical application.

Two groups of pedestrian samples are taken, and the attention of pedestrians to advertisements is taken as the reference object. The statistical statistics of the viewing process behavior of its advertisements can be obtained in Table 3. From 2 groups of pedestrians, each group randomly selects 3 pedestrians and analyzes these selected samples. In this way, it is judged whether the monitoring and detection system is accurate when counting the viewing time.

In all samples, the data of six pedestrians are randomly selected. The proportion of the time spent watching advertisements when they stopped and the proportion of time spent watching while walking were tabulated as shown in Table 3. Although at the third pedestrian, the error is as high as 22%, the average statistical error is 3.76%. Therefore, the detection results show that the monitoring and detection system can more accurately record the duration of pedestrians watching advertisements.

5. Discussion

The outdoor advertising effect evaluation system designed in this paper is mainly based on the video recorded by the monitoring camera. The system analyzes and processes the

Table 3: Viewing time and ad attractiveness.

	Statistical methods	Total duration/ frame	Stop and watch duration/frame	Watch while walking duration/frame	Stop and watch	Walk and watch (%)	Attraction
1	System	96	0	96	0	100	Ordinary
	Manual	106	0	106	0	100	Ordinary
2	System	83	0	83	0	100	Ordinary
	Manual	68	0	68	0	100	Ordinary
3	System	119	46	59	38.66%	50	Moderate
	Manual	122	48	34	39.34%	28	High degree
4	System	105	66	28	62.86%	27	High degree
	Manual	124	68	39	54.84%	31	Moderate
5	System	120	73	40	60.83%	33	Moderate
	Manual	129	75	34	58.14%	26	High degree
6	System	131	115	30	87.79%	23	High degree
	Manual	136	112	33	82.35%	24	High degree

recorded video by installing special surveillance cameras at the appropriate positions of the billboards. The obtained pedestrian data is classified and evaluated, such as the total number of viewers, viewing behavior, traffic, viewing time, etc. Compared with manual statistics, the system has the characteristics of objectivity and automation. The data obtained by the system can effectively evaluate and predict the effect of an advertisement. Assisted by dynamic tracking technology, the system can accurately count the flow of people in a certain period of time. Dynamic tracing technology is an advanced debugging technology. It can help software engineers answer some difficult questions about software systems at a very low cost and in a very short period of time to troubleshoot and solve problems more quickly. In the face of various scenes and complex backgrounds in reality, the background subtraction algorithm can effectively eliminate the interference of redundant backgrounds. It makes the statistical results more realistic and accurate. At the same time, the interfering background is removed, and the adverse effect on the final result is effectively removed, and the algorithm can further improve the accuracy of the system detection. As for obtaining the flow of people, it is the basic function of system monitoring. In addition, the system further filters the pedestrians who have watched the advertisement. The faces of passing pedestrians are detected and analyzed, and finally, various behaviors are classified and counted. The algorithm used for face detection in this paper is a multipose face detection algorithm with a pyramid cascade structure, which can accurately identify and judge various facial changes in real time. In some crowded scenes, the face detection algorithm will have missed detections, and there could be false detections. The real-time image is quite different from the standard database. At the same time, this paper proposes a further line-of-sight direction analysis on the obtained face images based on the face recognition method that combines the second-order HOG and MB_LBP. This recognition method can simultaneously obtain the face texture features and the gradient information related to the face pose and is finally classified by the random forest algorithm.

6. Conclusions

This paper adopts random sampling to simulate the scene of actual pedestrians watching advertisements. In addition to the statistics of the basic traffic, the number of viewers, and other data, here, we further analyze and explore the viewing patterns of pedestrians. The system analyzes and recognizes various motion trajectories of pedestrians through algorithms and automatically classifies them. According to the data and tables obtained in this paper, it can be seen that the outdoor advertising effect evaluation system designed in this paper can effectively and accurately count pedestrian data. The system has a minimal error and high accuracy, with an average statistical error of 3.76%. Obviously, the system can effectively analyze, process, and classify pedestrian data and information in actual scenarios. At the same time, it has a good reference and evaluation effect for the publicity and distribution of advertisements. The monitoring and detection system has a monitoring accuracy of 96.7% for the pedestrian viewing ratio. Hence, the corresponding error is 3.3%.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by the Basic Scientific Research Projects of Colleges and Universities of Liaoning Province (Grant no. LJKR0205).

References

[1] X. Gong, Y. Zhu, H. Zhu, and H. Wei, *Chmusic: A Traditional Chinese Music Dataset for Evaluation of Instrument Recognition*, 2021.

[2] Y. Ding, D. Luo, H. Xiang, and W. Liu, “Design and implementation of blockchain-based digital advertising media promotion system,” *Peer-to-Peer Networking and Applications*, vol. 14, no. 9, pp. 1–15, 2021.

[3] Y. Dong, B. Du, and L. Zhang, “Target detection based on random forest metric learning,” *Ieee Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 8, no. 4, pp. 1830–1838, 2017.

[4] J. Xia, N. Falco, J. A. Benediktsson, P. Du, and J. Chanussot, “Hyperspectral image classification with rotation random forest via KPCA,” *Ieee Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 10, no. 4, pp. 1601–1609, 2017.

[5] M. Papathomas, “On the correspondence from Bayesian log-linear modelling to logistic regression modelling with g-priors,” *Test*, vol. 27, no. 1, pp. 1–24, 2018.

[6] S. Huda, J. Abawajy, M. Abdollahian, R. Islam, and J. Yearwood, “A fast malware feature selection approach using a hybrid of multi-linear and stepwise binary logistic regression,” *Concurrency: Practice and Experience*, vol. 29, no. 23, pp. e3912.1–e3912.18, 2017.

[7] M. R. Baneshi, A. A. Haghdoost, F. Zolala et al., “Can religious beliefs be a protective factor for suicidal behavior? A decision tree analysis in a mid-sized city in Iran,” *Journal of Religion and Health*, vol. 56, no. 2, pp. 1–9, 2017.

[8] B. T. Pham, K. Khosravi, and I. Prakash, “Application and comparison of decision tree-based machine learning methods in landside susceptibility assessment at pauri garhwal area, Uttarakhand, India,” *Environmental Processes*, vol. 4, no. 3, pp. 711–730, 2017.

[9] A. I. T. Tulloch, N. Auerbach, S. Avery-Gomm et al., “A decision tree for assessing the risks and benefits of publishing biodiversity data,” *Nature Ecology & Evolution*, vol. 2, no. 8, pp. 1209–1217, 2018.

[10] J. Tanha, M. Van Someren, and H. Afsarmanesh, “Semi-supervised self-training for decision tree classifiers,” *International Journal of Machine Learning and Cybernetics*, vol. 8, no. 1, pp. 355–370, 2017.

[11] H. Wang, R. Zhu, and M. Ping, “Optimal subsampling for large sample logistic regression,” *Journal of the American Statistical Association*, vol. 113, no. 2, pp. 1440037–1438957, 2017.

[12] H. Izadbakhsh, R. Noorossana, and S. T. A. Niaki, “Monitoring multinomial logistic profiles in phase I using log-linear models,” *International Journal of Quality & Reliability Management*, vol. 35, no. 3, pp. 678–689, 2018.

[13] T. Kawashima and H. Fujisawa, “Robust and sparse regression in generalized linear model by stochastic optimization,” *Japanese Journal of Statistics and Data Science*, vol. 2, no. 2, pp. 465–489, 2019.

[14] A. Basu, A. Ghosh, A. Mandal, N. Martín, and L. Pardo, “A Wald-type test statistic for testing linear hypothesis in logistic regression models based on minimum density power divergence estimator,” *Electronic Journal of Statistics*, vol. 11, no. 2, pp. 2741–2772, 2017.

[15] S. Lee and N. Moon, “Location recognition system using random forest,” *Journal of Ambient Intelligence and Humanized Computing*, vol. 9, no. 4, pp. 1–6, 2018.

[16] Y. Xia, B. Wang, and J. Zhi, “Identification of wheat leaf disease based on random forest method,” *Journal of Graphics*, vol. 39, no. 1, pp. 57–62, 2018.

[17] C. Brokamp, R. Jandarov, M. Hossain, and P. Ryan, “Predicting daily urban fine particulate matter concentrations using a random forest model,” *Environmental Science & Technology*, vol. 52, no. 7, pp. 4173–4179, 2018.

[18] Q. Zhang, X. Sun, K. Feng et al., “Predicting citrullination sites in protein sequences using mRMR method and random forest algorithm,” *Combinatorial Chemistry & High Throughput Screening*, vol. 20, no. 2, pp. 164–173, 2017.

[19] R. L. Marchese Robinson, A. Palczewska, J. Palczewski, and N. Kidley, “Comparison of the predictive performance and interpretability of random forest and linear models on benchmark data sets,” *Journal of Chemical Information and Modeling*, vol. 57, no. 8, pp. 1773–1792, 2017.

[20] K. J. Yeon, “Consumer interest areas and attention to bluetooth product advertising design,” *Journal of Digital Design*, vol. 17, no. 2, pp. 93–103, 2017.

[21] A. M. Mohan, “In “darkest of markets,” beer pack design provides 24/7 “on-air” advertising,” *Packaging world*, vol. 25, no. 3, pp. 10-11, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 7542067, 9 pages
https://doi.org/10.1155/2022/7542067

Research Article

Innovation and Development of University Education Management Informationization in the Big Data Environment

Xiaojun Li

Academic Affairs Office, Henan Institute of Technology, Xinxiang 453000, Henan, China

Correspondence should be addressed to Xiaojun Li; hnlxj@hait.edu.cn

Received 25 January 2022; Revised 15 March 2022; Accepted 21 March 2022; Published 25 April 2022

Academic Editor: Ahmed Farouk

With the arrival of the big data era, the role of big data can be fully utilized, and the comprehensive data evaluation is carried out to perform education information evaluation. In the general circumstance of computerized learning, college teaching regulation has new features and novel orientations. Along with the speedy progression of sci-tech, the pace of dissemination of data is continuously quickening, and it is being increasingly easy for the public to interact and carry on with their lives. Because people use the network to access a variety of data information, the system cannot handle huge amounts of data; this is the cause of the era. In the process of the comprehensive approach of the information age, with the impact of the Age of Big Data, the administration of intelligence in universities has transformed. Big Data InfoTech has infiltrated into all realms of community lifestyle. How to cope with the transformation of informationization of university education management in the era is a serious challenge for relevant personnel. This study begins by discoursing the essential implication of big data, followed by a diagnosis of the questions involved in the establishment of computerization in high schools under the environment of big data, comprising the imminent solutions to the dilemmas in collegiate education maintenance, the issues raised by privatization in high schools, and the strategies for education management. This is followed by the proposal of the innovative educational administration informationization development trend in the big data context. In this research, there are 11 professors in the expert group, accounting for 44%, 8 associate professors, accounting for 32%, and 6 lecturers or below, accounting for 24%. This study makes full use of a large number of procedural data generated in educational management activities to achieve an efficient, comprehensive, accurate, and objective evaluation, which provides strong technical support for educational management informatization evaluation.

1. Introduction

It can be seen that the current assessment index system is mainly for the overall information development of colleges and universities. Although management informationization has been widely recognized as a dimension in university information assessment, the relevant management information evaluation indicators are still more. Simply, there is no comprehensive evaluation index system for education management informationization, and most of the current education informationization indicators are based on result ability data and ignore the potential value of process data. It is a strategic choice for education reform and development to drive education modernization with education informatization to promote the leap-forward development of education. College education informationization is an important part of educational informational undertakings. It is an important way to promote higher education reform and cultivate innovative talents. It is the leading edge of educational information development. The informationization construction of colleges and universities has greatly promoted the development of education and has brought tremendous changes to teaching methods, educational concepts, and educational systems. This change is both an opportunity and a challenge. Colleges and universities should be able to conform to the requirements of the times and establish a more effective and brand-new resource integration model in education and scientific research. This resource integration model is an innovation in education management. Humanity has attained an epoch of materialization: the period of computerization [1]. The breakneck expansion of information technologies has elicited far-reaching modifications in many arenas and quickened the headway of the InfoTech community [2]. At the same time, with the speed-up of the worldwide socioeconomic consolidation process, the scale of informationization has been established as a key indicator of the socioeconomic competitiveness and state of the art of a country and region, as well as an important indicator of the level of consolidated national power and modernization. Level of industrial expansion. In the traditional sense, the education and teaching environment of campuses, classrooms, libraries, etc., have quietly changed, and the time, space, methods, concepts, and systems of education and teaching have also changed a lot. This kind of change is both an opportunity and a challenge. Colleges and universities should be able to adapt to the requirements of the times and establish a more effective and new resource integration model in education and scientific research. This resource integration model is an innovation in education management. It should involve innovations in many areas, such as management thinking, management methods, management content, and management organization. For colleges and universities, the object of management must also be innovative. Innovation in every position and management object of a university is necessary and possible [3]. With the development and popularization of the Internet, the data generated by college education informationization has increased, and massive data are also hidden, and these data are treated, and it is important to assess education informationization in colleges and universities.

2. The Basic Connotation of Big Data

The first one who referred to the era of "big data" was the world renowned McKinsey and Company [4]. McKinsey said that "the dynamics of all spheres of industry are permeated through data enablement, and data have emerged as an essential ingredient of manufacturing. The sheer volume of data that people are probing and applying heralds a new cycle of higher productivity and the onset of consumer excess" [5]. Big data generally refers to the quantity of more than 1 TB, also known as massive data or huge amounts of data [6]. However, for the big data difference and the small data volume limit, academic circles have different opinions. However, it is widely agreed that the large capacity of big data is a relative statement, which contains a combination of multiple data points across different types, different things, different industries, and different fields. The era of big data is not about mastering data, but more importantly, the use of data [7]. Big data are an invaluable tool for the management of all segments of society. One can visualize big data to estimate the magnitude of the possibilities of devastation and anticipate the growth so as to enable appropriate solutions to be given to the situation effectively [8]. With the rapid development of big data, countries have given high attention, accelerated their layout in education, and released national strategic planning.

3. Problems in the Innovation of University Informationization under the Big Data Environment

3.1. Difficulties in the Management of College Education

3.1.1. Lack of Understanding of Education Management Informationization. The assessment is an important means of promoting the development of education in colleges and universities. At present, some scholars have carried out research on educational informationization in colleges and universities and have also proposed some college education information evaluation indicators [9]. However, the current college education information assessment is a simple management information indicator for the overall information development of universities [10]. As the pioneering position of the computerized version of education, the process of informationization of tertiary institutions has had ever-increasing effects on the instructional work of tertiary institutions. In the previous sense, the educational and teaching environments such as campuses, classrooms, and libraries have quietly undergone astonishing changes, and the quality of hours and spatial scope of instruction has also significantly evolved. In order to better develop and construct the informationization of education management in colleges and universities, it is necessary to have a correct and in-depth understanding of the connotation of education management informationization. It is necessary to truly recognize the revolutionary impact of information technology on education management informationization and establish a modern, scientific, and information-based education management concept in the process of education management informationization. At the moment, most universities in China are limited in the connotation and growth of computerization in teaching administrations, and they have not been considered from a long-term perspective. Many college teachers and students, administrators, and even some leaders believe that education management informationization is the application of information technology in education management. Simply use the application of information technology in education management as education management informationization and ignore modernization. The scientific education management thought and systematic management concept play a leading role in the construction process of education management informationization. College education management information is a work in each department associated with the school, including teaching education management, scientific research and education management, personnel education management, student education management, and experimental equipment education management [11]. If there is no corresponding support for education management information, the information processes in other fields in colleges will encounter problems in many coordination and management.

Suppose the determinant of a certain judgment matrix is

$$A = \left(a_{ij}\right) = \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix}. \quad (1)$$

Normalize each column of the judgment matrix:

$$\overline{a} = \frac{a_{ij}}{a_{kj}}. \tag{2}$$

Each column is normalized, and the judgment matrix is added row by row:

$$\overline{\mathrm{w}} = \sum_{i=1} \frac{a_{ij}}{a_{kj}}. \tag{3}$$

In addition,

$$\overline{w} = (\overline{w}_1, \overline{w}_2, \overline{w}_3, \ldots, \overline{w}_n). \tag{4}$$

When the judgment is completely consistent, then

$$\lambda_{\max} \approx i \sum_{i=1}^{n} n. \tag{5}$$

The calculation formula for solving $\lambda_{\max}$ is as follows:

$$\lambda_{\max} \approx \sum_{i=1}^{n} n \frac{(AW)_i}{nw}. \tag{6}$$

3.1.2. Lack of Systematic Planning for Information Management of Education Management. The study built a data-driven index system at the information level of college education management, providing theoretical guidance and support for the information evaluation of college education management. Related to subsequent education management information evaluation, the study gives a certain reference. The "data" of the information age have become a vocabulary that everyone is talking about. With the continuous expansion of the scale of colleges and universities, the large increase in the number of teachers and students, and the increase in business departments, the data have reached an alarming amount. Many data centers have the phenomenon of repeated construction, and different systems are independent of each other [12]. These basic data cannot be synchronized and shared in real time. In this case, each college and various functional departments not only have to pay for the maintenance and update of the system and the back-end database by themselves, but once some data problems occur, the original data may be lost [13]. These problems arise because the system is not unified and the data are not integrated. It is necessary to have a clear and unified scientific plan for the development of education in the whole school and introduce the concept of information flow into the construction of the education regulation system of colleges and universities. Build a data stream-based information system to achieve the mutual circulation of messages and data between various functional departments. How to comprehensively use the result ability data and process data to create an objective, accurate, and efficient assessment of the information level of college education management?

3.1.3. The Overall Quality Level of Education Managers Is Likely to Decrease. Education managers have a complex information; they are likely to be confused when choosing, especially when obscure content appears, such as all kinds of confusing information, which makes judgments difficult, and management or decision-making is also very easy. Because of the limitations of information technology and the monopoly of information sources and procedures, the system is systematic, standardized, and procedural. This can not only cause direct and one-sided but also allow people to react linearly without any effort, making the behavior rigid. If administrators rely heavily on informative resources, they are detached from practice as they are unable to probe independent topics. The abovementioned behaviors will adversely affect the overall quality development of educational administrators.

3.2. Problems Arising from the Informationization of Education Management in Colleges and Universities

3.2.1. The Management Concept and System Are Lagging behind and the Understanding Is Superficial. In order to complete more work in a unit of time and improve management efficiency, coupled with the inability to coordinate the relationship between management and service, some colleges and universities have caused the phenomenon of "emphasis on management and lack of service in the process of building education management information." Many managers are self-sufficient in the sense of "manager" and neglect the role of being a "server." Some teachers and students believe that the more informational, the more cumbersome and complex the process of handling various matters and business, that the school is to complete the surface engineering and information.

Achieving high quality, high matching, and rich service content of job search information is the goal of future website construction. It is necessary for Chinese universities to further integrate internal and external resources, excavate internal and external information in the education system, establish information associations, and promote the release and use of information value. Realizing "big data" worthy of the name is large in quantity and value. Figure 1 shows the distribution of smart employment platforms used by universities in different cities.

In terms of teaching information management, colleges and universities attach different degrees to it, but the problems are there. First, the degree of understanding and the corresponding plans and mechanisms have not been established and improved, and they have not been given enough attention. Some institutes, moreover, ignore the key mandate of investment in educational administrations, heavy governance; in respect of organizational settings, staffing matters have not been dealt with, no equivalent workforce for informatization and commercialization of the scientific construction, lagging behind in thoughts, and still, in a complex and messy context, a lot can be done, and at this point, application of infotainment and administration cannot be implemented productively. There are three stages in the development of big data in colleges and universities: management is the main use and supplemented,

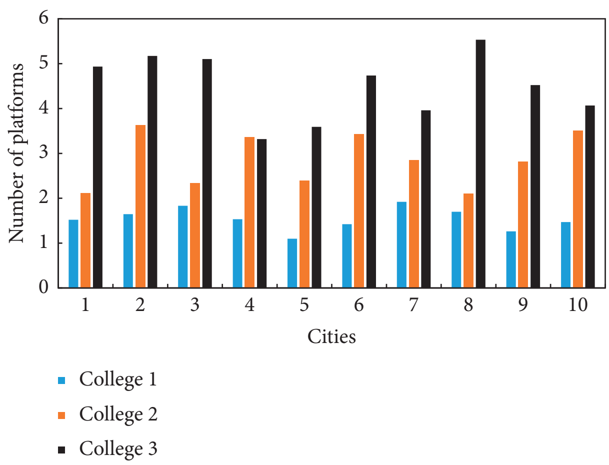


Figure 1: Distribution of smart employment platforms used by universities in different cities.

management and use are equally emphasized, and management is the supplementary use. It is still in the first stage, and there is a widespread problem of "emphasizing construction and light utilization." The big data-sharing situation of universities is shown in Table 1.

In order to further understand the development trend of the evaluation index system at the higher education informatization level, with reference to the representative index system with common characteristics in recent years, a comparative analysis of the number of indicators at all levels under the first dimension is carried out, as shown in Table 2.

Table 1: The big data-sharing situation of universities.

Serial number	Big data park name	Data-sharing rate (%)
1	Big data base	20
2	Big data new district	22
3	Big data park	18
4	Data valley	18

Table 2: A comparative analysis of the number of indicators at all levels under the first dimension.

Years	2017 (%)	2018 (%)
Infrastructure	14	22
Digital teaching resources	23	22
Teaching and learning applications	28	28
Management information	18	11

3.2.2. The Construction of Information Resources Cannot Keep Up with the Development of the Times and There Are Problems in the Development of Information Systems. The basis of education management informationization is mainly the powerful construction of information resources, but the construction of information resources is very backward in China [14]. First, there is a lack of guidance and coordination of a strong education administration. Second, there is no communication between universities, and there is no basic starting point to unify and support each other [15]. Third, there is little communication and collaboration between the various departments within the school. The decentralized departments each carry out work arrangements on the management information system about the department, which means the data are collected multiple times, increases the burden of work, makes the overall work of the school not effectively improved, and wastes manpower. Colleges and universities should not only concentrate on hardware and software management personnel but also pay the same attach to the training of education and management personnel at all levels to improve practical application capabilities, information literacy, and the reserve of knowledge in information technology.

In the construction of information systems, sufficient human, material, and financial resources should be invested. An information system is very important as software for integrating information across space [16]. Therefore, in the construction process, also consider leaving enough time for development. Software developers are required to have extensive software development experience. Not only is it prominent in programming skills but also it requires relevant educational management experience. Or those involved in system development need to be good at communicating with relevant education management personnel to accurately meet customer needs. Of course, colleges and universities do not necessarily say that they must fully develop their own educational information systems. They can engage with existing companies that are well made in the education management information system and introduce relevant resources [17]. Under such measures, the pace of information construction in schools can be accelerated, and follow-up related work can be facilitated to achieve efficient management.

3.2.3. Problems in the Orientation of Education Management System and Team Building. As an ordinary university, especially a new university, the education management system is a school year system. If the direct leap of the credit system is fully implemented, teachers and students cannot fully adapt to the existing management. In the education management system, the orientation of the credit system education management system, and the gradual transition of the credit system education management system [18], the teaching plan conforms to the teaching law and is stable for a period of time, but in the long run, it must be adjusted and revised in time to suit the new environment of society, the progress of the economy, and science and technology.

Among the various indicators, the evaluation criteria have clear regulations and are based on the principle of simplicity and operability. The informationization of education management places higher demands on the integrated caliber of the evaluation and administrative team. Education managers must know the current educational philosophy, have rich management knowledge, and know how to continue to innovate. Since the system is fully dependent on the network platform, network technology must also be mastered. Therefore, education administrators must have high quality and comprehensive development talents. Therefore, universities should pay attention to the regulation of hardware and software and also to the training of personnel at all levels of educational management and improve their knowledge of practical application, information literacy, and information technology [19]. Moreover, the system of information management should be sound, especially the system of assessment and reward and punishment. These systems can only motivate and promote the development of information management teams if they are scientifically standardized.

Professional title and educational background: to a certain extent, the level of a professional title can measure the authority of an expert in a certain field and reflect the expert's research level in the field. The higher the professional title, the more representative the research results. In this research, there are 11 professors in the expert group, accounting for 44%, 8 associate professors, accounting for 32%, and 6 lecturers or below, accounting for 24%. There are 3 people with a postdoctoral degree, 11 people with a doctorate degree, 9 people with a master's degree, and 2 people with undergraduate (bachelor), as shown in Figure 2.

On the whole, from the perspective of the development of higher education informatization evaluation indicators, with the continuous development of information technology, the focus of the evaluation index system of higher education informatization level has gradually shifted from infrastructure to teaching and learning applications, and emphasis on information technology and teaching applies deep integration to change the traditional education model, change students' learning methods, and use information technology to improve student's learning ability. Figure 3 can laterally reflect that my country's construction of guarantee mechanisms and management informatization is slightly faster than other aspects. Figure 3 shows the development process of the evaluation index system of higher education informatization level.

The first round of expert evaluation of infrastructure indicators is shown in Table 3, involving two secondary indicators, namely, the campus network and the complete construction of equipment configuration. Experts tend to concentrate on the choice of infrastructure, with more than 90% of those who choose "necessary" options. Among them, 23 people in the "campus network" chose the "necessary" option, accounting for 92%; 2 people chose "unnecessary;" the selection ratio of the "necessary" option of "equipment configuration and construction" reached "96%," and the selection of experts was good.

Determine the distribution of the number of teachers at different evaluation levels according to the evaluation standards for the level of higher education informatization. The level distribution of university education informatization levels is shown in Figure 4.

3.3. Factors That Cause Problems

3.3.1. Understand That Education Management Information Is Not Comprehensive Enough. For the importance of teaching information management, the level of understanding of colleges and universities is different, the planning and decision-making mechanisms are not comprehensive enough, and the arrangement of relevant personnel is not reasonable enough. The scientific management mechanism of the complete set has not been developed so far. According to the statement, computers can replace the role of the office [20]. Computers are connected to the Internet, and modern education management is informatized. Some managers fear that the enthusiasm of employees will be weakened by the deepening of information technology.

3.3.2. Less Policy Support and Cooperation Mechanisms. The opening of colleges and universities benefits from the informationization of education governance, and the sharing of information resources benefits from the opening of colleges and universities [21]. Under the contemporary policy, colleges and universities have their own operating systems with relatively closed interests, resource sharing, redistribution of teachers' individual rights, and innovations in support and reconciliation methods. These are all urgent problems. Furthermore, the requirements of teachers' comprehensive quality should be reflected in the ability to adapt to the information age and should be innovated and improved in the evaluation of their teaching. Therefore, the creation of a scientific system of educational governance is necessary [22].

3.3.3. The Construction of the Teaching Staff Cannot Keep Up with the Pace of Informatization Construction. First is because of the entrenched influence of traditional educational concepts on teachers. Second, in the new era, there are more requirements for teachers' abilities, whether it is knowledge structure and specific knowledge such as management knowledge and technical knowledge, as well as thinking and an excellent ability to integrate book content and network information. The conscious use of information technology in teaching activities is also a must. However, among the current teaching staff in Chinese universities, these qualities and abilities are relatively weak, so the requirements of education management work in the context of informationization and scientificization are not easy to achieve [23].

3.3.4. Limited Funds for the Construction of Education Management Information. The system is a complex whole, composed of a series of hardware and software [24]. Funding must be supported at the outset to ensure smooth progress. However, with today's financial problems, China's colleges and universities have difficulties; it is difficult to ensure that there are sufficient funds, thus limiting the progress of information construction in education.

4. The Development Strategy of College Education Management Informationization under the Big Data Environment

4.1. To Be Based on the Network Platform. With the influence of big data EON, the knowledge needs of teachers and students are difficult to meet, so we should transform

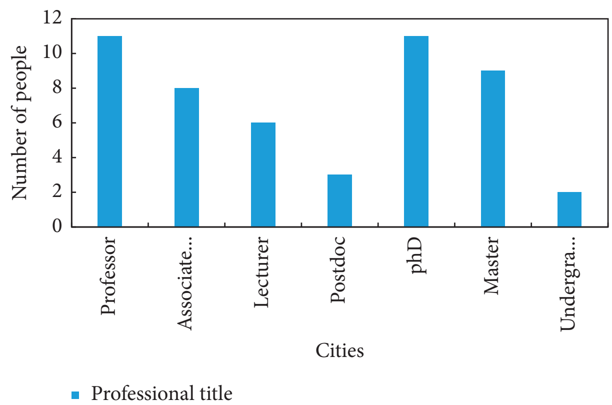


Figure 2: Level of a professional title.

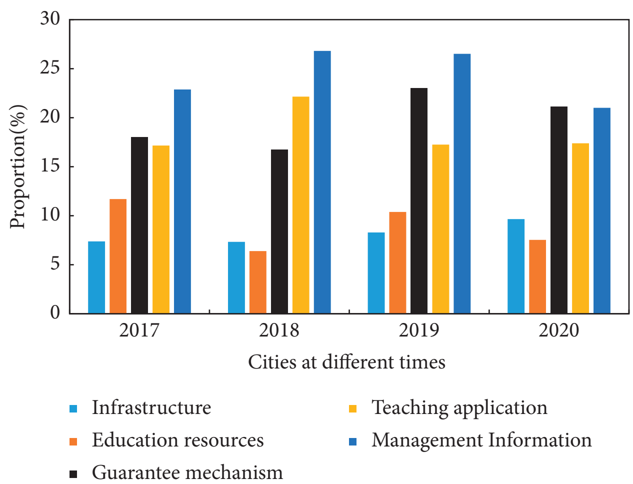


Figure 3: The development process of the evaluation index system of higher education informatization level.

traditional education and teaching methods to achieve this goal. Every educator needs to combine big data thinking with actual daily work. After analyzing the data, the corresponding strategy is formulated according to the actual needs. In turn, the big data management method and the teaching work can be combined and realized, and the development of education can be promoted. During the traditional education and teaching process and the implementation of teaching information, under normal circumstances, the development decisions of colleges and universities are mainly based on the experience of running a school. However, under the influence of the era, the main factors of teaching include the leading factors of teaching experience and management as well as the opinions of students. Only through systematic analysis and exploration of these data selection and formulation can the best teaching method be achieved [25]. Using actual data, it is possible to achieve the goal of targeted management according to the actual situation, and it can also promote enthusiasm for teaching activities. Considering the materialization of big data from the perspective of colleges and universities, schools must concentrate on promoting the informationization reform of education, constantly improve the network communication platform for education and sharing information, and promote the goal of open data and fair measures, to meet the needs of the majority of teachers and students in the data, effective data, and information port of the university management and to enhance the visibility of colleges and universities.

4.2. Improve the Management Informationization of Schools. To improve people's handling of corresponding data problems, grasp the root of the problem, find the root cause of the problem, and solve the problem completely is the main purpose of big data. In the traditional data management mode, due to the one-sidedness and subjectivity of decision-making, the data do not have integrity and consistency. However, by rationally and scientifically applying big data, this problem can be solved perfectly. In order to better innovate the reform, we should replace the unscientific management model with a new management model. The implementation of decision-making in colleges and universities is restricted by the self-control and willpower of all people on campus. Therefore, it is necessary for the management to vigorously promote the implementation of human management. The development should be considered from a long-term perspective. Decision-making adopts scientific and reasonable prejudgment methods, rationalizes the definition of the specific needs of teachers and students, and implements detailed distribution of daily management [26]. The construction and promotion of big data technology in colleges and universities need to be continuously expanded, and the education model should be transformed into a data-based establishment. The data of business intelligence technology is mainly provided by the manager. This technology is used by the public enterprise and does not involve the adoption of colleges and universities. However, from a broad perspective, business intelligence technology can be widely applied to the reform of university management information. The corresponding concepts and strategies are the main points of business intelligence, and the relevant data need to be rationalized and applied in combination with the actual basis to provide better judgments and decisions for managers.

4.3. Improve Network Security Construction. Under the influence of the era of big data, schools should use the standards of the new big data era to require the construction of information-based campuses and thereby enhance the status of the campus network in education, data management, and daily teaching. Meanwhile, teachers also need to guard against the teaching loopholes that arise during the education and teaching process. Colleges and universities should timely remedy and prevent network security protection and use information leakage as the main prevention purpose to avoid it in advance [27]. At the same time, real-time monitoring is applied to the information network environment, and system vulnerabilities and remedial measures are implemented for the network monitoring system to prevent system vulnerabilities, and bugs on some campus websites should be repaired on time. The primary

Table 3: The first round of expert evaluation of infrastructure indicators.

Index and index level	Indicator options					
Secondary indicators	Necessary		Unnecessary		Uncertain	
Campus network	Number of people	Proportion (%)	Number of people	Proportion (%)	Number of people	Proportion
Complete equipment configuration	23	92	2	8	0	0
Index and index level	24	96	1	4	0	0

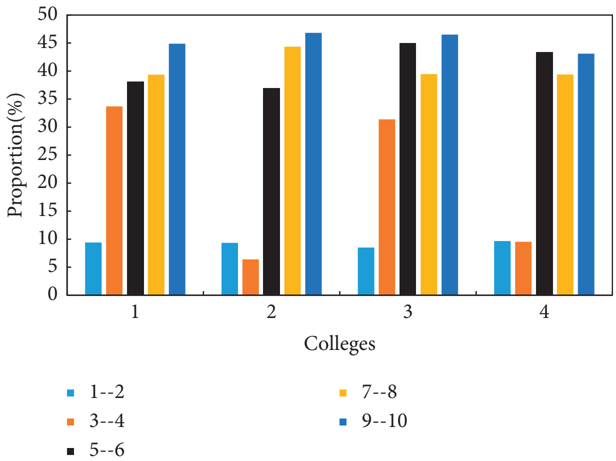


Figure 4: The level distribution of university education informatization level.

purpose of building cybersecurity is to better maintain data security and provide better protection. Although the damaged device can be repaired and the vulnerabilities are fixed, it is impossible to completely repair the lost data. Since the personal information of all teachers and students in the university is included in the campus network, the security of the internal network management server of the university must be further strengthened. The management authority and access rights for accessing the campus network should be rationally deployed. The faculty of the network management team in the university and the management of the relevant personnel should be strictly strengthened so as to ensure that the relevant personnel of the project have the corresponding professional qualities in line with their positions.

4.4. Building a High-Quality Education Management Team. Education administration not only is a general administration but also has the dual capabilities of scholarly stewardship and bureaucratic supervision. Without a strong education management team, it is impossible to have a first-class teaching level and teaching quality. In the information age, only by improving the overall quality of the education management team can we not fall behind in the development process of colleges. First is the quality of education management. Since the education management team is composed of individuals, it is the key to establish a high-quality management team and cultivate the quality of education management personnel. Training, education management, and education management can invite experienced teachers and specialized personnel to enter the training. After that, we should deepen the mastery of knowledge, such as psychology and management science education, and also improve the information quality of students, especially in computer and network technology, so that they can effectively use the campus network and Internet to work and study. Furthermore, it is necessary to improve the quality of the education management team in the university and to further develop the whole. This is related to the personal qualities of the education management personnel and the overall situation of the education management team. If the structure is reasonable, people can help each other, and mutual promotion will make people feel a more sense of collectiveness and, at the same time, facilitate the strengthening of cohesiveness and centripetal force; it is convenient for people to actively create and develop so that the overall role of the education management team is better. In the end, enthusiasm is critical, so it is necessary to establish a system of competition and incentives to guide the management of cadres, thereby increasing enthusiasm. Responsibility, system, and reward and punishment are the three main links of the postresponsibility system [28]. The implementation of the corresponding policies will play a significant role in the improvement of the enthusiasm of education management, such as the evaluation of titles, the management of teaching staff, and other issues. The inclination toward preferential policies will inevitably increase people's enthusiasm.

5. Conclusion

Foreign countries have more results in the research of college education informationization indicators but, basically, stay in the macrolevel of education informationization. Domestic information on education has also carried out a lot of work, and university education information has begun to develop in the direction of application services from infrastructure construction. With the application of various information technologies in the field of education, it will inevitably affect the educational concepts, forms, and methods of modern society. How to fully apply modern information technology in today's information age is a hot issue in various disciplines in the current education field. The ongoing expansion and updating of InfoTech have disrupted the management and business paradigms of legacy estates, and education is no exception. The developed countries abroad attach great importance to education informatization and practice innovation and have achieved remarkable results in higher education. Big data technology has become an inevitable trend of education reform and development. The development in line with the trend of the times is a practical matter that should be recognized by university administrators. The information age brings convenience to people, but it also requires relevant personnel to improve the level of information technology, otherwise, it is difficult to rationally apply this information software. Therefore, efficient managers should take advantage of the development of the great era, significantly propel the progress of informationization of enterprise education governance, and promote the comprehensive merging of big-scale data technology and innovation in education, providing guidance and advice on the information development of college education management through assessment practice, providing decision-making support for the education management informationization of universities, and also providing demonstration cases for information-driven university education management information assessment practices.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] D. Yan, "New trends in education reform in the information age and its coping strategies," *Guangdong Education (Comprehensive Edition)*, Guangdong Education Publishing, no. Z1, pp. 107-108, Guangzhou, China, 2014.

[2] T. Zhujiang, "Looking at the development direction of school multimedia display equipment from the change of multimedia terminal equipment," *Global Market Information*, no. 4, pp. 55-56, 2012.

[3] S. Li, "Analysis on the necessity and countermeasures of teaching management innovation in colleges and universities," *Caizhi*, no. 21, pp. 60–62, 2015.

[4] H. Dong, "Research on computer information processing technology under the background of "big data"," *Digital World*, vol. 392, no. 12, p. 203, 2017.

[5] N. Li and J. Liu, "A probe into the development path of informatization innovation of college education management in the age of big data," *Education Modernization*, vol. 5, no. 05, p. 295, 2018.

[6] X. Sun, "Prism gate": citizens and governments in the age of big data," *Theoretical Herald*, no. 7, p. 10, 2013.

[7] L. Qin, "Analysis of technology innovation management methods based on big data environment," *Communication World*, no. 7, pp. 71-72, 2017.

[8] J. Teng, Y. Liu, and P. Jiaolong, "The development of science and technology and the era of big data: the acquisition and innovation of new information in earth science," *Progress in Geophysics*, vol. 31, no. 1, pp. 1–22, 2016.

[9] C. A. T. Romero, J. H. Ortiz, O. I. Khalaf, and W. M. Ortega, "Software architecture for planning educational scenarios by applying an agile methodology," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 8, pp. 132–144, 2021.

[10] J. Y. Hong, H. Ko, L. Mesicek, and M. B. Song, "Cultural intelligence as education contents: exploring the pedagogical aspects of effective functioning in higher education," *Concurrency and Computation: Practice and Experience*, vol. 33, 2019.

[11] K. Y. Chau, K. M. Y. Law, and Y. M. Tang, "Impact of self-directed learning and educational technology readiness on synchronous E-learning," *Journal of Organizational and End User Computing*, vol. 33, no. 6, pp. 1–20, 2021.

[12] L. Hui, "Research on teaching reform of management information system course based on interest teaching," *Curriculum Education Research*, no. 15, pp. 23-24, 2013.

[13] B. Su, "Exploring computer network security problems and countermeasures," *China Management Informationization*, no. 6, p. 68, 2015.

[14] Y. Zou, *Research on the Construction of Network Information Resources in China under the Guidance of the Scientific Development Concept*, Chengdu University of Technology, Chengdu, China, 2007.

[15] H. Jiao, X. Li, and Q. Xiao, "Design of a unified platform for college quality courses based on collaborative relationship," *Intelligent Computers & Applications*, vol. 5, no. 3, pp. 81–83, 2015.

[16] L. Lu, "Application is the king: the only way to informatization of education management," *Distance Education in China*, no. 18, pp. 67–69, 2003.

[17] S. Sun, "Reflections on the reform and development of higher education in the new era," *Higher Education Management*, vol. 24, no. 4, pp. 23–25, 2002.

[18] B. Tang and C. Yu, "Exploration of networked management of credit system education," *Hebei Vocational Education*, vol. 3, no. 24, p. 55, 2007.

[19] B. Guohua, "Information technology education should focus on information literacy," *Science and Technology Journal*, no. 27, pp. 127-128, 2013.

[20] F. Liu, "Using computer knowledge to do office work management in the office," *Computer Knowledge and Technology*, vol. 13, no. 23, pp. 245-246, 2017.

[21] C. Zhong, "Analysis of the Co-construction and sharing of university's excellent course resources under the macro background of open education resources," *China Education Information Technology*, no. 3, pp. 21–23, 2012.

[22] J. Zhao, "Realization of component-based software reuse in university educational administration management system," *Computer Knowledge and Technology*, vol. 5, no. 13, pp. 3422-3423, 2009.

[23] D. Yang, "Analysis of the opportunities and challenges faced by college teaching reform under the background of informatization," *Chinese Education Journal*, no. S1, 2015.

[24] L. Shi, "Thoughts and requirements of application integration of national education management information system," *China Education Information Technology*, no. 7, pp. 10-11, 2013.

[25] Ye Sun, "Analysis on the construction of teaching management information system in colleges and universities under

the background of big data," *Chinese information*, vol. 23, no. 12, p. 28, 2016.

[26] X. Liu, "Exploration and thinking on the construction of education management information in colleges and universities under the background of big data," *Jiangsu Science and Technology Information*, vol. 32, no. 33, p. 38, 2017.

[27] H. Yang, "Analysis of network security problems and countermeasures in private colleges and universities in the new era," *Network Security Technology and Applications*, no. 2, pp. 87-88, 2014.

[28] Z. Bai, "Several problems should be solved in the implementation of the civil service post responsibility system," *Modern Audit and Economics*, no. 2, pp. 20-21, 2000.

Hindawi
Scientific Programming
Volume 2022, Article ID 6157740, 14 pages
https://doi.org/10.1155/2022/6157740

Research Article

Financial Risk Control and Audit of Supply Chain under the Information Technology Environment

Mingliang Xiong[1] and Limin Chen[2]

[1]*School of Economics Management, Huizhou University, Huizhou 516007, Guangdong, China*
[2]*School of Business, Wuyi University, Wuyishan 354300, Fujian, China*

Correspondence should be addressed to Limin Chen; damin@wuyiu.edu.cn

Received 13 January 2022; Revised 23 February 2022; Accepted 4 March 2022; Published 15 April 2022

Academic Editor: Ahmed Farouk

With the continuous improvement of society's recognition of supply chain finance and the development of domestic enterprises, the scale of Chinese supply chain financial service market has become larger and larger, and the status of supply chain financial services has gradually become clear. This emerging financing method can solve the problem of financing difficulties for small- and medium-sized enterprises. Many commercial banks are involved, but there are also many risks. As a representative of industrial integration, how commercial banks manage risks and improve the financial service supply chain is the focus of the article's research. The article designs a set of risk management system based on machine learning and trains similar models to verify consumers by learning user behavior patterns. The system realizes the server-side authentication module and the intelligent terminal protection module and achieves the purpose of real-time protection of the intelligent terminal system. The system will adapt to mainstream Android and IOS on the market, including portable terminal devices and smart wearable devices. If it is found that the device has not been operated by the user, the user will be provided with corresponding feedback results, and a series of automatic protection operations such as device lock and system alarm will be provided. At the same time, we provide two modes of online detection and offline detection. The device only needs to have our cloud user model to authenticate users in an offline environment to ensure that systems in different environments can run. The article solves the imbalance between user data and negative samples and most unlabeled user data and designs a set of management learning methods to ensure user certainty. By cooperating with enterprises, we can learn and analyze this set of data in our system. The results show that the accuracy rates of effective operation and user static data are 93.77% and 95.57%, respectively.

1. Introduction

The era of rapid development of information technology has arrived. With the emergence and gradual development of the concept of big data, information is gradually replacing traditional content media, which is more suitable for many companies in the market, and its competitors are also growing. With the continuous and rapid development of the global financial integration trend in the financial market, higher requirements are put forward for the development and management of commercial banks. Banks' emphasis on the use of information technology is gradually shifting from traditional businesses to electronic and centralized data management and data management decision-making. The progress of e-banking gradually replaces traditional banking services, and it has become the main battlefield for competition among large commercial banks. The processing of a large number of customer information, accounts, and transactions generated by the commercial bank network will undoubtedly increase the amount of information, such as timely access to important information, and risk management plays an important role in the entire economy. If an accident occurs, risk management cannot solve it, and good risk management should be a theoretical step to avoid accidents in advance. With the advent of the era of big data, the ability of individuals to collect and use information is further improved, making accurate analysis and decision-making based on as much data as possible. In recent years, commercial banks have attached great importance to bank risk management. Large commercial banks conduct big data mining on existing data to increase customer and bank revenue to analyze, monitor, and remind customers of abnormal credit behavior to reduce credit risk.

The problem of commercial bank information asymmetry has a significant impact on the development of the commercial bank's financial service supply chain, the most important of which is to increase the possibility of credit risk. However, in the process of granting loans to financing parties, banks will inevitably include customer group surveys. During this period, once information asymmetry occurs, the possibility of credit risk will increase significantly.

By integrating and adapting the data storage structure of commodity banks, establishing a risk management business data mart, analyzing historical business data, dividing the data mart into multiple business segments, and using data mining, commercial banks provide technically reliable data management and consider loan income. Risk monitoring and early warning can mine detailed customer account information, related party information, funds, and other information flows, calculate the potential risks of customer activities, and provide an auditable way to monitor the risk dynamics of lenders. It focuses on the information integration before, during, and after the bank's credit extension, analyzes the historical data of loan customers, effectively integrates the information shared by the bank before, and filters and analyzes the data, uses the method of technical communication to assess the credit risk of loan customers, and provides leading ideas for customers' loan issuance and approval of bank loans. Through data mining technology, the similarity of bad customers can be found, and the evaluation can evaluate loan customers more effectively, manage the overall risk of customers, and provide credit more effectively.

2. Related Work

In the field of risk control and auditing, domestic and foreign experts also have a lot of research. Tajani F's research aims to propose a decision support method for public and private entities involved in the enhancement of public property. In particular, with regard to the circumstances in which abandoned public properties can be sold, and the functional scope of the best use is determined, the developed model allows to evaluate the financial feasibility of these measures in the corresponding investment risk [1]. Hosack GR developed a practical method of a priori derivation to derive the parameters and model structure of the Bayesian generalized linear model. The predictive derivation of the subjective probability distribution is used to evaluate the effectiveness of risk control options (RCOs) in reducing the risk of collisions between Australian territorial waters and ships in the exclusive economic zone [2]. The coal mine occupational safety and health management and risk control technology and related software developed by Zhou LJ can standardize and effectively support coal mine occupational safety and health management and can also scientifically and effectively control accident risks. Its effective implementation can further improve the coal mine occupational safety and health management mechanism and further improve risk management methods [3]. PM ascini concluded that the governance of privatization risk control presents the formidable challenge of finding an appropriate balance between public goals and the involvement of private interests. By excluding or marginalizing the most vulnerable groups, privatization of risk control does not always achieve the equal opportunities pursued by social investment policies [4]. Zhao B assesses the critical link between safety and change over time. It further analyzes the changing trend of system risk under this joint effect and demonstrates how the function of the organization should be synchronized with different levels of automation transformation [5]. Du *J* proposes a multilevel threshold public goods game model and introduces an insurance compensation mechanism to discuss risk control and study the evolution of global cooperation. It is found that high risks and high thresholds are conducive to global cooperation [6]. Although these studies are relatively comprehensive, they are not in-depth enough, and the public acceptance rate is generally low.

3. Development of Risk Control System in Information Technology Environment

3.1. Data Warehouse Technology. Data warehouse is abbreviated as DW or DWH. A data warehouse is different from a database. This is mainly manifested in that it is a collection of data in a multi-distributed database. It deliberately introduces redundancy and adopts anti-paradigm design methods to make the data warehouse not a database product in the traditional sense, but a data collection platform. Its meaning is to organize and manage multiple data, additionally mine data resources, and use comprehensive analysis tools to provide a basis for management decision-making [7]. So far, there is no absolute definition of data warehouse, and the definition given in the expert book is generally accepted: the data warehouse is topic-focused, integrated, and nonvolatile, data collection reflects time variation, and it uses decision-making support. A data warehouse is a form of organization used to store and manage information and data. Its physical nature is still a computerized data storage system. However, since the purpose of use is different, it is necessary to compare the quantity and quality of the stored data. The data warehouse function is shown in Figure 1 [8].

3.2. System Business Architecture Design. According to the analysis of user needs, the system architecture generally consists of a support layer, a business layer, and a management layer: from the support layer, it includes a system management subsystem and an interface management subsystem. From the business level, it includes customer management subsystem and credit rating subsystem, credit management system, loan management subsystem, post-loan management subsystem, non-asset management subsystem execution, credit line management, and early warning subsystem throughout the entire process. From a

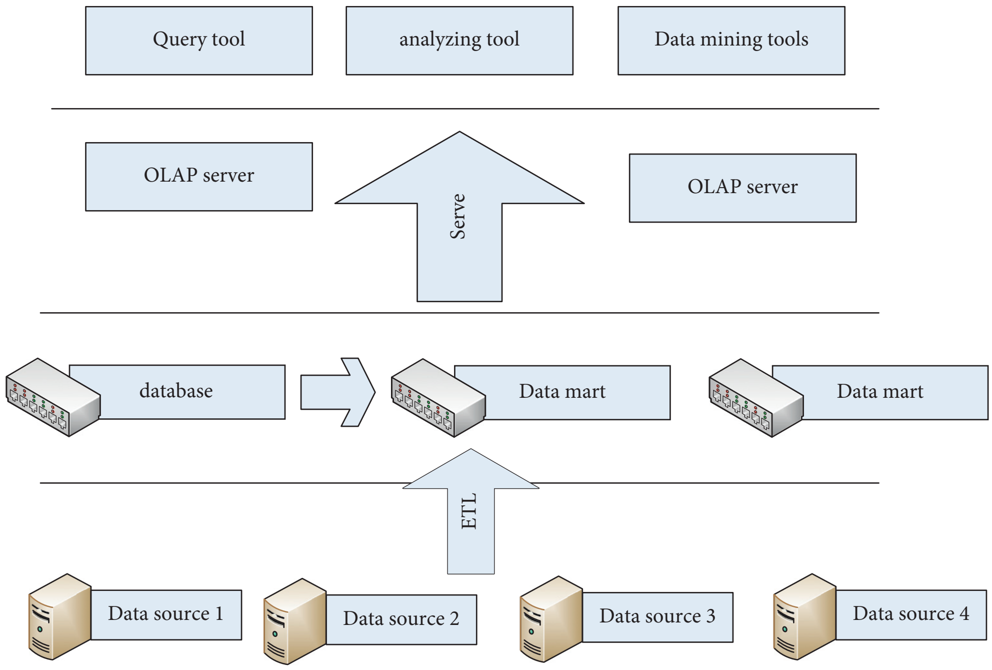


Figure 1: Schematic diagram of data warehouse functions.

management point of view, it includes a report query subsystem, a decision analysis subsystem, and a BCU supervision subsystem. The business architecture of the system is shown in Figure 2 [9].

The system architecture adopts the MVC design pattern, which separates the input, processing, and output of the system. Applications using MVC are divided into three core components: model (M), view (V), and controller (C). They each deal with their own tasks. The modules in the system are loosely coupled. The interaction between each module is realized through the interface access defined by each. One module is not allowed to directly access the database tables involved in another module. The figure is the interface that the user sees and interacts with. For previous Web applications, the viewer interface contains HTML elements. In today's Web applications, HTML still plays an important role, but some new technologies have emerged one after another, including Adobe, Flash, and some markup languages, as well as XHTML, XML/XSL, WML, and other Web services, and it is harder to deal with application interface issues. One of the greatest benefits of MVC is that it can handle many different views for the application. In fact, there is no real visual processing even if the data are stored online or the employee list, the view can only be used as a way to output the data and allow users to manipulate it [10].

3.3. System Function Design. Because the bank credit risk control system involves a wide range of external systems, with numerous input data, complex functions, and rigorous processes, it is unrealistic to describe all functions and processes one by one in a paper. The article uses credit rating as a typical function. Carrying on the key analysis, the design and realization of other functions can draw inferences from one another, and so on. Here, we take credit rating as an example to illustrate its functional design. After analyzing its main business process, the details of its business process can be further deepened, as shown in Figure 3 [11].

After an in-depth analysis of the business process of credit rating, the main functional module structure can be summarized, as shown in Figure 4.

3.4. Construction of Indicator Data Mart. Risk prediction must first determine the object of evaluation. Obtaining data through risk indicators is one of the important methods. A risk assessment model is a combination of risk indicators. A single risk indicator explains a single risk point. These indicators can be combined because of different risk assessment models to serve different management goals flexibly. Risk indicators are indicative descriptions of risk points in data mining. Risk indicators should be classified from different perspectives. Individual lenders are taken as an example to analyze the construction process of risk indicators [12].

The "5C′′" evaluation standard is taken as an example to sample and extract data. From the "5C′′" evaluation criteria, it can be seen that the following five aspects should be considered: financial strength, qualifications, operating conditions or business cycles, character and prestige, and analysis of the borrower's credit status. The sampled data should include the information of the five aspects. However, in actual operation, not all data items can be used as factors for analyzing the credit of the borrower. It must be combined with the expert evaluation method to determine the risk index system for the collected data.

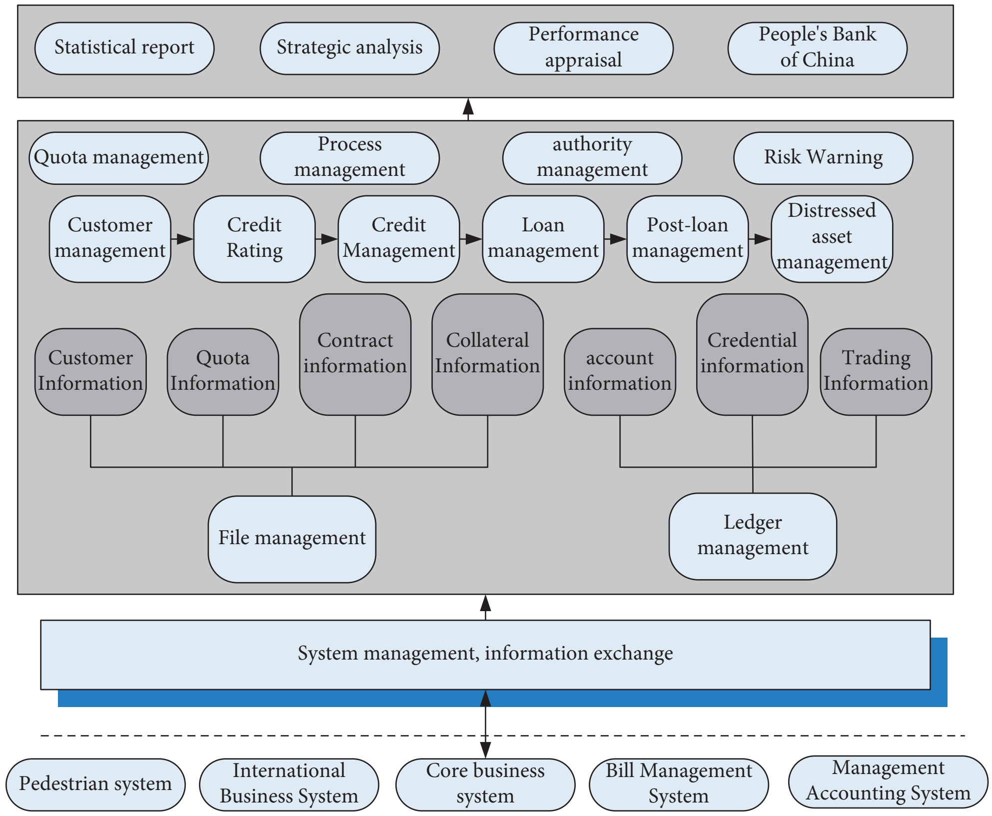


Figure 2: Layered diagram of system business architecture.

The "5C" method is used to analyze the credit status of the borrower from five aspects: character, capacity, capital cash, collateral, and condition.

Through comprehensive consideration to evaluate the credit of the lender, the following four factors should be considered: the professional situation of the borrower, the business dealings with the bank, the family situation, and the natural situation of the borrower [13]. Each factor can include the following factors.

Family situation: family monthly per capita income and debt-to-income ratio.

Occupation status: company nature, title, position, working years, and monthly income.

Business dealings with banks: accounts, business dealings, deposits, and loans.

Natural conditions: gender, education level, age, marriage, health status, and housing nature.

The external data of the risk control system come from the bank's data warehouse, which provides historical business data of the bank, most of which are standardized structure data, while the data of the risk control system come from the risk data mart. Personal credit information in the system mainly includes "personal basic information form" (name, ID number, gender, education background, residential address, marital status, occupation, position, job title, working years of the unit, industry, annual income, communication telephone, etc.) and "personal credit information form." The fields collected according to risk indicators are shown in Table 1 [14].

Among the 25 factors collected, some are not suitable as data for the general credit scoring model and should be adjusted again. For example, the main source of income, contact address, and contact phone number should be deleted.

The quality assurance of data cleaning includes the accuracy, consistency, completeness, completeness, and validity of the data. The data uploaded by the data market must ensure that the above functions are realized. Table 2 is an example of some types of data source errors. Data cleaning must first complete the completeness of the data, then perform a consistency check and accuracy check when the data are completed, and finally fill in the missing data, splicing the split wrong data, and so on. The data preprocessing process is shown in Figure 5 [15].

In the process of data preprocessing, the missing data required for the calculation of the risk control system will be supplemented by manual Excel upload. Manual data supplementary recording will be operated through a browser, and at the same time, functions such as setting up, uploading, verifying, reviewing, and downloading supplementary data will be realized.

Banks face a variety of risks all the time in their daily business activities, these risks are not isolated and unrelated, but mutual influence and interconnection. Therefore, commercial banks must conduct multidimensional management of the risks they face. Multidimensional risk management integrates the risks faced by banks from multiple angles and provides technical

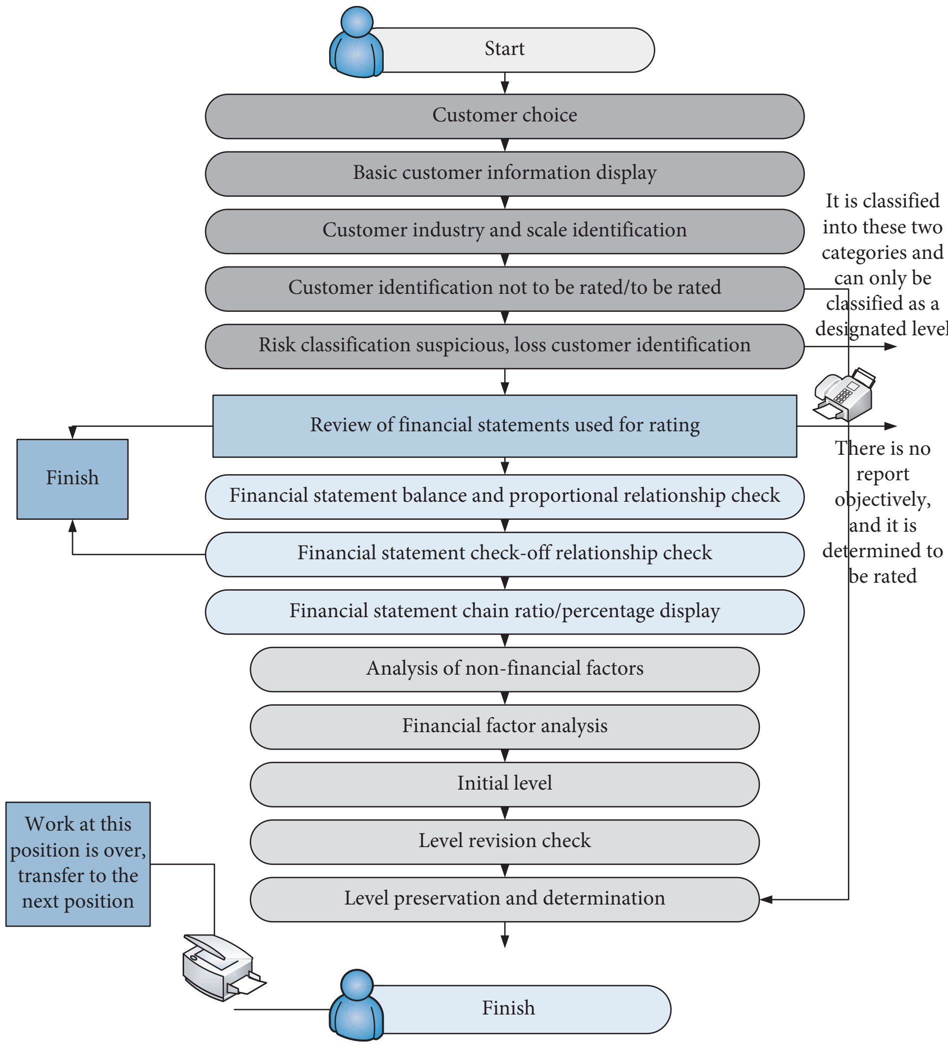


Figure 3: Flow chart of credit rating "preliminary evaluation."

support for bank risk prevention and control. Credit risk multidimensional analysis is to perform statistics, analysis, and mining on the intermediate table data that have been loaded in the indicator library to find out the potential risks in loan customers. The analysis theme will be determined first, and then, the model will be designed based on the analysis theme.

CreditRisk + Model

The model does not make assumptions about the causes of defects, but it is a random event by default, and people cannot predict the time and number of defects. If the default scale of each loan is small and the defaults of each loan are independent of each other, it can be verified that the number of default events in the portfolio follows a Poisson distribution, which is as follows:

$$\Pr(\text{nbreachesoccurred}) = \frac{e^{-L}L^n}{n!}. \tag{1}$$

$$G_j(z) = \sum_{n=0}^{m} P(\text{nbreachesoccurred})zm = \sum_{n=0}^{m} \frac{e^{-L}L^n}{n!} z^{m!} = e^{-L_j + L_j z^l}. \tag{2}$$

The probability generating function of the portfolio is as follows:

$$G(z) = \prod_{i=1}^{m} Gi(z) = e^{-\sum_{fm1}^{n} L_j}. \tag{3}$$

It can be deduced that the probability that the loss is nL is as follows:

$$p(nL) = \frac{d^n G(z)}{n! dz^n} \beta_{z=0}. \tag{4}$$

3.5. Raw Data Processing. We mainly use the data of the gravity sensor to process the raw data collected by the collection system. The main work is data calibration and movement status recognition. In daily life, the user may spend most of the time the mobile phone is not in use but is habitually thrown on the table. Therefore, this part of the data cannot be used as user behavioral habits for learning. The reason for this part of the data will be briefly described here: when the WeChat and other applications pushed

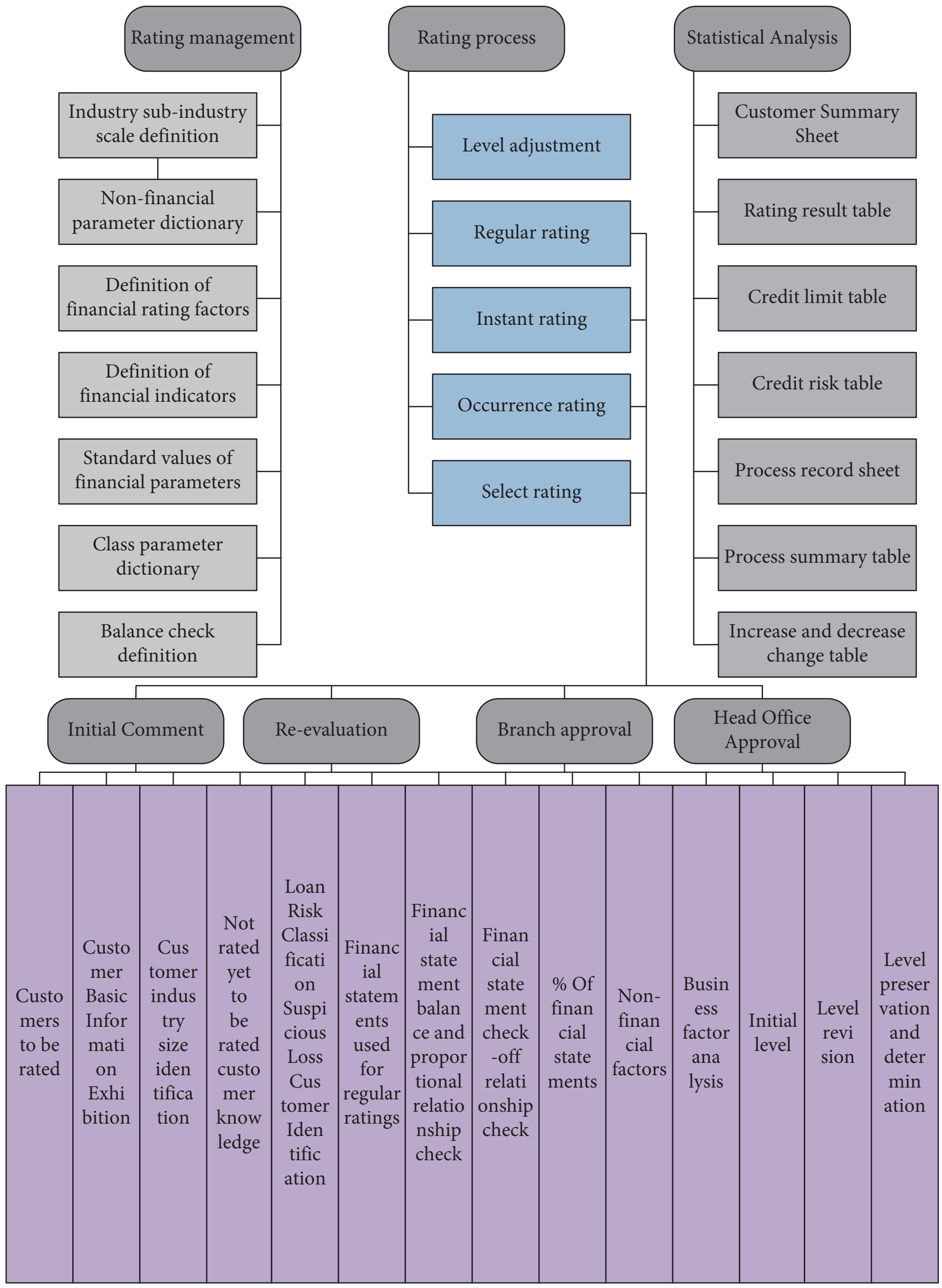


Figure 4: Credit rating function module structure.

information, the user did not pick up the phone, but the phone screen is automatically lit and the application is in the loading stage at this time, so the article work will collect sensor data within 3s. There can be a clear dividing line to define the characteristics of the gravity sensor data of this part of the smart terminal placed on the plane and the gravity sensor data used by a user in a normal state:

$$\{-1.5\langle X_{gr}(k)\langle 1.5\}\cap\{-1.5\langle Y_{gr}(k)\langle 1.5\}. \tag{5}$$

$$\{9\langle \left|X_{gr}(k)\right|\langle 10\}. \tag{6}$$

We use the difference between the acceleration sensor and the gravity sensor to analyze the user's motion state. Since whether the user is in motion or not is directly related to the acceleration that the user is in, and the acceleration sensor value of the smart terminal is synthesized by the user's acceleration and gravitational acceleration, so the difference is the absolute acceleration of the user, (7) defines the absolute acceleration.

$$d(i) = \left(X_a(i)X_{gr}(i),\ Y_a(i) - Y_{gr}(i),\ Z_a(i) - Z_{gr}(i)\right). \tag{7}$$

$$\frac{\sum_{i=1}^{K} |\vec{d}(i)|}{K} \Big\rangle |\vec{A}|. \tag{8}$$

Table 1: Collected data.

Variable	Type	Width
Gender	String	2
Age	String	4
Marital-status	String	4
Education	String	12
Industry	String	30
Position	String	40
Title	String	12
Working_year	String	12
Hous_ state	String	12
Economic_sources	String	20
Address	String	40
Telephone	String	16
Health_ state	String	4
Credit_card	String	2
Health_card	String	2
Endowment_ card	String	2
Deposit	String	2
Income_ren_ months	Number	10DEC:0
Loan amount	Number	10DEC:0
House_income_y	Number	10DEC:0
Repayment-months	Number	10DEC:0
Income_months	Number	10DEC:0
Default _payments-m	Number	10DEC:0
Cumulative_default_m	Number	10DEC:0
Asset_liability	Number	10DEC:0

Table 2: List of common partial errors.

Error type	Error example	Revise	Error index
Data correctness	Customer liability amount -999999.999	The debt amount cannot be negative, and it may be an error in the data report but cannot be determined, so to ensure accuracy, only this piece of customer data can be removed.	0.02
Consistency error	Contract ID: CD53321312032013 corresponds to two loan customers A and B	It may be that the customer name is duplicated, and the customer ID can be used to rematch	1.21
Split error	Registration area: the area name is split	Concatenate the split fields	2.15
Integrity error	The ID of a contract participant cannot be associated	Eliminate such invalid data	1.56
Missing data	Participating subject industry type is empty	Rematch according to the industry ID of the participant	3.21

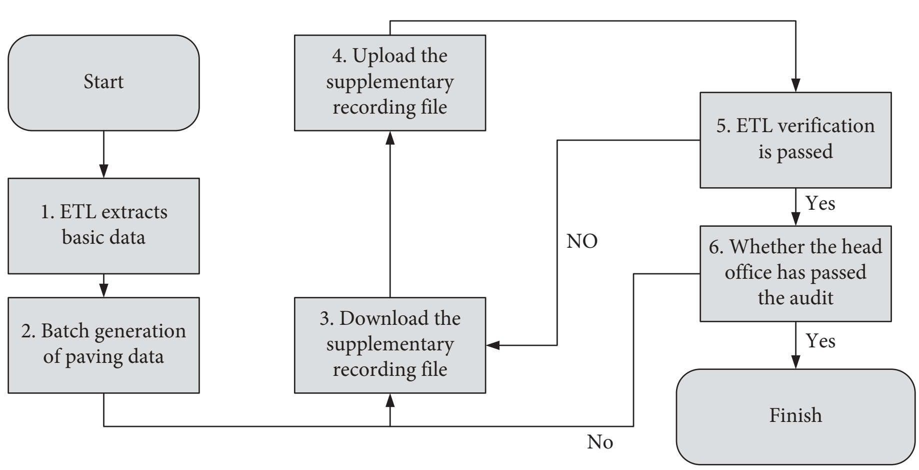


Figure 5: Data preprocessing process.

The model uses motion sensor data to distinguish user characteristics. However, this part of the data is a set of data arranged in time series, and traditional classification algorithms cannot be used directly to calculate on this set of data. Table 3 shows the data collected by our collection service within three seconds of users. This part of the data is discrete time-series data and does not reflect the user's operating habits during this time period. Therefore, the work in this study extracts a series of feature values from the original data to describe the user's exercise habits.

First, we segment the original data into 0.2s-segment segments, so that there are 10 sensor data in every 0.2s, and we extract the 0.2s behavioral features based on these 10 sensor data. In the following, the features of this set of data are described as a vector with p feature values. Among them, the subscript i represents the ith group of vectors:

Table 3: Data collection table.

Sensor	$t = 0s$	$T = 0.02s \sim t = 2.98s$	$T = 3s$
Xa	2.84935	......	2.989334
Ya	6.2918396	......	5.9676056
Za	4.96371	......	6.8680725
Xgy	-0.008712769	......	-0.0062561035
Ygy	0.02015686	......	-0.06413269
Zgy	0.011703491	......	-0.021270752
Xgr	2.9546714	......	2.9980776
Ygr	6.3256245	......	5.9881134
Zgr	6.8867106	......	7.1641064

$$Fi = \{F1_i, F2_i, \ldots Fp_i\}. \tag{9}$$

We adopted a 50% sliding window and chose a balanced scale between the amount of calculation and accuracy:

$$\left\{X_a(k), Y_a(k), Z_a(k), X_{gy}(k), Y_{gy}(k), Z_{gy}(k), X_{gr}(K), Y_{gr}(K), Z_{gr}(K)\right\}_{K=1}^{10} \Rightarrow F1. \tag{10}$$

$$\left\{X_a(k), Y_a(k), Z_a(k), X_{gy}(k), Y_{gy}(k), Z_{gy}(k), X_{gr}(K), Y_{gr}(K), Z_{gr}(K)\right\}_{K=5}^{15} \Rightarrow F2. \tag{11}$$

Table 4 describes the average AVG and standard deviation STD of these values. It can be seen that the average radius is much smaller than the average Euclidean distance between cluster centers. Therefore, we believe that the user's motion sensor data can be used as the user's electronic fingerprint for user identity authentication.

Our system uses these statistical features described in Table 4 and extracts 56 feature values through the above sliding window method:

Average value:

$$\frac{\sum_{K=1}^{K} x(K)}{K}. \tag{12}$$

Maximum value:

$$\max\{x(k) | k \in \{1, \ldots K\}\}. \tag{13}$$

Standard deviation:

$$\sqrt{\frac{\sum_{K=1}^{K} \{x(k) - \overline{x}\}^2}{K-1}}. \tag{14}$$

Minimum:

$$\min\{x(k) | k \in \{1, \ldots K\}\}. \tag{15}$$

Average difference:

$$\frac{\sum_{K=1}^{K} |x(k) - \overline{x}|}{K-1}. \tag{16}$$

Zero crossing rate:

$$\frac{\sum_{K=0}^{K-1} \|\operatorname{sgn}([x(k+1)]) - \operatorname{sgn}[x(k)]\|}{K}. \tag{17}$$

Root-mean-square value of skewness:

$$\frac{\sum_{K=1}^{K} [x(k) - \overline{x}]^3}{K\sigma^3}. \tag{18}$$

Kurtosis:

$$\frac{\sum_{K=1}^{K} [x(k) - \overline{x}]^4}{K\sigma^4} - 3. \tag{19}$$

Average Euclidean distance:

$$\frac{\sum_{K=1}^{K} \sqrt{x(k)^2 + y(k)^2 + z(k)^2}}{K}. \tag{20}$$

The model of sample storage in the cloud is shown in Figure 6. In the preprocessing operation, the data collected each time will be divided into a static state and a motion state. Then, this time the data will be stored in the corresponding location in the form of a single file and contain a triple tuple (timestamp, motion state, and file absolute path) to describe it.

4. Financial Risk Control and Audit

To facilitate the calculation results, the indicator scores are adjusted accordingly, and the total is taken. The weights are as follows: transaction asset evaluation (13%), core enterprise strength evaluation (25%), supply chain operation status (30%), and financing company evaluation (32%). In addition, supply chain finance emphasizes risk management in the transaction process, so it is the focus. When designing the form, first the strength of the core business is checked, its strength is understood, the operation of the supply chain is understood, and transaction attributes are checked. The second is the evaluation of small- and medium-sized enterprises. The four dimensions add up to 100 points, as shown in Table 5 [16].

Table 4: User data gap assessment table.

	Still	Execute
AVG (ri)	7.27	5.31
STD (ri)	7.24	1.93
AVG (dcij)	10.66	18.83
STD (dcij)	4.47	10.02

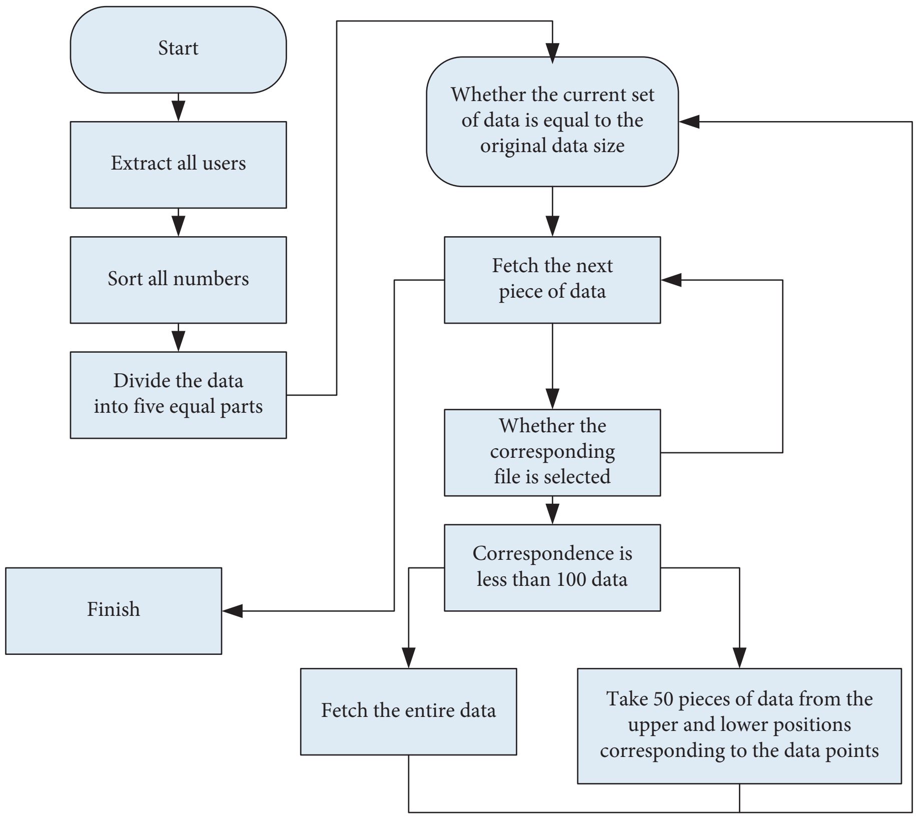


Figure 6: Flow chart of stratified sampling.

Table 5: Supply chain finance credit rating score.

	Core enterprise strength evaluation					
First level indicator	Comprehensive strength (11 points)		Industry evaluation (9 points)		Contingent liabilities (5 points)	
Secondary indicators	Industry status (7 points)	Credit rating (4 points)	Industry development stage (4 points)	Industry environment (5 points)	External guarantee situation (3 points)	Potential legal dispute (2 points)
Index description	Comprehensive evaluation of the company's total assets, sales revenue, and industry rankings	The credit rating of the company in the rating agency or banking system	Emerging industries, growing industries, mature industries, declining industries	Comprehensive judgments of the industry's political environment, competition status, legal environment, etc.	Measured by the ratio of the guarantee balance to the company's net assets	Whether there is a large amount of contract disputes or legal proceedings affecting the reputation of the company
Score	High: 7 points Middle: 4 points Low: 2 points	AAA: 4 points, above AA: 3 points, above A: 1 point, below A: 0 points	Mature industry: 4 points Growth industries: 3 points Declining industries: 1 point, thriving industry: 1 point	Good: 5 points Middle: 3 points Bad: 1 point		None: 2 points, yes: 0 points
	1.536	5.5453	3.57857	7.13462	2.57	1.657

The credit rating is shown in Table 6.

Case analysis takes the upstream supplier S company as an example, and K bank and S company have regular business transactions, dealing with current loans, bank receipts, bills of exchange, securities, discounts, and other credit services and liquid loans. So far, the bank has accumulated more than 40 million yuan in collection fees, and it has a good historical credit. Figure 7 shows the company's main financial indicators from 2018 to 2019.

S Group is a state-authorized investment institution and state-owned enterprise. It is a comprehensive petroleum company that implements the integration of upstream, midstream, and downstream production and marketing, and cross-border and cross-industry operations. *Z* Petroleum Group has a strong momentum, strong comprehensive energy, high credibility, and a comprehensive energy rating of 11 points. Over the past five years, the overall domestic petroleum industry has been operating relatively robustly, with the output of most products increasing at a rate of 1° per year. Due to the slow growth of consumer demand, the growth rate of refined oil consumption was initially lower than expected. In 2015, the national crude oil processing volume was nearly 467.9 million tons, a year-on-year increase of 3.73%. In 2016, the domestic crude oil output was nearly 208.25 million tons, a year-on-year increase of 1.7%. The crude oil processing volume was nearly 44.398 billion tons, an increase of 6.9% over the previous period, and the industry appreciated. The level is 9 points. The external guarantee rate does not exceed 50%, there are no contract disputes and lawsuits that affect the company's reputation, and there are 3 points for contingent debts.

80% of S company's accounts receivable are well managed and the account period is short, and they can all be restored within one year. 1 point is calculated for the billing period and ageing. The company basically has no repurchase positions, the return record is given 2 points, the lender's accumulated debt ratio is less than 1% and is given 2 points, and the total transaction asset valuation is 10 points [17].

S company's products are widely used in the energy field. The energy industry is a state-supported industry with a relatively high growth rate. The company government supports the development of small and medium enterprises and implements priority policies such as tax relief and loan interest relief. *Z* Petroleum Group has cooperated with S company for many years [18]. The way of cooperation is to sign a cooperation agreement for the following year at the end of each year, which includes fees, packaging conditions, adoption procedures, settlement procedures and deadlines, liability for breach of contract, and dispute resolution procedures. *Z* Petroleum Group uses the ERP system to place orders with suppliers at the beginning of the month, providing information such as the number of products required per month and the delivery date. The company arranges related products according to the content of the order, puts the products and invoices to the place of delivery designated by the Petroleum Group, and prepares to receive the goods. The duration is 120 days. Therefore, in the evaluation of the supply chain index S by K Commercial Bank, the relationship length is 7 points, the relationship strength is 11 points, and the past performance is 3 points. The status of third-party logistics companies in the industry is not high, but the warehouse management is relatively standardized, and a relatively complete database gets 5 points. All projects are scored according to the position of the S company, with a total score of 86. It is an A-level company worthy of the credit and reputation of commercial banks. All participating companies depend on each other in the supply chain to provide funds for credit risk, and the credit supply chain plan must address all levels of credit risk, but in fact, each level can only raise this aspect of credit risk management to a standard level. Credit incidents of upstream and downstream companies may harm the interests of these companies [19].

The nonperforming loan ratio from 2014 to 2020 remained at a relatively low level, which was 0.03% in 2016. After 2016, the management continued to withstand capacity risks, and the management bank K was in a downward market, and the loan rate showed no upward trend. In 2017 alone, nonperforming loans reached 745 million yuan, and the nonperforming loan ratio was 1.8%. This is also the first time that K Commercial Bank has seen total nonperforming loans. At the end of 2013, the balance of nonperforming loans was 649 million yuan, and the nonperforming loan ratio was 1.03%. The nonperforming loan ratios in 2019 and 2020 are 0.88% and 1.15%, respectively [20]. Although both were lower than the city's commercial banks' nonperforming loan ratio of 1.37% that year, they were still at a relatively high level for newly built and rapidly developing commercial banks. It can be seen that in our city, since the establishment of K Commercial Bank, the nonperforming loan rate has increased, mainly due to problems in bank information management and credit risk disclosure. From Figure 8, we can see the supply chain trend of financial risks so far [21].

The financing company currently provides pre-loan evaluation materials for K Commercial Bank loans. Because interest rates are flat, loans are unfair to borrowers in different risk situations, and low-risk loans will not get higher returns. Once the bank lends, the lender may bring moral hazard to the bank, because the lender can provide the company with false business information to maintain a higher interest rate, and the commercial bank will not be able to obtain accurate business information, nor can it accurately assess business operations.

When developing financial supply chain business, the four parties need to work together [22]. The basic business development process is shown in Figure 9.

In summary, the company obtained additional credit funds from K Commercial Bank after using hedging. Taking into account the margin expenditure, the company's actual capital use is also greater than the traditional financing business. Finally, the effective introduction of hedging avoids market risks caused by commodity price fluctuations, guarantees the credit protection of K Commercial Bank, and realizes market risk management.

Table 6: Credit rating.

Score	Credit rating	Credit status	Numerical value
90 points (inclusive) or more	AAA	Credit excellence	56
80 points (inclusive)-90 points	AA	Good credit	26
70 points (inclusive)-80 points	A	Good credit	34
60 points (inclusive)-70 points	BBB	Average credit	254
50 points (inclusive)-60 points	BB	Poor credit	2156
40 points (inclusive)-50 points	B	Poor credit	26
30 points (inclusive)-40 points	CCC	Bad credit	31
20 points (inclusive)-30 points	CC	Very bad credit	155
10 points (inclusive)-20 points	C	No credit	261
10 points or less	D	No credit	12

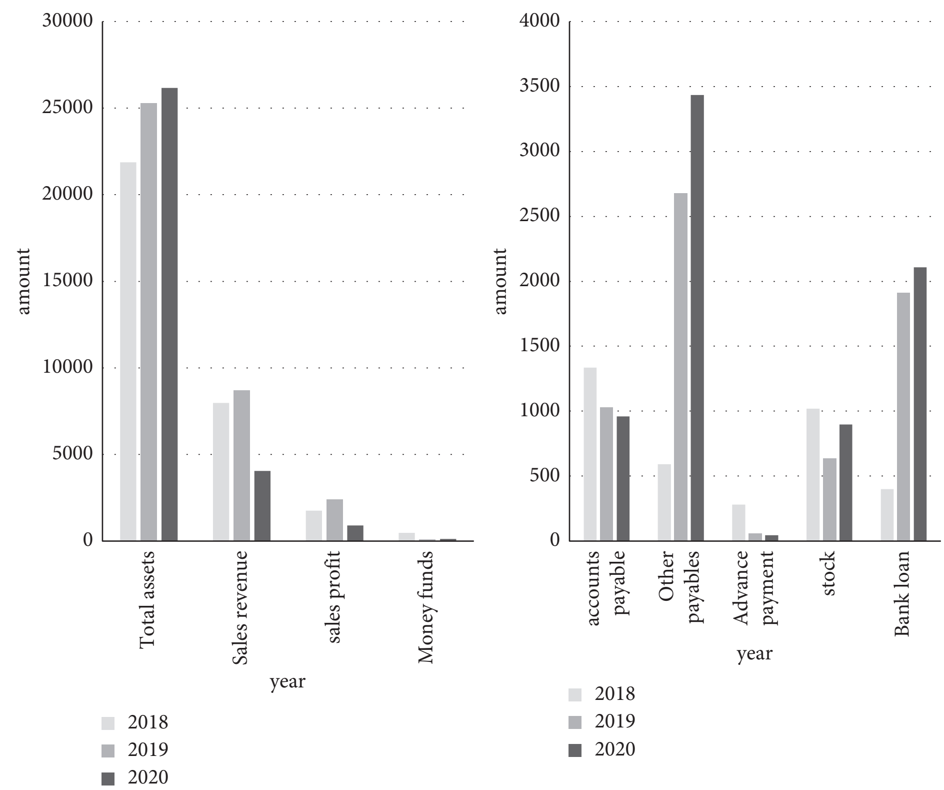


Figure 7: Company's main financial indicators from 2018 to 2020.

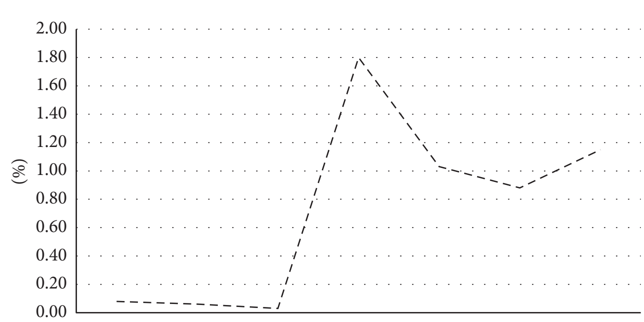


Figure 8: Trends in the NPL ratio of K Commercial Banks.

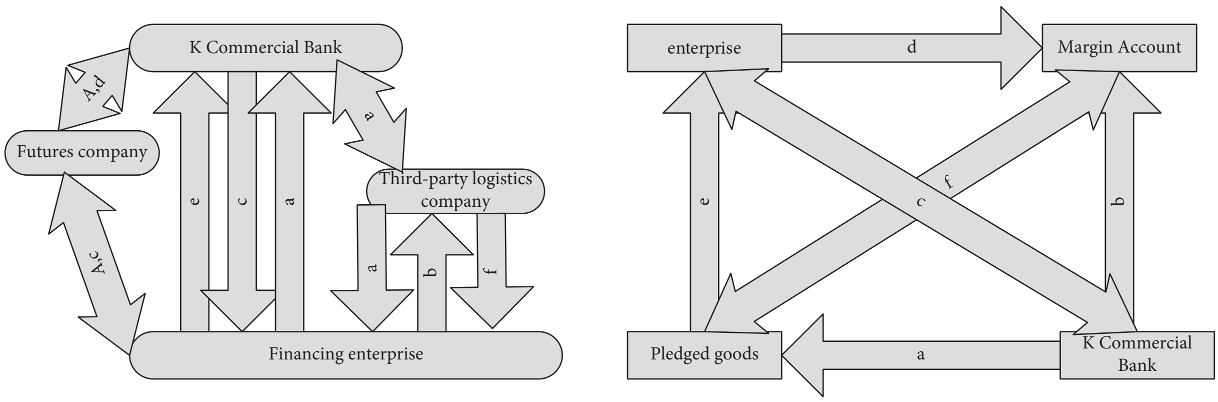


Figure 9: Risk control process in different situations. After using hedging, the business is compared, as shown in Figure 10.

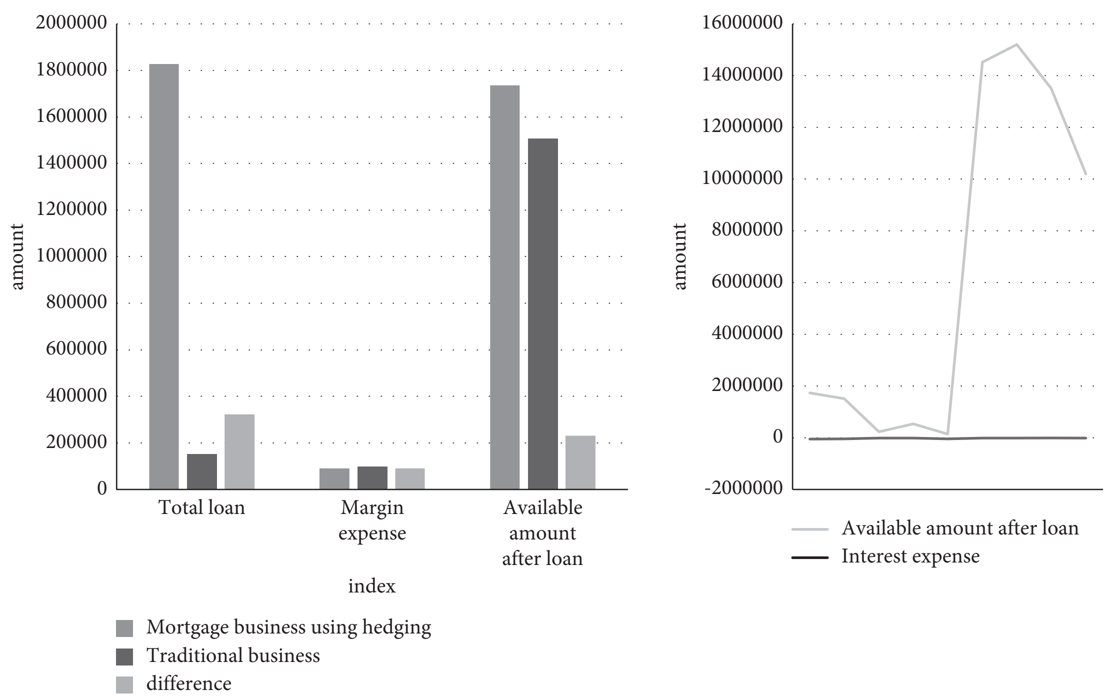


Figure 10: Comparison of the introduction of hedging business and traditional business.

5. Discussion

The article is based on the development of bank financial supply chain business, using literature research, comparative analysis, case analysis, qualitative and quantitative analysis, and other methods, including supply chain management theory and comprehensive risk management theory. Combining the development status of K Commercial Bank's financial supply chain business and three typical risk cases of K Commercial Bank, it examines the main theories of the agent, introduces the principle chain of financial supply risk analysis, quickly analyzes the basis for risk selection, and the supply chain financial credit rating. In the follow-up research, the supply chain financial risk management was investigated, and combined with the theoretical consequences of supply chain risk, it provided a method for improving the level of financial supply chain risk management, and the research results obtained are as follows [23].

K Commercial Bank launched an accounts receivable financing model for upstream financial supply chain companies. At present, the business background of risk management under this model is incomplete, and there are serious problems in dealing with the credit risk of key businesses, ineffective implementation of rules and regulations, and insufficient incentive and restraint mechanisms. Therefore, it is necessary to strengthen the audit of the validity of accounts receivable, prevent small and medium-sized enterprises from transferring accounts, do a good job in the payment management of CNPC's main business, and establish an account receivable financial management information ledger, and using scientific and technological means to strengthen the response and management of accounts receivable financing, establish an early warning mechanism for customer financing risks, establish a special accounts receivable financial management department, cultivate professional talents, and effectively solve problems.

At this stage, K Commercial Bank created an integrated warehouse management financing model for financial companies under the supply chain. The risk management of this financing model is not commensurate with the bank's information technology and risk management system, and the professional quality of the practitioners needs to be improved. Progress measures include improving internal control, selecting third-party logistics with good credit ratings, setting a reasonable pledge rate, determining the source of funds, and using future resource hedging functions to correct market risks. For financial companies with upstream and downstream supply chain connections, K Commercial Bank has launched an inventory pledge investment model. The risk management of this financing model is that the involvement of third-party logistics companies increases financial risks and transfer risks. There are dual-negative effects between banks and enterprises. It can manage the risk management points of the financial operation of the entire supply chain and adopt the method of setting a reasonable rate of return and presenting financial resources to avoid market risks. At the same time, we must pay attention to the management of market risks and the management of future margin accounts. Finally, the purpose of avoiding risks and continuous improvement is achieved.

The risk management system mainly performs the following functions: 1. realizing risk prediction before borrowing, predicting the potential loan default risks of loan customers, and providing preliminary judgments for bank credit and credit approval personnel; 2. realizing post-loan risk monitoring and early warning, excavating loan customer account information, related party information, capital flow, and other information, dynamically monitoring loan customers, and providing services for banks to detect and avoid risks in a timely manner; 3. considering the aggregated information before, during, and after the bank's credit granting, integrating the previously divided information, and analyzing and predicting the credit risk of loan customers; and 4. enhancing the bank's credit management and risk control capabilities. Through data mining, the loan investigation cycle is reduced, the model is used to analyze the data, and the prospectiveness of bank risk monitoring is improved [24].

The system is currently operating stably. The report data obtained from the system display layer are consistent with the data pushed by the bank's front-end system. According to the banking business needs, new reports are continuously developed and regularly pushed to the report database to provide visual query and analysis functions for the service bank and regularly pushing the demand solidification report of each risk control project.

6. Conclusion

In the article, the risk control system is introduced. The method based on machine learning provides two modes of offline user authorization and authentication and online user authorization and authentication. Through the learning of the user sensor model, we have trained a model for the user to use the smart terminal, which is used to describe the specific way the user uses the device. Different from previous related research studies, we have no specific requirements on the user's exercise state and the placement of the equipment, and the user can train his own user model unconsciously. In addition, the ideal verification mode provided by the work in this article allows users to provide continuous authentication to users when the network is disconnected or the network environment is poor and to protect users' smart terminals anytime and anywhere. Through the data research of large-scale users, our system adopts the method of stratified sampling and semi-supervised learning to solve the problems that arise in the actual application environment such as unbalanced data sets and unlabeled data. This set of learning mechanisms enables the work of this study to perform user identification and authentication through data collected from enterprise suppliers. Due to the limited time and ability, this article has many shortcomings, which require continuous research and analysis. The research of the article is mainly based on K Commercial Bank, starting from the supply chain finance business model, and mainly considers the problem of commercial bank K supply chain financial risk management, so that in the next step, we can continue to study how to use bank financing to improve company performance from the perspective of K Commercial Bank to accelerate the company's capital operation, so that the company can get more benefits. It can also start to study the problem of gradual mergers from the capital level. The content of capital finance and logistics can be further discussed. As the core enterprises of the supply chain, K Commercial Bank and *Z* Petroleum Group have natural business advantages that other commercial banks in the town cannot match. Using CNPC's big data platform and industry financial information to further expand the supply chain, commercial finance is the key aspect that needs to be considered in the next step of how commercial bank K's supply chain finance manages risks. What we are taking is a new microloan technology innovation road of data plus the Internet. Regardless of whether it is the Internet or data, all that can be grasped is information, not assets; that is, Ali's approach to risk control is to have accurate judgments and correct decisions on risks and to control losses within an acceptable proportion. It is not the compensation that can be obtained after a certain business decision fails. This method of evaluating credit based on the Internet and past transaction data of enterprises may be the future direction of development, as well as the direction of future improvement and perfection of our system.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This work was supported by the Planning Project of Educational Science of Guangdong Province: "Research on spatial and temporal differentiation technology innovation of industrial agglomeration and environmental pollution decoupling of the Guangdong-Hong Kong-Macao Greater Bay Area" (2019GXJK068).

References

[1] F. Tajani and P. Morano, "Evaluation OF vacant and redundant public properties and risk control," *Journal of Property Investment & Finance*, vol. 35, no. 1, pp. 75–100, 2017.

[2] G. R. Hosack, K. R. Hayes, and S. C. Barry, "Prior elicitation for Bayesian generalised linear models with application to risk control option assessment," *Reliability Engineering & System Safety*, vol. 167, pp. 351–361, 2017.

[3] L.-J. Zhou, Q.-G. Cao, K. Yu, L.-L. Wang, and H.-B. Wang, "Research on occupational safety, health management and risk control technology in coal mines," *International Journal of Environmental Research and Public Health*, vol. 15, no. 5, p. 868, 2018.

[4] P. Mascini and R. V. D. Veen, "Editorial: the privatization of work-related risk control," *Zeitschrift für Sozialreform*, vol. 66, no. 3, pp. 195–206, 2021.

[5] B. Zhao, T. Tang, and B. Ning, "System dynamics approach for modelling the variation of organizational factors for risk control in automatic metro," *Safety Science*, vol. 94, pp. 128–142, 2017.

[6] J. Du and Y. Jia, "Evolutionary game dynamics and risk control in global dilemmas with insurance compensation," *IFAC-PapersOnLine*, vol. 50, no. 1, pp. 7669–7674, 2017.

[7] L. Huang, H. Li, T. Liu, and J. Chen, "Potential infection risk control in the radiology department during economic recovery after the COVID-19 pandemic," *Journal of Medical Imaging and Radiation Sciences*, vol. 51, no. 3, pp. 503-504, 2020.

[8] I. Pujiarti, D. Koestiono, A. Aprilia, and R. A. Febriana, "Risk control strategies for red chili seed production," *Agrisocionomics: Jurnal Sosial Ekonomi Pertanian*, vol. 4, no. 2, pp. 298–310, 2020.

[9] J. S. Busby, B. Green, and D. Hutchison, "Analysis of affordance, time, and adaptation in the assessment of industrial control system cybersecurity risk," *Risk Analysis*, vol. 37, no. 7, pp. 1298–1314, 2017.

[10] B. Zhao, T. Tang, and B. Ning, "System dynamics approach for modelling the variation of organizational factors for risk control in automatic metro," *Safety Science*, vol. 94, pp. 128–142, 2017.

[11] T. Kontogiannis, S. Malakis, and N. Mcdonald, "Integrating operational and risk information with system risk models in air traffic control," *Cognition, Technology & Work*, vol. 19, no. 1, pp. 1–17, 2017.

[12] S. B. Yang, J. Zhang, and X. X. Qin, "Study on the flight test risk assessment of civil aircraft flight control system failure," *Journal of Aeronautics, Astronautics and Aviation*, vol. 52, pp. 171–181, 2020.

[13] H. Wang and S. Smys, "A survey on digital fraud risk control management by automatic case management system," *Journal of Electrical Engineering and Automation*, vol. 3, no. 1, pp. 1–14, 2021.

[14] W. E. Forum, W. Bank, and A. D. Bank, "The africa competitiveness report 2011," *World Bank Publications*, vol. 63, no. 4, pp. 701–706, 2017.

[15] W. Bank, "Turn down the heat: climate extremes, regional impacts, and the case for resilience," *Government Information Quarterly*, vol. 31, no. 2, pp. 346-347, 2017.

[16] C. O. Learning and A. D. Bank, "Open and distance learning," *Dfid*, vol. 4, no. 3, pp. 297–305, 2017.

[17] M. C. Frank, M. Braginsky, D. Yurovsky, and V. A. Marchman, "Wordbank: an open repository for developmental vocabulary data," *Journal of Child Language*, vol. 44, no. 3, pp. 677–694, 2017.

[18] M. Chen, J. Wu, B. N. Jeon, and R. Wang, "Monetary policy and bank risk-taking: evidence from emerging economies," *Emerging Markets Review*, vol. 31, pp. 116–140, 2017.

[19] D. Appelbaum, A. Kogan, and M. A. Vasarhelyi, "Big data and analytics in the modern audit engagement: research needs," *Auditing: A Journal of Practice & Theory*, vol. 36, no. 4, pp. 1–27, 2017.

[20] M. S. Gaddis, "Audit studies: behind the scenes with theory, method, and nuance || emerging frontiers in audit study research: mechanisms," *Variation, and Representativeness*, pp. 179–195, Springer, New York, NY, USA, 2018.

[21] None, "Correction: medical research and audit skills training for undergraduates: an international analysis and student-focused needs assessment," *Postgraduate Medical Journal*, vol. 94, no. 1112, 324 pages, 2018.

[22] P. Wallage, "Audit research summaries," *Maandblad voor Accountancy en Bedrijfseconomie*, vol. 91, no. 7/8, pp. 244–249, 2017.

[23] E. Office, "Audit research summaries," *Maandblad voor Accountancy en Bedrijfseconomie*, vol. 91, no. 1/2, pp. 58–62, 2017.

[24] N. Buaphuean, S. Janjarasjit, and P. Ussahawanitchakit, "Strategic audit professional commitment and audit survival: an empirical research of certified public accountants (CPAs) in Thailand (the business review, cambridge * ISSN 1553-5827 * the library of congress, Washington, DC)," *Family Business Review*, vol. 23, no. 1, pp. 167–184, 2021.

Hindawi
Scientific Programming
Volume 2022, Article ID 8027003, 9 pages
https://doi.org/10.1155/2022/8027003

Research Article

Interpersonal Interface System of Multimedia Intelligent English Translation Based on Deep Learning

Xiaojing Li[1] and Shuting Ding[2]

[1]*Qingdao Agricultural University, Qingdao 266109, Shandong, China*
[2]*School of Foreign Languages, Qingdao Agricultural University, Qingdao 266109, Shandong, China*

Correspondence should be addressed to Shuting Ding; 200401052@qau.edu.cn

Received 21 December 2021; Revised 23 January 2022; Accepted 14 March 2022; Published 14 April 2022

Academic Editor: Ahmed Farouk

Artificial intelligence is a very challenging science, and people who are engaged in this work must understand computer knowledge, psychology, and philosophy. Artificial intelligence includes a wide range of sciences; it is composed of different fields, such as machine learning and computer vision. In recent years, with the rise and joint drive of technologies such as the Internet, big data, the Internet of Things, and voice recognition, the rapid development of artificial intelligence technology has presented new features such as deep learning, cross-border integration, and human-machine collaboration. Intelligent English translation is an innovation and experiment of the English language industry in the field of science and technology. Machine translation is the use of computer programmes to translate natural language into a specific natural language. This interdisciplinary subject includes three subjects: artificial intelligence, computational linguistics, and mathematical logic. Machine translation is becoming more and more popular with the public, and its advantages are mainly that machine translation is much cheaper than manual translation. From this study, it can be seen that the accuracy rate of the traditional ICTCLAS method is 76.40%, while the accuracy rate of the research method in this article is 94.58%, indicating that the research method used in this article is better. Machine translation greatly reduces the cost of translation because there are very few processes that require human participation, and the translation is basically done by computers. It is also an important research content in the field of English major research. Due to the wide range of language cultures and the influence of local culture, thought, and semantic environment, traditional human translation methods have many shortcomings. Nowadays, the demand for translation is unsatisfactory. Based on this, this paper analyzes the application status of intelligent translation, the prospect of intelligent translation, and realizes the optimization design of the human interface system for the intelligent translation of English. Through experiments, it is found that the multimedia intelligent English translation system based on deep learning not only improves the accuracy of English translation but also greatly improves the efficiency of people learning English.

1. Introduction

The process of machine translation is very simple, and the translation time can be estimated more accurately. The running speed of computer programmes is very fast, which cannot be kept up with manual speed. So far, machine translation has experienced several key turning points in its development, and with the good development and application of artificial intelligence in many aspects, especially in the fields of image, speech, and natural language processing, machine translation has once again used neural networks to continue to move forward. Language and text are the main tools for communication between people. Different countries and ethnicities have different languages. Language barriers have always been the biggest difficulty in communication between people of all nationalities in the world. With the rapid development of computers, English has become the universal language. With China's rapid economic development, foreign exchanges have become more important, and people's growing desire for knowledge has made the Internet the fastest and most convenient way for Chinese people to understand the world. At present, English is the most populous language in the world, which leads to a large amount of information on the Internet being in English. Although English is now widely educated in China, only a few people have a higher level of English. For most people, there is still a long way to go to translate English information accurately. With the progress of the translation industrialization process, the research on English multimedia intelligent translation is particularly important in today's environment. Excellent and accurate translation will make people understand that the world becomes simpler.

For instance-based machine translation, the main knowledge source is the instant translation library of parallel corpus. There are mainly two fields of information in the library: one is the source language sentence and the other is the corresponding target language sentence. When inputting a source language sentence, the translation system finds out the source language sentence that is most similar to the sentence in the library and simulates the corresponding target language sentence to translate the corresponding translation. The whole translation process is to find and reproduce, only to compare, without analyzing the source language sentence. China's economy is developing rapidly, and China's opening up to the outside world is also following the development of the new era. Based on the development of globalization, science and technology are also continuing to innovate and progress, thus realizing diversified foreign language learning pathways, including the development of translation tools. The demand for its practicality and functionality is also constantly improving, and it also makes English intelligent translation a research focus. For example, in May 2018, Wang Qiqi made a deep discussion on the application status of the language service industry in artificial intelligence, analyzed its background and application status, and made suggestions and prospects [1]. In May 2018, He Liutao discussed a series of problems in the development of intelligent translation in the context of artificial intelligence and proposed solutions, which played a realistic role in the development of intelligent translation in China [2]. In August 2018, Zhang Fan used the statistical machine translation method based on maximum entropy to obtain relevant parameters through direct maximum entropy model training and obtained the best combination of different English language features to solve partial structural ambiguity in the massive English language. The problem is to improve the accuracy of English machine translation [3]. In March 2019, Qi Qiyu, based on the analysis of the background of the times from the perspective of translation theory, expounded the application of artificial intelligence in the translation industry, analyzed the positive and negative effects of artificial intelligence on translation, and combined the actual translation practitioners and language learners to make relevant suggestions [4]. Due to the needs and importance of intelligent translation in today's society, many areas of research are now exploring intelligent translation and have achieved good results [5–8].

With the deepening of human-machine interface research, in intelligent recognition, the human-machine interface system is the main component of intelligent recognition. Many studies have used the human-machine interface and achieved good results. For example, in June 2018, Yinxiang, Yu Kang, Jin Chengqian, and Du Juanlin designed and developed the human-machine interface to test with the navigation controller. The results show that the human-machine interface can send operation instructions according to the established serial communication protocol. Receive data and information from the navigation controller. It can meet the requirements of human-computer interaction in the automatic navigation system of agricultural machinery [9]. In September 2018, Bao Jiaming designed a new multitank multitemperature water heater structure and designed the touch screen human-computer interaction control interface design of the water heater with the single-chip microcomputer as the core controller. It is capable of simultaneously supplying high-temperature boiling water, boiling hot water, and cold water below 10°C [10]. In February 2019, Xu Xinyu analyzed the development trend of the human-machine interface under the guidance of artificial intelligence from three aspects: recommendation systems, computer vision, and speech recognition, and summarized and forecasted the future development direction of the human-machine interface [11–14].

Machine translation is a technology used in computer technology to transform a natural language into another language. It is an emerging science technology that combines multiple disciplines and integrates them with each other. It promotes the field of intelligent translation. The development of research achieved a lot of results in the field of intelligent translation. For example, in March 2019, Lu Wenjie, Tan Ruyi, Liu Gongshen, and Sun Huanrong proposed a semi-supervised neural network model for small-language translation based on the analysis of the coding-decoding framework and attention mechanism [15]. In April 2019, Zhou Jianing studied the development history and purpose of simultaneous interpretation, explored the theoretical basis of speech recognition and machine translation, focused on the implementation of speech recognition and machine translation, and designed a simultaneous interpretation system based on *c#* language [16]. The existing methods of machine translation also show unique advantages in other languages [17–20].

Through the research on the application status of intelligent translation and the prospect of intelligent translation, this paper finds that the practical application function and market demand of intelligent translation from now to the future are very high. Based on the advantages of the human-machine interface system, this paper studies the English multimedia intelligent translation. According to the hierarchical phrase translation model in machine translation, combined with its own learning experience, the human-machine interface translation system consists of four parts: preprocessing, image segmentation, feature extraction, and classifier design. Through the experimental test, the human-machine interface translation system designed in this paper has made a certain breakthrough in the correct rate recall value compared with other systems, and can complete the translation work with high quality [21–23].

2. Design of Human-Machine Interface Translation System

The simplest definition of a human-machine interface is that between a person and a machine, through a certain interface, the person can give instructions to the machine, and the machine can report the execution status and system status to the user through this interface. In other words, the correct communication of information and instructions between man and machines is the main definition of human-machine interface. The display, main unit, and image acquisition card mainly constitute a complete hardware component of the human-machine interface translation system. According to the function, the software system can be divided into several parts: preprocessing, feature extraction, image segmentation, and classifier design. The processing flow is shown in Figure 1.

The processing flow of the human-machine interface translation system is one of its processing flows. First, the collection card is used to obtain a video stream through the detection system, so that each frame in the video stream belongs to the processed image; second, the image is grayscaled and the background is removed to get a binarized image, which is then cut to get text and character images; third, extracting the character feature and extracting the word recognition result by the classifier; and fourth, displaying the Chinese term corresponding to the word.

$$\begin{aligned} A_k &= G^{eu_i} M\left(\vartheta_j\right)^{IJ}, \\ JK_M &= FM\left(\lambda_j\right)^{C}, \\ MK &= g^{D+u_i e/F}, \\ G_S &= M^{u_0}. \end{aligned} \tag{1}$$

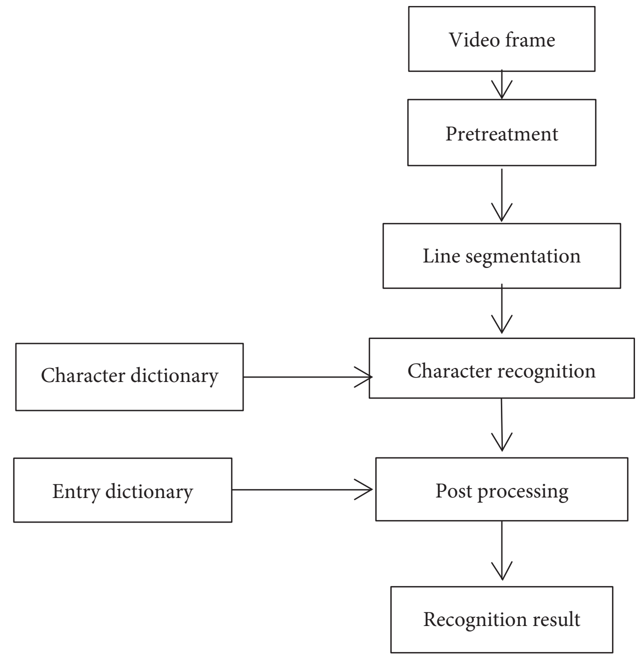


Figure 1: Process flow of the human-machine interface translation system.

$$\begin{aligned} Z_0 &= MX^s e\,(G, M)^{AS} = J\,(G, M)^{AS}, \\ B_1 &= G^{\beta \cdot s}, \\ B_2 &= G^{\delta \cdot s}. \end{aligned} \tag{2}$$

Decoder-end weight sharing can complement each other during model training:

$$\begin{aligned} V_j &= V - \sum_{i=1}^{N-1} \frac{V_i}{p}, \\ R_{i,j,2} &= T + H. \end{aligned} \tag{3}$$

2.1. Pretreatment. Pretreatment refers to the preparation process carried out before the final processing and perfection, which is specifically applied in different industries or fields. Because the content processed by this system is obtained from the detection host interface through the collection card, and there is no distortion, most of the detection programme interfaces are also composed of tables, characters, etc. The contents of the characters are removed to obtain binarized text. The description is based on the regional grayscale difference growth algorithm, and the text is scanned horizontally and vertically, respectively. When the accumulated value is larger than the preset threshold, it is represented as a table line, thereby obtaining a binarized text. Binarization is the simplest method of image segmentation. Binarization can convert grayscale images into binary images. The grayscale of pixels is set greater than a certain critical grayscale value to the maximum grayscale value, and the grayscale of pixel is set less than this value to the minimum grayscale value, so as to achieve binarization.

2.2. Image Segmentation. Image segmentation is the technique and process of dividing an image into a number of specific areas with unique properties and proposing objects of interest. It is a key step from image processing to image analysis. The right segmentation is the only way to get the right goals and implement them effectively. The gap between the lines obtained after the horizontal projection is also a blank line, and the gap threshold is set to realize the division of the character line. But this algorithm is complicated and time-consuming, especially when the calculation amount is too large, it is not suitable for use in this system. Therefore, for overlapping characters, it is possible to implement cutting by using a broken character. The part of the shadow belongs to the overlapping part of the character, which does not cause a cumulative error, and should be fully considered when identifying, so that the recognition accuracy rate is reduced. To make this shaded part, you can extend the shadow part.

$$
\begin{aligned}
&C_{i,j,1} = F^{H},\\
&C_N = C_0, C_1, C_2, \ldots, C_J,\\
&\mathrm{H}_{i,j} \in M_p^{*}\left(1 \le i \le n, 1 \le j \le n_i\right),\\
&T_{i,j} = R^{t_i,j},\\
&P_M = YU,\\
&\mathrm{R} = \left\{\kappa_1, \kappa_2, \kappa_3, \ldots, \kappa_n,\right\}.
\end{aligned}
\tag{4}
$$

2.3. Feature Extraction. Statistical machine translation is the mainstream method of machine translation today. This may be due to many reasons, such as accuracy, scalability, high computational efficiency, and the ability to quickly transplant to new language pairs and domains. The hierarchical phrase translation model is one of the mainstream models of statistical machine translation. This model combines the traditional phrase translation model with a syntactic translation model, which greatly improves the translation performance compared to the traditional phrase translation model. At the same time, analysis errors and system burdens caused by the ability to analyze sequences are avoided.

The extraction process of hierarchical phrase rules includes the extraction of common phrase rules and the extraction of rules containing variables. The most basic condition for extracting a phrase is "alignment consistency." When extracting variable rules, by enumerating all possible combinations in the SPAN range, there are three possibilities, including variables, one variable, and two variables. The rules mainly include source, target, two-way lexical translation probability, and two-way phrase translation probability. The calculation needs to estimate the fraction of each phrase. For rules without variables, the fraction is 1 each time the rule is extracted. For the rule containing variables, the fraction is one of the total number of variables. When calculating the probability of bidirectional phrase translation, fractions are used to calculate. Hence, the project implementation details need to be paid attention. When the number of extracted rules reaches a certain level, you need to output the temporary file and clear the used memory.

The classifier belongs to the core of the recognition system. The feature extraction and classifier settings are all key content. If the feature extraction has certain certainty, the classifier design and capability can be simplified, and the feature extraction is restricted. In order to realize the separability judgement between various types, a variety of criteria are proposed, and the minimum feature dimension is realized to improve the accuracy of classifier classification. The distance between the sample to be used and the end of the benchmark is a function of the classification decision. This classifier is preferred by the employer. According to practice, this is a more intuitive and effective classification.

A single English word is identified by the classifier because classification errors are unavoidable, so the result of the classification is further processed. The process of classifier implementation of classification is mainly to achieve single-character recognition and does not fully use the context information. For the result of repeated character segmentation, the candidate characters are incorporated into the words according to the order of confidence from high to low and then searched from the dictionary. After the search is successful, this is the result of the recognition. If the candidate's character is illegal, then the character is rejected. For words with rejected characters, they are ignored during word search.

In order to improve the translation effect, not only the words should be explained one by one but also the translation of complex, long sentences. Then, based on the actual characteristics, this paper will make a sentence or phrase combination that cannot satisfy the Chinese word order habits as a whole and achieve effective recognition. For shorter sentences, you can also use the above method. However, for longer paragraphs or sentences, such as helper documents, if this type of processing is used, the processing cannot meet the real-time requirements of the system. Then, you can use the sample matching method to achieve full-text matching and finally achieve full-text translation. Among them, the interface of the detection system and the screen change are more frequent in order to realize data collection. In scene development, changes in the collected data generally do not affect the scene detection system, and scene switching will not change too much, which reduces the system burden and improves the interface display effect.

3. Application Status of Intelligent Translation

In recent years, artificial intelligence technology has made great breakthroughs in the direction of speech recognition and language processing. Artificial intelligence has also made new progress in language translation and has been widely used in many fields.

3.1. The Level of Technological Development. In terms of voice technology, in recent years, deep learning artificial intelligence has also made great progress in the direction of language processing, especially in machine translation. In February 2011, IBM's "Watson" system conducted a natural language question and answer in the dangerous edge of a variety show, defeating two human champions, indicating a significant improvement in the computer's natural language processing capabilities. Google has applied the Google Neural Machine Translation (GNMT) system to enable the translation of complete sentences, which is a landmark breakthrough in artificial intelligence in machine translation. Domestic Keda Xunfei, Tencent, NetEase, Baidu, and other companies have also launched free online translation products on machine translation, making great progress in Chinese-English translation. Figure 2 shows the performance of artificial intelligence in natural language processing. Artificial intelligence has also made great progress in the direction of language processing, especially in machine translation. Its accuracy has also been greatly improved, such as Siri, Voice Search, and Echo. A big breakthrough can achieve the exchange of different languages and the

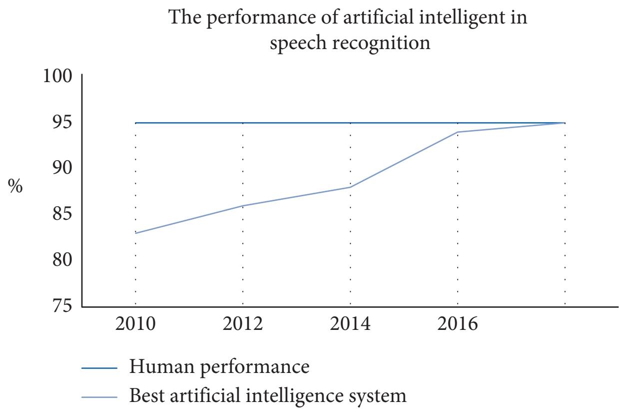


Figure 2: The performance of artificial intelligence in speech recognition.

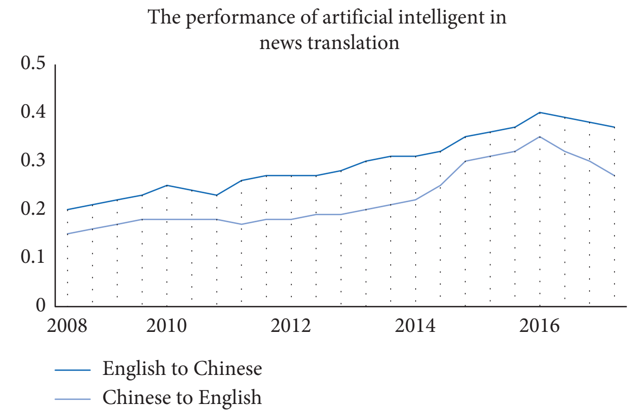


Figure 3: The performance of artificial intelligence in news translation.

conversion of speech to another language to a certain extent. In October 2016, Microsoft Research in the United States achieved significant breakthroughs in speech recognition technology. This is the first time that artificial intelligence speech recognition has been adjacent to humans. It has achieved an error rate of only 5.9 percent across the era. Figure 1 shows the performance of artificial intelligence in speech recognition in 2010 (Figure 2).

Figure 3 shows the performance of artificial intelligence in news translation.

Figures 3 and 4 show the performance of artificial intelligence in sentence translation and news translation, respectively. From Figure 4, the bilingual translation quality of BLEU, an automatic machine evaluation method, can be seen.

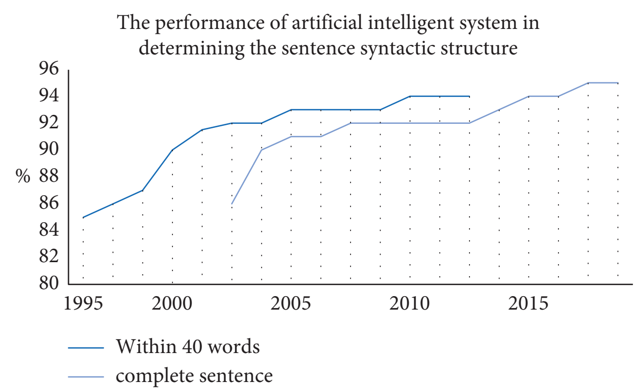


Figure 4: Performance of the artificial intelligence system in determining the sentence syntax structure task.

3.2. Business Applications. Major Internet giants at home and abroad are constantly expanding the market for artificial intelligence translation and developing commercial applications for artificial intelligence translation. In particular, the online translation tools provided by major companies are widely used in the market, and the development of the language translation service market is in full swing. Some companies have shut down the artificial intelligence translation engine due to huge market demand, and instead offer paid translation services.

At the same time, AI translators have become the most popular commercial products for artificial intelligence languages and translations. After Microsoft and Google successively launched their own translation machines, domestic NetEase, Sogou, Tencent, Keda Xunfei, and Split Tower Technology also gradually launched their own translation machines. At present, the AI translator has achieved good sales performance, the market prospect is promising, the function is powerful, and the language translation recognition is more precise and intelligent. Consider Keda Xunfei Company as an example: the company launched the Xunfei Translator 2.0, which not only supports Chinese and English, Japanese, Korean, and other 33 languages for simultaneous translation but also supports Cantonese, Sichuan, Henan, and other dialect translations. At the same time, it also has photo translation and is equipped with 4G, WIFI, offline translation, and other modes, and the English translation level can reach CET-6 level.

4. The Prospect of Intelligent Translation

4.1. Prospects of Artificial Intelligence Translation Technology. Before introducing technologies such as deep learning, artificial intelligence took 50 years to get the machine to have initial intelligence, and in 2006, Professor Jeffrey Sinton of the University of Toronto in Canada proposed the concept of deep learning and applied the technology to make computers. It took 6 years to identify the cat. The Alpha Go Zero software, also developed by deep learning technology, can evolve through self-learning, and it takes only 3 days.

4.2. Prospects for the Application of Artificial Intelligence Translation Market. With the development of the globalization of the world economy and economy, the exchanges between people of all countries have become more frequent and frequent.

4.3. Impact on the Current Artificial Language Translation Market. The range of artificial intelligence has been continuously expanded and strengthened. At present, the market price of Chinese-English translation is 200 yuan for 1,000 words. Within the professional and Chinese-English translation, only 200 yuan is in the early stages. In addition to advanced translation, human translation may be difficult to find a job.

5. Data Source

The sample from this article comes from 13689 basic Chinese and English syntax collected from the Internet. The test set used in this paper is a random extraction of 200 out of 13689 data. The resources used include 167,318 data partition tables, 633 data key tables, and 27 data pattern tables. The recall rate and F value of the word segmentation were tested and compared with ICTCLAS. The results are shown in Table 1.

In this paper, 13689 data are randomly divided into three parts, which are the training set (10166 sentences), the development set (1300 sentences), the test set (2223 sentences), and the training four-dimensional language model using SRILM tools. This paper conducted three sets of experiments. The first group uses ICTCLA to segment words and decode them using a common hierarchical phrase decoding model. The second group decodes it using a generic hierarchical phrase-based decoding model. The third group uses the proposed method and unit division method to decode it. The decoding uses a dictionary-level phrase model and a manual template. The dictionary contains 9555 entries and the manual template contains 495 templates. The BLEU score is used as an evaluation index for translation results. The results are shown in Table 2.

6. Results and Discussion

6.1. Data Analysis. It can be seen from Table 1 that the recall value of ICTCLA is 68.23%, and the recall value of this research method is 95.74%. It can be seen from the above results that the method is more accurate than ICTCLA, and the extraction rules are better, which improves the translation quality and remote sorting ability of sentences.

This article analyzes inaccurate examples of translation and finds that there are mainly the following types of errors:

(1) Different semantic environments

Chinese: White lie
Reference answer: White lie
Translation results: kind lie

(2) Lenovo is different

Chinese: like a duck to water
Reference answer: like a duck to water
Translation results: like fish to water

(3) Differences in aesthetic form

English: you are a lucky dog
Reference answer: you are a lucky one
Translation results: you are a lucky dog

Table 1: Word segmentation module test results.

	Correct rate (%)	Recall value (%)	F value (%)
ICTCLAS	76.40	68.23	72.09
Method of this paper	94.58	95.74	95.15

Table 2: Translation module test results.

	Development set/test set
ICTCLAS	0.7038/0.7132
Method of this paper	0.7444/0.7521
Method + unit division	0.7626/0,7730

Before training, we first need to configure some hyperparameters in the neural network. The main parameters are shown in Table 3.

The model size before and after model memory optimization is calculated. Then, the statistical results before and after optimization are shown in Table 4.

From the data in Table 4, it can be seen that the storage before optimization increases with the increase of the vector dimension, from 4.01 GB to 36.93 GB. The optimal model is chosen to adjust the parameters, so the data set is smaller. The data set is organized as shown in Table 5.

From the data in Table 5, it can be seen that the scale of the training set is 500, the scale of the validation set is 2, and the scale of the test set is 1. Based on the principle of conducting comparative experiments on different network models, in addition to setting the network model as a changing condition, the hardware and software environment and other experimental parameter settings are all set to constant conditions. Some parameter settings are shown in Table 6.

6.2. Intelligent Translation System Results Example. Figure 5 is the home page of the intelligent translation system, in which it automatically detects the Chinese and English locale by default (manually select the desired locale) and enters the statement to be translated in the text box, and the system automatically displays the translation result to the right. In the side frame, manually select the locale and click the desired locale directly, as shown in Figure 6.

Through the English translation in Figure 6, we can observe that the translation system can be accurately placed in the academic sentence translation, so that the system can also be introduced to have good performance in ordinary translation.

In Figure 7, the translation system has translated excerpts from Zhu Ziqing's famous prose “Hurry up”. Taking literary works as the reference of the translation system greatly improves the standards and requirements of the translation system and reflects the translation quality of the system. According to the translation results of Figure 7, the system also has good performance in the middle of the English translation.

Table 3: The main parameters.

Parameter	Parameter meaning
Reload_ = True	Whether to reload the model and save the model at intervals
Dim word = 512	Prevent abnormal programme interruption
dim = 1024	Word vector dimension
Decay_ $c = 0$	Hidden state size

Table 4: Statistical results before and after optimization.

Word vector dimension	Before optimization (GB)	After optimization (GB)
128	4.01	0.16
256	14.03	0.39
512	20.61	0.78
1024	36.93	1.60

Table 5: Organization of the data set.

Data set settings	Scale/thousand lines	Quantity/group
Training set	500	1
Validation set	2	2
Test set	1	1

Table 6: Some parameter settings.

Parameter type	Parameter
Vocabulary size	8000
Word vector dimension	512
Batch size	1024
Number of network layers	6
Dropout	0.2

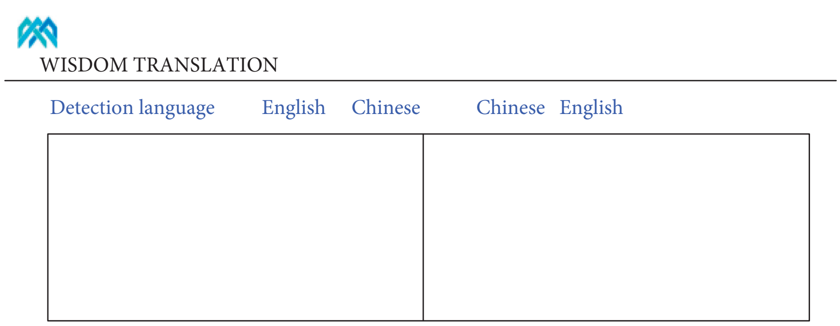


Figure 5: Intelligent translation system home page.

Finally, by example, the system has excellent translation performance and intuitive and accurate translation. In order to further enrich the corpus, it can also provide users with a very convenient interface, which is convenient for users to submit the correct results of their translations to the background administrator for verification. This also follows the idea of translation memory and greatly expands the source of the corpus.

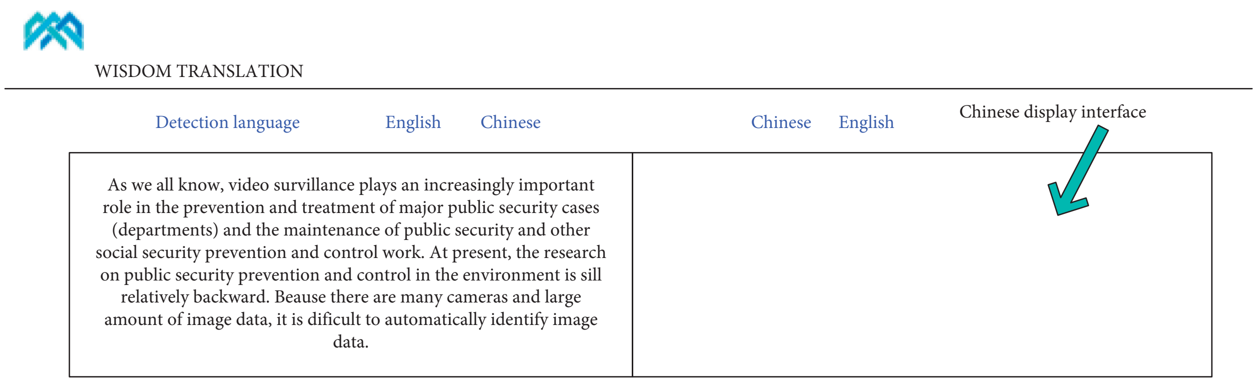


Figure 6: Results shown in the intelligent translation system.

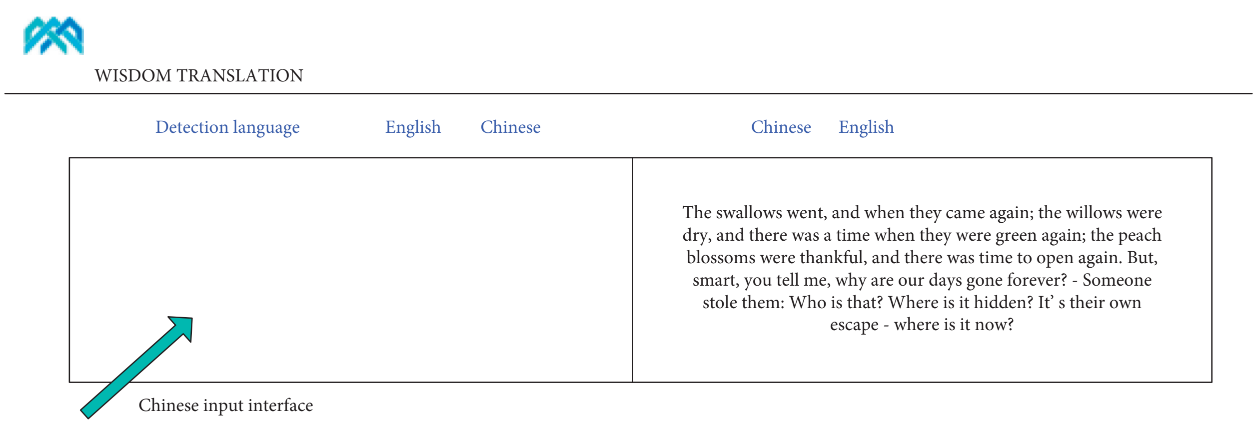


Figure 7: Translation system: translation of Chinese into English.

7. Conclusion

Several major advantages of statistical machine translation, such as no manual intervention and short development cycle, have made this research development very rapid in the past two decades, especially in many specific fields to meet the needs of various social life. Foreign companies such as Google and Microsoft, domestic Baidu, NetEase Youdao, and other Internet companies have provided users with free online multilanguage translation systems [22, 24, 25]. However, each company's main language translation direction is different. For example, Google mainly targets multilingual translation centered on English, and Baidu mainly targets multilingual translation centered on English and Chinese. We cannot deny that machine translation has become more and more important in our lives. At present, in most cases, the results of machine translation are only to help users understand the general meaning of the original text to a certain extent, and the translation results cannot be directly published as a smooth translation. If you want to further obtain a completely correct translation, you still need to professional translators make corrections. With the harmonious development of international relations, exchanges and cooperation projects between countries are increasing. English is one of the commonly used languages in the world. Chinese-English translation is the focus of academic theory research [22, 26–28]. The design of the translation system includes four modules: preprocessing, feature extraction, image segmentation, and classifier design. The feature extraction part is the most important. A small number of translation dictionaries and artificial templates are added to the hierarchical phrase model. Translate the units and then glue the results together in the reverse order to form the final translation [29–31]. Experiments show that the translation system designed in this paper has better performance than the traditional intelligent translation system, and it tries to eliminate differences as much as possible and consider ways to automatically obtain keywords, patterns, and translation dictionaries, extending our existing resources [32, 33].

Data Availability

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

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

This work was supported by the Shandong Province Key Project of Art Science (201706499) and the Shandong Province Culture and Tourism Research Project (21WL(Z) 74).

References

[1] Q. Qi, "Discussion on the influence and suggestion of artificial intelligence on the translation industry," *Modern Trade and Industry*, vol. 40, no. 9, pp. 178-179, 2019.

[2] Y. Wang, "Research on the application status and prospect of artificial intelligence in language service industry," *Southern Review Series*, no. 5, pp. 22-23, 2018.

[3] H. Choi, K. Cho, and Y. Bengio, "Context-dependent word representation for neural machine translation," *Computer Speech & Language*, vol. 45, pp. 149–160, 2017.

[4] F. Zhang, "English machine translation model based on modern intelligent recognition technology," *Modern Electronic Technology*, vol. 41, no. 16, pp. 151–154, 2018.

[5] R. Zhao and D. Tang, "The application advantages of intelligent translation in the context of global economics," *Neijiang Science and Technology*, vol. 39, no. 7, pp. 117-118, 2018.

[6] Liang, "Construction of Liangya auxiliary translation learning system," *Automation and Instrumentation*, no. 8, pp. 142–144, 2018.

[7] X. Lu, *Exploring Artificial Intelligence Translation from the Perspective of Discourse Translation*, Beijing Foreign Studies University, Beijing, China, 2018.

[8] Y. Liu, "Analysis of the application and development of artificial intelligence in the language service industry from the generation of artificial intelligence translation," *China Strategic Emerging Industries*, no. 4, pp. 153-154, 2018.

[9] X. Li, H. Liu, W. Wang, Y. Zheng, H. Lv, and Z. Lv, "Big data analysis of the internet of things in the digital twins of smart city based on deep learning," *Future Generation Computer Systems*, vol. 128, pp. 167–177, 2022.

[10] H. Song and M. Brandt-Pearce, "A 2-D discrete-time model of physical impairments in wavelength-division multiplexing systems," *Journal of Lightwave Technology*, vol. 30, no. 5, pp. 713–726, 2012.

[11] M. Adil, M. K. Khan, M. Jamjoom, and A. Farouk, "MHADBOR: AI-enabled administrative-distance-based opportunistic load balancing scheme for an agriculture internet of things network," *IEEE Micro*, vol. 42, no. 1, pp. 41–50, 2022.

[12] M. Adil, M. A. Jan, S. Mastorakis et al., "Hash-MAC-DSDV: mutual authentication for intelligent IoT-based cyber-physical systems," *IEEE Internet of Things Journal*, 2021.

[13] M. Adil, H. Song, J. Ali et al., "EnhancedAODV: a robust three phase priority-based traffic load balancing scheme for internet of things," *IEEE Internet of Things Journal*, 2021.

[14] F. Zhu, C. Zhang, Z. Zheng, and A. Farouk, "Practical network coding technologies and softwarization in wireless networks," *IEEE Internet of Things Journal*, vol. 8, no. 7, pp. 5211–5218, 2021.

[15] X. Yin, Y. Kang, C. Jin, and J. Du, "Development of man-machine interface for agricultural machinery automatic navigation system," *Agricultural engineering technology*, vol. 38, no. 18, pp. 79–82, 2018.

[16] J. Bao, "Design and development of man-machine interface for electric heating water heater," *Electronic Technology and Software Engineering*, no. 18, pp. 40–42, 2018.

[17] X. Xu, "Research on the development trend of human-machine interface under the guidance of artificial intelligence," *Industrial Design*, no. 2, pp. 137-138, 2019.

[18] W. Lu, R. Tan, G. Liu, and H. Sun, "A small language machine translation algorithm based on semi-supervised learning," *Journal of Xiamen University*, vol. 58, no. 2, pp. 200–208, 2019.

[19] K.-C. Rim, P.-K. Kim, H. Ko, K. Bae, and T.-G. Kwon, "Restoration of dimensions for ancient drawing recognition," *Electronics*, vol. 10, no. 18, 2021.

[20] Y. Jiang, K.-K. R. Choo, and H. Ko, "A special section on deep & advanced machine learning approaches for human behavior analysis," *Journal of information processing systems*, vol. 17, no. 2, pp. 334–336, 2021.

[21] S. N. Alsubari, S. N. Deshmukh, A. A. Alqarni, and N. Alsharif, "Data analytics for the identification of fake reviews using supervised learning," *CMC-Computers, Materials & Continua*, vol. 70, no. 2, pp. 3189–3204, 2022.

[22] H. Zhu, H. wei, B. Li, X. Yuan, and N. Kehtarnavaz, "Real-time moving object detection in high resolution video sensing," *Sensors*, vol. 20, no. 12, 2020.

[23] J. Zhou, "Research on simultaneous interpretation based on C#," *Modern Business and Trade*, vol. 40, no. 12, pp. 182-183, 2019.

[24] M. Chinea-Rios, G. Sanchis-Trilles, and F. Casacuberta, "Vector sentences representation for data selection in statisticalmachine translation," *Computer Speech & Language*, vol. 56, 2019.

[25] M. Esplà-Gomis, F. Sánchez-Martínez, and M. L. Forcada, "Predicting insertion positions in word-level machine translation quality estimation," *Applied Soft Computing*, vol. 76, pp. 174–192, 2019.

[26] W. Li, C. Ji, X. Ning, D. Li, and G. Mei, "Research on intelligent translation algorithm of German compound words based on machine learning," *Electronic world*, no. 5, pp. 62–65, 2019.

[27] G. Xiao, Q. Cheng, and C. Zhang, "Detecting travel modes using rule-based classification system and Gaussian process classifier," *IEEE Access*, vol. 7, Article ID 116741, 2019.

[28] Y. Li, Y. Zuo, H. Song, and Z. Lv, "Deep learning in security of internet of things," *IEEE Internet of Things Journal*, no. 99, p. 1, 2021.

[29] Y. Bi and B. Jiang, "Research on the calculation method of Korean sentence structure similarity," *Chinese Journal of Information Science*, vol. 33, no. 3, pp. 59–63+101, 2019.

[30] D. Banik, A. Ekbal, P. Bhattacharyya, and S. Bhattacharyya, "Assembling translations from multi-engine machine translation outputs," *Applied Soft Computing Journal*, vol. 78, pp. 230–239, 2019.

[31] W. Zhang, "The principles and methods of Chinese and English lyrics translation under the difference of Chinese and western cultures," *Education Modernization*, vol. 5, no. 5, pp. 308-309+316, 2018.

[32] F. Tan, "Analysis of the processing of cultural imagery in Chinese-English idioms translation," *Art Science and Technology*, vol. 30, no. 9, 2017.

[33] X. Wang, X. Wang, and H. Ma, "Chinese-English translation problems and countermeasures of propaganda materials," *Science and Technology*, no. 36, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 7207372, 12 pages
https://doi.org/10.1155/2022/7207372

Research Article

Application of Rough Concept Lattice Model in Construction of Ontology and Semantic Annotation in Semantic Web of Things

Hongsheng Xu [1,2] and Huijuan Sun [3]

[1]College of Electronic Commerce, Luoyang Normal University, Luoyang 471934, Henan, China
[2]Henan Key Laboratory for Big Data Processing & Analytics of Electronic Commerce, Luoyang Normal University, Luoyang 471934, Henan, China
[3]College of Computer and Information Technology, Henan Finance University, Zhengzhou 410046, Henan, China

Correspondence should be addressed to Hongsheng Xu; xhsls@lynu.edu.cn

Received 30 December 2021; Accepted 25 January 2022; Published 13 April 2022

Academic Editor: Ahmed Farouk

In order to solve the problem of interoperability in Internet of Things, the Semantic Web technology is introduced into the Internet of Things to form Semantic Web of Things. Ontology construction is the core of Semantic Web of Things. Firstly, this paper analyzes the shortcomings of ontology construction methods in the Semantic Web of Things. Then, this paper proposes construction of semantic ontology based on improved rough concept lattice, which provides theoretical basis for semantic annotation of the sensing data attributes. In addition, this paper describes the semantic annotation system for the Internet of Things based on semantic similarity of ontology. The system consists of three steps: ontology mapping integration module, information extraction module, and semantic annotation of sensing data. Finally, the experimental results show that this semantic annotation method effectively improves the flexibility of sensor information and data attributes and effectively enhances the expression ability of sensor information and the use value of data.

1. Introduction

In recent years, data in the Internet of Things exist in a heterogeneous and decentralized structure. In order to solve the problems of interoperability and intelligence in the Internet of Things system, Semantic Web technology is introduced into the Internet of Things, forming the Semantic Web of Things. However, the diversity of objects and the limitedness of subjects constitute the inherent contradiction of the Internet of Things. In order to solve these defects, the semantic annotation method based on ontology is introduced. This novel method enables web services, agents, and machines to understand sensory information. In a word, this approach can substantially improve the function of the Internet of Things.

With the development of the Internet of Things technology, the information collected by the Internet of Things presents the characteristics of mass, heterogeneity, and diversity. Perception data in wireless sensors are not only heterogeneous in location, structure, and routing protocol but also diverse in data format, storage method, and attribute description [1]. This heterogeneity mainly hinders the integration and fusion of data among different domains and also increases the difficulty of data processing and application development among cross-regions. Finally, it is difficult to realize the interaction and collaboration of resources and data.

As the foundation of Semantic Web of Things, construction of sensor ontology has become the key to research. Sensor ontology can add semantics to raw sensor data, enrich sensor information, and enable machines to understand the meaning of sensor data and make intelligent decisions. Therefore, ontology construction is the core work in Semantic Web of Things. Also, ontology is the basis of semantic annotation in Semantic Web of Things.

Semantic annotation is to provide additional descriptive information to a resource and then find (potential) similarities between ontologies. Using ontology mapping technology mainly calculates the similarity between two ontology element pairs, and the similarity between elements is related to ontology definition, ontology instance, and ontology rules or constraints. Finally, the state of the sensor and the changing trend of the state can be reflected in detail and accurately [2]. The authors have organized and developed the SSN ontology for the heterogeneity of the current device. Here, the semantic description of the sensing device improves the interoperability between the sensing devices at the semantic level [3]. The authors propose a service-oriented sensor ontology while simultaneously describing an adaptive sensor network based on ontology [4]. The traditional concept lattice construction method based on rough set is not suitable for construction ontologies [5].

The Semantic Web of Things system is divided into three layers: perception layer, network layer, and application layer. The research contents of perception layer semantic interoperability mainly include construction of the core ontology in the Semantic Web of Things, establishment of semantic middleware, and the semantic annotation of sensory collected information. The research contents of network layer semantic interoperability mainly include composition of semantic sensor web, the network transmission based on ubiquitous web, and application of Semantic Web technology [6]. The research contents of application layer semantic interoperability mainly include combined application of ontology, semantic combination of sensor data, semantic reasoning of information, and semantic analysis of information.

These ontologies lack descriptions of implicit concepts, specific system characteristics, and emerging concepts in the domain. At the same time, these ontologies cannot be directly used in specific Internet of Things systems. Therefore, studying the automatic construction technology of sensor ontology is an important task of this paper. The paper proposes building ontology of Semantic Web of Things based on the improved rough concept lattice model.

In order to effectively improve the flexibility of attribute description in perception information and enhance the sensor analysis capability and use value of collected information, this paper proposes an automatic annotation method for sensor data based on ontology technology. This method can accurately reflect the location and state changes of sensing entities and promote the realization of cross-domain heterogeneous resource interaction and data sharing in Semantic Web of Things. The semantic description of the sensing information attributes is made explicit and unified by the sensor ontology. The rough concept lattice isomorphism model is used to construct the semantic ontology architecture of the sensing data. The hierarchy analysis of ontology semantics is carried out based on concept lattice and variable precision rough sets, and finally the semantic annotation framework in the Semantic Web of Things is formed. Finally, it is proved by experiments that this semantic annotation method effectively improves the flexibility of sensing information and data attributes and effectively enhances the expressive ability of sensing information and the use value of data.

2. Using Semantic Rough Concept Lattice Model to Building Ontology of Semantic Web of Things

With the development of Semantic Web technology, it provides a better solution to the Internet of Things problem. As the core of the Semantic Web, ontology is an explicit specification of a conceptual model. The goal of an ontology is to describe related domain knowledge, provide a common unambiguous understanding of the domain knowledge, and formally give a clear definition of the interrelationships between concepts. Ontology provides support for the massive and heterogeneous resource search and development of the Semantics Web of Things.

At present, the most famous construction of the sensor ontology is that the World Wide Web Consortium has developed the SSN-XG project [7]. Generic sensor ontology (SSN) describes sensors and observations in terms of capabilities, measurement processes, observations, and distributions. This ontology is used to add some semantic information to sensor data and to find information related to sensor data. The sensor ontology is built based on the general sensor ontology and can annotate the sensor data in JSON format. Ontology also has some specific concepts that can improve the adaptability of the system. The ontology is mainly a description of the sensor system, sensor components, and observation process.

Definition 1. Domain knowledge space: ontology O is defined as two tuple $<B, R>$, where B is the concept set in the domain O and R is the relationship set of the concepts in the domain space. Class: a description of objects with common attributes and features. Class example is the description of the class, a is for the class, and b is an example of B recorded as shown by

$$B = B - a_i. \tag{1}$$

Ontology mainly includes the contents of concepts, attributes, instances, and axioms, with four tuple $O = (C, R, I, P)$, where C is set of concepts or classes (it is used to describe resources abstracted and classified); R represents a collection of relations between concepts (it is used to describe the various relationships between concepts, including the hierarchical relationship, logical relationship, relational operations, and dependence); I denotes the set of the concept instance; and P is used to describe the specific object and individual. A representation of the axiom set is used to describe a tautology proposition by efficient and consistent detection.

Definition 2 (see [8]). HTC is a partially ordered set (x, y), where C is a finite set of concepts, and it is a partial order on H. General relation is a generalized relations describing the concept of the relationship between the father and the son, equivalent to the subclass of relationship. Senior parent object with low subobject features is shown by equation (2), and subobjects inherit all the attributes and characteristics of the parent object.

$$b^* = y_1\left(1 - \frac{\alpha_i^j}{C}\right) - \sum_{i=1}^{P} y_i \alpha_i^* K\left(x_i, x_j\right). \tag{2}$$

The ontology development process is divided into the following stages: (1) specification; (2) recognition ontology development; (3) predetermined user; (4) application environment; (5) formal; and (6) description scope. Ontology describes the scope including the vocabulary, characteristics, and granularity.

Theorem 1. *The intersection between the direct subclasses of the class is null. That is, C_l, C_2 are C direct subclasses, and suppose C_2 is up to C_1. The disjoint principle of subclass guarantees that a subclass is a disjoint decomposition of the superclass.*

Ontology is constructed by ontology mapping. The mapping between ontologies is realized by two kinds of mapping functions: one is that the mapping does not change the concept of the ontology; the other is that the mapping changes the concept of the ontology and explains the change.

Perception data are heterogeneous not only in attributes and communication protocols but also in terms of data format and attribute description. Due to the lack of a certain structure, it is necessary for machines to automatically understand unstructured data and extract the required knowledge from it. It must be preprocessed using natural language processing (NLP) techniques. This paper mainly uses formal concept analysis technique to construct the sensor ontology from the unstructured data.

If a decision table $S = (U, A, V, f)$, $A = C \cup D$ is a set of attributes, V is a collection of attribute values, f is the information function, and $D = \{d_1, d_2, \ldots, D_n\}$, then the decision table can be decomposed into n different decision-making single decision table $\{S_1, S_2, \ldots, S_n\}$, in which, $Si=(U,Ai,Vi,fi)$ is the domain table, U is the discourse domain, $Ai = C \cup \{di\}$ is the attribute set, V is the set of attribute values, respectively, C is called the condition attribute set, and $\{di\}$ is the decision attribute set..

Theorem 2. *Given decision table $S = (U, C \cup D, V, f)$, $\beta = \left\{\beta(X_i, Y_j) | 0 < i \leq |U/C|, 0 < j \leq |U/D|, \beta(X_i, Y_j) > 0.5\right\}$, if only one repeated element in β is retained and arranged in ascending order as $\beta = \{\beta_1, \beta_2, \ldots, \beta_k\}$, $1 \leq k \leq |U/C| * |U/D|$, so $\gamma(C, D, \beta_1) > \gamma(C, D, \beta_2) > \ldots > \gamma(C, D, \beta_k)$ [5].*

Therefore, the concept lattice method can help to construct ontology, which provides a way to guide the construction of ontology.

Concept lattice and variable precision rough set theory are closely linked; the rough set theory and concept lattice are combined into a rough concept lattice model, and it first analyzes the relationship between rough set and concept lattice. In this paper, the reduction idea of β-upper and lower distributions in variable precision rough sets is applied to the reduction of formal context. Therefore, this paper proposes a concept lattice construction model based on variable precision rough set. Firstly, the definition of positive and negative fields between attribute sets is improved, and the variable precision rough set model is expanded according to the idea of maximum intersection. Then, this paper combines the β value selection method to improve the approximate knowledge reduction algorithm based on variable precision rough set theory.

The concept lattice construction algorithm is combined with the improved rule acquisition algorithm of variable precision rough set, and the final construction algorithm of semantic rough concept lattice is as follows.

Then, this paper uses variable precision rough sets to reduce the formal context by selecting appropriate β values, in order to reduce redundant objects and noise. Based on the reduced formal context, the sensor ontology is constructed by using the rough concept lattice technique [9].

The ontology model constructed by using the improved rough concept lattice is mainly embodied in the concept of hierarchy.

Definition 3. For two ontology sequences m, $s_1 = <a_1 \ldots A_r>$ and m_k, $s_2 = <m_1 \ldots m_k>$, if there is a function, $j_1 < j_2 < \ldots V < j_{r-1} < j_r$, making $j_1, A_1, a_1, \ldots, A_R, M_{JR}$, then S1 is called sub ontology of S2, or called S2 contains S1, and both S2 and S1 are in the same ontology, abbreviated as is shown by equation (3) [3].

$$\overline{m} = \frac{1}{N}\sum_{k=1}^{N} m_k,$$
$$S_1 = \sqrt{\frac{1}{N}\sum_{k=1}^{N}\left(m_k - \overline{m}_k\right)^2}. \tag{3}$$

Construction of domain ontology includes 7 steps. The first step is to determine the professional field and category of the ontology. The second step is to examine the possibility of reusing existing ontology. The third step is to list the important terms in the ontology. The fourth step is to define the class and the class hierarchy. The fifth step is to define the properties of the class. The sixth step is to define the facets of the attribute. The seventh step is to create an instance.

The construction steps of domain ontology in Semantic Web are as follows:

(1) Start with an empty resource and identity data collection.

(2) Add the equipment and identification data to the formal context as needed.

(3) Construct the rough concept lattice corresponding to the formal context.

(4) Edit directly according to the needs of the ontology.

(5) Edit the ontology prompted by the program.

(6) RFCA can generate new objects, which are directly composed of attributes.

(7) The whole process can be repeated continuously until the sensor ontology in OWL format is finally output.

Input: decision table $S=(U, C\cup D)$, from the data sheet of the new lattice nodes, and update the lattice nodes.
Output: the updated L and context $(X, \{x^*\}, D, R)$ rough concept lattice semantic structure.
Step 1: variable precision can be identified by the definition of matrix calculation information decision system C, DS = <U, D, V, f>, the formation of a recognizable matrix $M=[m_{ij}]$.
Step 2: execution of all the condition attributes in the decision table: if $\gamma^{\beta}(C,D)=\gamma^{\beta}(C-\{a_i\},D)$, then $B=B-a_i$;
Step 3: for ($k=1$; $k\le n$; k++) $\mathrm{USC}_k=\{\ d_k\ \}$;
Step 4: add a new lattice node C new= (Extent (C_1), $\{x^*\}$);
Step 5: attribute$\{c_j\}(j=1,2,\ldots,|C|)$, added to the attribute set, that is, $R_1=\{c_j\}$;
Step 6: simplified discernible matrix. The parameters of the simplified discernible matrix include R_i, $\triangle\gamma^{\beta}_{P\cup C}$, c_j. $R_i=R_{i-1}\cup\{c_j\}\longrightarrow\min(\triangle\gamma^{\beta}_{P\cup C}(R_{i-1}\cup\{c_j\},D)), c_j\in C-R_i$;
Step 7: take out all the updated lattice nodes, and according to the contents of the elements number from small to large order, return to the collection COLL3;
Step 8: calculate and arrange the attribute set P, in order to add the reduction set. Go to step 5;
Step 9: [Is $|X_j\cap Y|/|X_j|>1-\beta$]; if yes, then $X_j\cup R\longrightarrow R$; otherwise, go to step 6 to check the next X_j;
Step 10: find C_k subnode set CHD (C_k), according to the number of elements from small to large order;
Step 11: for ($C_p\in$ CHD (C_k))
[Increase] Set $i=i+1$, $j\longleftarrow 1$, go to step 2;
Step 12: final reduction of output L;

Algorithm 1: Construction algorithm of concept lattice based on semantic variable precision rough set.

2.1. The Construction Strategy of Sensor Ontology Based on Rough Concept Lattice Model.

Step 1: convert the sensor-perceived data and the sensor's own identification into two-dimensional text information according to the principle of RFID.

Step 2: form context is extracted from unstructured text information. Due to the lack of a certain structure, the natural language processing technology is used to automatically understand and extract the required knowledge tuples, and the concept lattice formalization technology is used to preprocess them.

Step 3: the formal context is reduced by using the rough concept lattice model, and the redundant objects and noise are reduced by selecting appropriate thresholds. Aiming at the reduced formal context, the rough concept lattice model is used to construct the unit ontology, and finally the domain sensor ontology is generated according to the top-level SSN ontology.

This paper uses the improved rough concept lattice method to generate sensor ontology. Combined with expert knowledge of Internet of Things, the domain sensor ontology is extracted and generated semi-automatically through the top-level SSN ontology.

The core idea of improving rough concept lattice model is to first preprocess the formal context of the domain. Then, the strong ability of variable precision rough set in terms of attribute reduction is used for the reduction of the concept lattice. The number of nodes of construction concept lattice is greatly reduced, and the system robustness and noise resistance are effectively enhanced.

3. Novel Model of Semantic Annotation in Semantic Web of Things

With development and application of Semantic Web technology, it provides a better solution to the problem of semantic annotation. Semantic annotation is a key technology to solve the information interaction between heterogeneous and distributed ontologies. Semantic annotation will be built on countless small ontologies, and a large number of small ontologies are usually heterogeneous. This will result in frequent operations for heterogeneous ontologies in the process of using semantic information. Semantic annotation technology can promote the realization of cross-domain heterogeneous resource interaction and collaboration in Internet of Things [10].

With the usual semantic annotation system, construction of ontology is also included in the system. By using rule template and clustering methods from text, ontology construction can produce the clustering results as a concept and relationship advice provided to experts in the field.

Semantic perception layer is semantic interoperability; semantic ontology in W3C has been created not only for the sensor itself but also for providing a structured descriptive information for sensor measurements. It can eliminate the heterogeneity of devices. Semantic ontology for the emergence of new equipment is described by the RFID label. A shared ontology is to realize the semantic multi-domain ontology interoperability; although the shared ontology can contain multiple fields, the storage and management of large ontology are difficult [11]. Sensor data are annotated in LOD application, and it is the field of intelligent ontology, as is shown by the following equation [12]:

$$L=\sum_i\sum_j np_{ij}=0p_{00}+1p_{01}+1p_{10}+2p_{11}+2p_{b1}=\frac{4\rho+5\rho^2}{H}. \tag{4}$$

In order to accurately and reasonably find similar concepts during semantic annotation, it is necessary to study the calculation method of similarity [13]. In the field of cognitive psychology, similarity is the psychological proximity between two or more mental representations. In practical applications, it is often necessary to give the degree of similarity between terms, vocabulary, and concepts from a quantitative point of view. Semantic similarity is a similarity indicator by using a quantitative representation. In recent years, scholars have proposed methods for calculating concept similarity from different theoretical perspectives. The information-based method is based on information theory and describes the similarity between concepts by calculating the information content (IC) of shared information between concepts. The method is divided into corpus-based method and ontology internal feature-based method according to the knowledge source.

The former calculates the IC value by calculating the probability that two concepts occur simultaneously in the corpus. But this method relies on a highly annotated corpus, which is difficult to obtain. In order to find similar concepts accurately and quickly during semantic annotation, feature-based methods and information-based methods are combined to extract features from the classification structure of ontology. This paper proposes an efficient, simple, and reliable method for calculating semantic similarity. This method can be used in single-ontology and multi-ontology contexts and is a context-sensitive semantic similarity calculation method. Let scene $K = (C_{\text{int}}, R)$, and the scene-related feature set of concept c is defined as

$$D_H(A, B) = \max\left\{\sup_{x\in A}\inf_{y\in B} d(x, y), \sup_{y\in B}\inf_{x\in A} d(x, y)\right\}. \tag{5}$$

Definition 4. If (β) is a posit, B, C, and D are elements in M. Then, the set $[b, C]$: $C = \{X \text{ in } M\,|b, x\}$ is defined by interval, and set $a = \{X \text{ in } M\,|x$ called ideal, principal ideal, ensemble $(\beta)\}$, $\beta = \{x = \text{epsilon } m\,|x$ said principal filter$\}$. Also, $P < C$ and $[P, C] = \{P, C\}$, as shown by

$$\beta^{P\cup C}: \left(\beta_{1,1}^{P\cup C}, \beta_{1,2}^{P\cup C}\right], \left(\beta_{2,1}^{P\cup C}, \beta_{2,2}^{P\cup C}\right], \ldots, \left(\beta^{P\cup C}_{|\beta^{P\cup C}|,1}, \beta^{P\cup C}_{|\beta^{P\cup C}|,2}\right]. \tag{6}$$

Definition 5. The classification feature set of concept c in ontology $O = \langle C, R\rangle$ is defined as $x \leq y \Leftarrow \varphi x \leq \varphi y$, $O(c) = \{c \mid c \in P,\ P \in \text{hype\_paths}(c)\}$.

Definition 6. From the viewpoint of ontologies $P_1, P_2, \ldots, P_n$, the steps to get the middle layer of P_n are as follows: on the $P_1, P_2, \ldots, P_n$ in the ontology, the operation of the middle layer to operate the ontology map ρ, and the $P_1, P_2, \ldots, I_n, \ldots, P_n$, the relationship between the concepts of the heuristic rules is added to the $x \leq y \Leftarrow \varphi x \leq \varphi y$, as shown by

$$p_0 = \left(1 + \frac{\rho}{1!} + \frac{\rho^2}{2!} + \cdots + \frac{\rho^k}{k!} + \cdots \frac{\rho^n}{n!}\right)^{-1}. \tag{7}$$

The similarity calculation problem based on semantic features and information content in the Semantic Web of Things is as follows. (1) How to organically combine feature-based methods and information-based methods to construct a composite similarity algorithm. (2) Research how to extract low-cost ontology classification structures as attribute feature sets. (3) Using the information content of concepts in the ontology to assign weights to features, how to solve the problem of inconsistent granularity between ontologies.

Definition 7 (see [4]). On the basis of the sensor model in Internet of Things, the support of the jump edge is increased. Given observation data sequence $(X_1, X_2, \ldots, X_n)$ is shown by equation (8), R stands for relationship between sequence $R(R_1, R_2, \ldots, R_N)$. Let $\beta(t) = b(\text{t})$, and $X(t)$ is defined by a set of transfer characteristics $(y, y, x) = \{f_m(I, Y_i, y_{i-1}, x)\}$ and $b_i(t)$ defines a set of state features $H(Y \text{ in } X) = \{(I, Y_\text{i}, x)\}$.

$$\begin{cases} x_0^1(t) = \left(1 - c^1(t)\right) f^1(t), \\ x_1^1(t+1) = \beta^1(t) \displaystyle\sum_{i=i_1}^{i_2} b_i^1(t)^* x_i^1(t), \\ x_{i+1}^1(t+1) = \left(1 - d_i^1(t)\right) x_i^1(t). \end{cases} \tag{8}$$

Aiming at the semantic annotation method of sensor data attributes in the Internet of Things, a data attribute annotation method based on Semantic Web technology is mainly proposed. By semantically describing the data attributes in the hierarchical structure of ontology, the data attributes are extracted from the relational database, so that the data attributes exist independently of specific applications.

4. Methods of Ontology Construction and Semantic Annotation in Semantic Web of Things by Semantic Rough Concept Lattice Model

This paper mainly studies the ontology construction, semantic annotation, and semantic similarity calculation in the Semantic Web of Things. This paper explores the automatic construction of sensor ontology in Semantic Web of Things. Due to the large amount and complexity of sensor information, this paper performs semantic annotation and classification analysis on sensor data.

Semantic similarity calculation methods based on ontology are analyzed and improved in Semantic Web of Things. It is very necessary to explore a similarity calculation method based on features in Internet of Things [15].

This paper first perceives and acquires a large amount of raw data and then constructs data resources with semantic structure information. Also, rule base in the perception layer is generated. The function of extracting named entities is completed from the input sensor information resources. Semantic annotation of sensor sampling is carried out by using the semantic construction hierarchy analysis of sensor ontology. The sensor data are semantically annotated by adopting the ontology segment with the highest correlation based on features and information content.

Based on this, this paper proposes a rough concept lattice model to solve the problem:

(A) Preprocess sensing information sources in the Internet of Things and extract knowledge tuples from sensing information sources.

(B) Calculate the semantic similarity of concepts and relationships in the knowledge tuple set, merge similar concepts, and use the rough concept lattice model to generate an initialization ontology.

(C) According to the top-level SSN ontology, the sensing concept, importance relationship, and Boolean relations in the ontology are initialized to form hierarchical sensor ontology.

In this paper, the TF*IDF method in probability statistics is used to obtain symbolic data representing equipment and resources. The specific method is calculating the frequency of the concept vocabulary in the RFID tag of the device. If the frequency is greater than 10 percent of the specified threshold, it is taken as the data in the device. Then, for the found conceptual data, a binary relation table of resources and identifiers is formed in combination with the corresponding resource sets. The concept node in it should be an important vocabulary that can represent the sensory information. The correlation between the concepts in the ontology is calculated according to the following method, so as to express the strong and weak relationship between the concepts, as is shown by equation (9). Equation (9) describes the degree of association between two words and its directionality.

$$f_{jk} = \text{relevancy}\left(T_j, T_k\right) = \frac{\sum_{i=1}^{n} \mathrm{d}_{ijk}}{\sum_{i=1}^{n} \mathrm{d}_{ij}} \times \text{weighting factor}\left(T_k\right). \quad (9)$$

4.1. Ontology Construction Model in Semantic Web of Things. A detailed description of the technical route for the construction of sensor ontology is as follows.

4.1.1. Extraction of Semantic Information Context. This paper discusses construction strategy of sensor ontology based on rough concept lattice model by combining the characteristics of sensor information in the Semantic Web of Things. This provides a solution for the automatic construction of ontology in Semantic Web of Things. This paper firstly uses natural language understanding and RDF technology to preprocess the collected sensor data and RFID tags. In this way, knowledge tuples of resources and devices are obtained.

Theorem 3. *For decision table $S = (U, C, D, f)$, based on the condition of dividing the mind: $U/RC = \{X_1, X_2, X_n\}$, and based on split decision remember $U/RD = \{D_1, D_2, D_M\}$, an information matrix of sensor ontology is shown by.*

$$u_c^{\beta} = \frac{\sum_{i=1}^{n} \left|T_i^{\beta}\right|}{|U|},$$
$$K\left(X_i\right) = \max_{j \le m}\left\{D\left(\frac{D_j}{X_i}\right)\right\}. \quad (10)$$

In the research on construction of sensor ontology in Semantic Web of Things, it is time-consuming and error-prone to manually construct ontology. In this paper, the improved rough concept lattice model is used to construct the sensor ontology. Therefore, it mainly reflects the hierarchical structure between sensing concepts. By calculating the TF*IDF value of each word, words with a high relevance to the sensing resources can be screened out. Usually, the last ten percent of words are deleted and the calculation is repeated until the set minimum number of words. Finally, a vocabulary set is formed.

4.1.2. Construction of Sensor Ontology Based on the Improved Rough Concept Lattice Model

(1) Improved Concept Lattice Model. In this paper, an improved upper and lower distribution attribute reduction algorithm based on variable precision rough sets is used to reduce the formal context [16]. By improving the method of calculating identifiable matrices, the algorithm is suitable for both compatible decision tables and incompatible decision tables. On the basis of not changing the lattice structure, the number of objects and attributes is reduced, the time complexity of constructing the concept lattice is reduced, and its covering ability and generalization ability are increased.

(2) Using the Improved Rough Concept Lattice Model to Generate the Unit Ontology. By choosing appropriate β values, the formal context is reduced by using variable precision rough sets. The purpose is to reduce unwanted objects and noise. Aiming at the reduced formal context, the rough concept lattice technique is used to construct the unit ontology. The specific method of constructing ontology with RFCA is as follows:

Step 1: calculate $C_1{:}\ = (A_1, B_1) \in \varpi(K_1)$, $C_2{:}\ = (A_2, B_2) \in \varpi(K_2)$, $\varphi(C_1) = \varphi(C_2) \Rightarrow C_1 = C_2$.

Step 2: equivalence class $X_i = U|C_i$ $(i = 1, 2, \ldots, n)$; for each condition attribute, calculate the value of β ($\beta \in (0.5, C]$) to approximate quality of classification β in $Y = U|D$ $(i = 1, 2, \ldots, N)$.

Step 3: when the current is y and the current sequence position is i, the proposed algorithm can obtain the optimal tag sequence of the current location, and j is not normalized probability value. Its recursive form is as follows:

$$d_{ij} = tf_{ij} \times \log_{10}\left(\frac{N}{df_j} \times w_j\right). \quad (11)$$

Step 4: the N (*N-gram*) method is applied to segment of the sentence, and the sentence is approximately matched with the words in the annotation vocabulary list. When the match is successful, annotate the corresponding type and adjust the result of the sentence segmentation to ensure that the word has been annotated by the type of the word..

Step 5: If (i==n) set $|L|/|U| \longrightarrow v$;

then the algorithm is completed by the measure of classification quality;

else go to Step 4;

Step 6: RFCA can generate new objects, which are directly made up of properties.

Step 7: while $||L_k|| > 1$ do $L_{k+1} := \varnothing$;

Step 8: the whole process can be repeated until the designer is satisfied.

Finally, the rough concept lattice is converted into the corresponding sensor ontology. The method here is to use the partial order method to represent the formed formal concept with resource attributes. Also, we only make the attribute appear once in the concept lattice when we annotate it. The key elements described by the sensor ontology are device attributes and the relationship between attributes. In this way, the sensor ontology is constructed.

4.1.3. Mapping of Ontology in the Semantic Web of Things. The concept lattice and variable precision rough set theory are used in the process of ontology mapping. This model comprehensively considers the multi-strategy model of feature information and structural information and constitutes a multi-strategy ontology mapping model. With the help of WordNet, the calculation method of concept similarity is adopted to calculate the similarity of attribute concepts between ontologies. Finally, the attribute mapping set of the unit ontology is obtained.

In order to get the data in Internet of Things, a network model of concept correlation is usually established [17]. At the same time, these words have higher TF*IDF value. The product of TF and IDF is a numerical representation of the association degree between words and resources. TF (term frequency) represents the number of times a word appears in the resource. IDF stands for the specificity of a vocabulary for a particular resource. DF (w) represents the total number of resources in which vocabulary w exists. The IDF is calculated by the following equation, where N refers to the total number of resources. The value of IDF (w) indicates the resource discrimination ability of the vocabulary w.

$$IDF(w) = \log \frac{N}{DF(w)} + 1. \tag{12}$$

4.2. Sensing Data Semantic Annotation Framework for Semantic Web of Things. This paper firstly collects sensor web data and adds domain-specific classes and concepts to it with the help of SSN ontology. The semantic sensor data are formed by preprocessing, and the ontology described in OWL is converted into the form of RDF triples. Concept classes, instances, attributes, and relationships are stored in the database according to different predicates in the triples.

The semantic annotation system is based on the rough concept lattice model. This paper proposes a semantic annotation system based on multi-ontology for sensor data in the Internet of Things, and this system contains three key technologies: (1) ontology mapping integration technology; (2) information extraction technology; and (3) semantic annotation method.

4.2.1. Ontology Mapping Integration. This paper adopts the ontology integration technology to deal with the heterogeneous problem between multiple ontologies. Ontology integration is to complete the process of ontology merging based on ontology mapping. After the analysis of the merged ontology, the paper generates the parse files and then uses the rules to generate the regular files, which are stored in the rule base. Ontology mapping is based on the similarity of the method: this method calculates the similarity between nodes from a grammar or semantic point of view, and it uses the similarity value to determine the mapping. The ontology mapping framework based on similarity calculation is divided into the following steps:

Step 1: domain experts specify the mapping relationship among ontology concepts before automatic mapping.

Step 2: select a set of relational concepts (parent-child relations) as a candidate concept set. There exist a lot of semantic relations among ontology concepts. For a given pair of concept mappings, the ontology concepts that have a semantic relationship with them are likely to also have a mapping relationship.

Step 3: calculate concept similarity in candidate concept set.

Step 4: before calculating the similarity of concept names, it is necessary to restore the abbreviations in the names according to the domain vocabulary. Then, the similarity degree of concept names is calculated by using edit distance.

Step 5: semantic similarity calculation is based on weighted measurement.

Step 6: since Semantic Web of Things needs to analyze the sensing data collected by different sensors, it is necessary to add weights according to the physical location. It mainly comes from the sampling degree of the sensor to the real object. This paper proposes a similarity measurement method based on weighted measurement. According to all the attributes (I_1, I_2) of the sensor data E_1 and E_2, a Cartesian product is made. So, $p\ (I_1, I_2) = \{<a_1, b_2> \ldots < a_n, b_n>\}$, and two groups of similarity calculation:

$$p(I_1, I_2) = \{\{\langle a_1, b_1\rangle \cdots \langle a_n, b_n\rangle\} | a_h \in I_1, b_h \in I_2, \forall h = 1, \ldots, n, \text{ and } a_h \neq a_k, b_h \neq b_k, \forall k, l \neq h\}. \tag{13}$$

Step 7: concept similarity is calculated by using specific instances of the concept. An instance of concept is also an instance of its ancestor concept. The theoretical basis for calculating concept similarity based on instances is that two concepts are the same if they all have the same instances.

Step 8: the attributes of concepts are important features to describe concepts and characterize the semantics of concepts. There are two types of conceptual properties, respectively, the data type and the object type. The data type attribute of a concept is its set of attributes. The object type attribute is a conceptual instance with a relationship, as is shown by the following equation:

$$\mathrm{Sim}\left(\left(E_1, I_1\right), \left(E_2, I_2\right)\right) = \frac{\left|E_1 \cap E_2\right|}{r} \times (1 - w) + \left[\frac{1 - w}{m} \max_{P \in p\left(I_1, I_2\right)} \left(\sum_{\langle a,b \rangle} \mathrm{as}\left(a, b\right)\right)\right] \times w. \tag{14}$$

Step 9: according to the similarity matrix, the concept of semantic similarity between the two ontologies is established.

Step 10: [Increase] Set $j + 1 \longrightarrow j$; go to step 2.

Step 11: a mapping of related attributes in a concept is established based on a set of attribute mappings. The mapping between ontologies includes concepts and concepts, attributes and attributes, concepts and attributes, and relationships and relationships. The mapping between concepts is determined by the calculation of similarity in the previous section. At the same time, the mapping between attributes is obtained when the similarity between attributes is calculated. Finally, the rules of the ontology are used to verify the mapping result.

4.2.2. Information Extraction Technology. Under the guidance of the rule base generated by the ontology mapping integration module, the information extraction module completes the function of extracting named entities from the input sensor information resources, as shown in Figure 1.

(1) Preprocessing Sensor Sampling. The preprocessing of sensor information is mainly word segmentation. The word segmentation divides the information collected by the sensor into a single descriptor of features and locations, such as temperature, humidity, coordinates, location, and other different types of features. This characterization process formally provides a shallow analysis of the resource. Analysis and processing are performed for different types of sensor information.

(2) Data Storage for Sensor Samples. The result of preprocessing is to store the sampled data. This paper adopts the storage method based on RDF. The characteristic of this storage method is that all RDF triples are stored in heterogeneous location tables, which is easy to query and has strong query adaptability.

(3) Construction Rule Base. The ontology uses the domain vocabulary-instance database as the basis for information search. The instance database is stored in the ontology file, which stores common sensor nodes and domain vocabulary in the list. When performing named entity recognition based on annotated samples, it is necessary to utilize the rules in the rule base. Under the guidance of the rules, the named entities related to the ontology concept are identified.

(4) Sensor Ontology Isomorphism Integration. In this paper, we propose to adopt the concept isomorphism ideas, to tangentially divide the heterogeneous contexts, to find the isomorphic ontology from the subcontexts, and to gradually integrate the large ontology. Ontology integration ideas are as follows:

Step 1: for the ontology context O in a wireless sensor network, it is decomposed into the ontology context O_{i} with less attribute order.

Step 2: for any one context K_1 obtained, a context isomorphism is checked in the context library.

Step 3: the sensor ontology is formed according to user needs and isomorphic lattice $B\ (K_2)$ in the database to generate $B\ (K_1)$.

Finally, this paper adopts the proposed attribute joint distribution mapping method based on multi-policy to integrate all the subontologies $B\ (O_i)$. Sensor ontology is $B\ (O)$.

5. Experiments and Analysis

In recent years, semantic similarity computation based on ontology has been widely and successfully applied in the fields of natural language processing, information extraction, and semantic annotation. This paper presents a semantic annotation framework for sensing data oriented towards semantic web. The semantic annotation framework includes three key technologies: perceptual data collection technology; ontology isomorphic integration technology; and composite semantic similarity method.

The method of semantic annotation for the sensing data in the Internet of Things is as follows.

5.1. Sampling Semantic Preannotation Based on Domain Sensor Ontology. The mapping between words and ontology concepts is established by analyzing the feature words sampled by the sensors. For sampled data, the basic idea of semantic preannotating from the perspective of domain ontology is as follows:

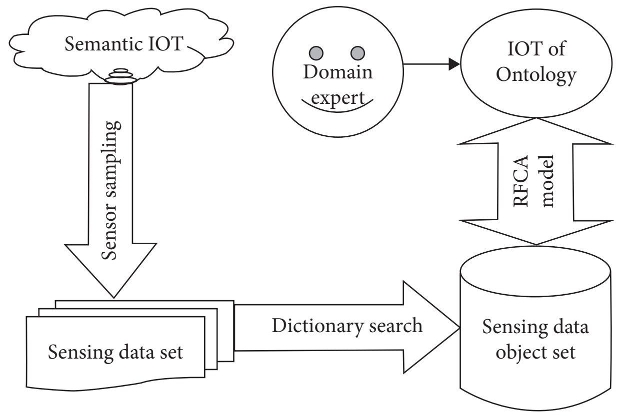


Figure 1: Ontology construction in Semantic Web of Things based on information extraction technology.

Step 1: relevant knowledge in the field is acquired. Under the joint guidance of domain experts and ontology creators, the domain ontology in Internet of Things is constructed based on the rough concept lattice model.

Step 2: extract the feature vocabulary representing the sensor from the sensor sampling to form a feature vocabulary set.

Step 3: the samples containing these feature words are associated with the corresponding feature words. When the feature vocabulary is associated with sampling, combined with SSN ontology, RDF based on domain ontology and the support vector space model method (SVM) are stored. Finally, a feature sampling set and its semantic annotation expression are formed.

In this way, the concept mapping relationship between the sensing sampling and the domain ontology is established. Because domain ontology is a precise and detailed description of related concepts, conceptual attributes, and the relationship between concepts, this method is used to semantic annotate the attributes of the sensor's sampled data. It can not only explicitly express the implicit semantic information of documents but also accurately divide sensor samples and their categories. At the same time, it can also reflect its semantic relevance to related categories.

5.2. Selecting the Ontology Segment with the Highest Semantic Relevance. After semantic preannotation of sensor samples based on domain ontology, the samples are annotated by using ontology fragments. The ontology fragments with the highest semantic relevance need to be selected for the sampled documents. The selection process is as follows:

Step 1: use ontology learning techniques to find key concept vocabulary in a contextual grammar environment. Features of the concept vocabulary are calculated. Suppose a concept set $P \subseteq C$, and the information content of P is defined as

$$\psi(P) = \sum_{c \in P} IC(c). \tag{15}$$

Step 2: by comparing the keywords with concepts in the ontology fragment, the semantic environment with the highest relevance is matched for the grammatical environment. When the traditional matching algorithm encounters a large number of concepts in the ontology, its localization efficiency will be relatively low. After the fusion of the feature-based method and the information-based method, the comprehensive correlation degree is integrated. Calculate the formula for the comprehensive similarity of the sensing data a and b. The data calculation formula in semantic sensor network is as follows:

$$\mathrm{Sim}''(a,b) \frac{\sum_{D \in D_\prime} \delta_D \mathrm{sim}\prime(a,b) + \sum_{D \in D_\prime, D2 \in D_\prime} \delta_{D1,D2} \mathrm{sim}^*(a,b)}{N}, \tag{16}$$

where N is the total number of calculated similarity results, δ is the weight of each ontology, and the coefficient can be determined based on the correlation with the current sensor node. The formula calculates the weighted similarity results in the same ontology and in different ontologies. The result is an average value. For different ontologies, the coefficients are adjusted according to the field of processing, and the ontologies close to the wireless sensor network should be given greater weights. This method introduces the idea of IC into the construction method of WSN. Feature weights and semantic distances are described by IC. The similarity between SSNs can be calculated in a multi-ontology environment.

5.3. Semantic Annotation for Sensor Data.

Step 1: if the concepts corresponding to the keywords are concentrated in the same sensor environment, the matching is successful. The matching semantic environment is determined as the semantic annotation reference. If the concepts corresponding to the keywords are evenly distributed in multiple semantic contexts, the matching fails. Then, only the contraction syntax environment is used to find keywords. Here it is repeated to match the semantic environment multiple times until the match is successful or shrinks to the minimal syntactic environment.

Context is related to the concept of similarity; set the scene K= (C_{int}, R). The similarity of concepts a and b in ontology O is defined as

$$\operatorname{Sim}(a,b) = \frac{\alpha\Psi\left(F_K(a)\cap F_K(b)\right)}{\alpha\Psi\left(F_K(a)\cap F_K(b)\right) + \beta(A,B)\Psi\left(F_K(a) - F_K(b)\right) + \left(1-\beta\Psi\left(F_K(b) - tF_K n(a)\right)\right)}, \tag{17}$$

where the coefficient α is an adjustable coefficient, which is used to adjust the weight between the common feature and the difference feature. The coefficient β is used to balance the weights of the two difference sets. In particular, when P is the empty set, the maximum similarity value is taken.

Step 2: here, several words with high correlation are used as keywords to locate the semantic environment. If the method of semantic distance calculation is used, the correlation between each concept and the keyword needs to be calculated, while it is possible to locate the semantic context by accurately finding the concepts with the highest matching keywords. However, the ontology in the sensor field contains a large number of concepts, and its positioning efficiency will be relatively low. Therefore, the method of syntax matching and statistics is used to locate the semantic environment. Computational context-dependent feature sets and similarity are defined as follows.

$$D_H(A,B) = \max\left\{\sup_{x\in A}\inf_{y\in B}\ d(x,y), \sup_{y\in B}\inf_{x\in A} d(x,y)\right\}, \tag{18}$$

where D_H is the Hausdorff distance of two concept sets and D (x, y) is their shortest distance through the conceptual information content. The Hausdorff distance can measure the maximum mismatch between two concept sets.

Step 3: in order to improve the accuracy of annotation, when performing semantic annotation, ontology not only considers the correlation between a single instance and the sampled data but also considers whether the instance appears in the sampling. At the same time, the ontology considers the attributes of the instance and the relevance of the concept to the document. This fully takes into account the semantic environment in which the sampling exists.

This paper designs a semantic annotation framework based on sensor ontology. The framework is divided into four levels: acquisition and preprocessing of sensor data, construction of sensor ontology, identification of named entities, and storage of semantic annotation results. Annotating sensor data through this framework can effectively express the semantics of sensor information. This paper analyzes and compares the proposed method based on improved rough concept lattice and Sense2Web + M3 operation method. Then, the Sense2Web + M3 operation method is the traditional semantic annotation model. The semantic annotation for the data plays a very important role in the aspect of data processing. The novel proposed method can effectively enhance the expression ability of sensor information and the use value of data.

This paper tests the performance of ontology construction and semantic annotation in Semantic Web of Things; the experimental environment here is as follows: the c# programming language is used, and the programming environment is Microsoft Visual Studio 2019; the data storage uses SQL Server 2019 as the dynamic real-time data storage carrier. The hardware experimental system includes as follows: the processor adopts Intel(R) core(TM) i7-10700CPU, of which the CPU frequency is 4.8GHz; the memory is 256G; the external memory is 1TB disk; the operating system is windows 10.

This experiment adopts sensor ontology query language for the sensor sampling value of attribute data query. All the tests are executed 100 times, and the test results are 100 times the average value, and experiments are to compare the proposed rough concept lattice semantic annotation method with the traditional semantic annotation platforms, as shown in Figure 2.

From the test results, it can be seen that the ontology query consumes access time, and the change of the RDF data volume increases linearly. When tripling the number of rows to six orders of magnitude, the dataset size is 2.1 GB, and the query access time is close to 6S in the Semantic Web. The energy consumption of data acquisition frequency is 1s, and acquisition nodes are 2800 in the energy consumption monitoring experimental platform. After two weeks of perception data.

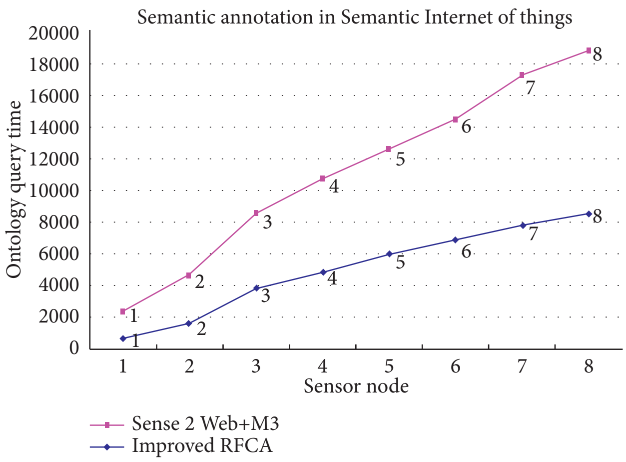


Figure 2: Comparison of the proposed rough concept lattice semantic annotation method with the traditional semantic annotation platforms.

the data collected reach 8,000 rows according to such experimental parameters. In order to illustrate the feasibility of this method, this paper simulates the experiment, and the numbers of the sensors are 1, 2, 3, 4, 5, 6, 7, and 8, respectively. In order to verify the accuracy of semantic annotation, the improved rough concept lattice is compared with the Sense2Web+M3 platform for semantic annotation data sequence. It can be seen from Figure 2 that the improvement of the rough concept lattice has obvious advantages, and the ontology query time has been significantly reduced so that the application of sensor data and the intelligence of data processing can be improved. So, the semantic annotation method is feasible for intelligent data.

This paper proposes a method for semantic annotation based on the rough concept lattice model. The method includes collecting and preprocessing sensor data, integrating sensor ontology, identifying named entities, and storing semantic annotation results. This paper also proposes an integrated unit ontology strategy based on the improved rough concept lattice isomorphism model. In order to find similar concepts accurately and reasonably, a semantic similarity method of comprehensive feature and content is proposed, which effectively annotates the entity resources to be named. It promotes a deeper understanding and more intelligent processing of data by wireless sensors.

6. Conclusion

Based on the research background of ontology construction, semantic similarity calculation, and semantic annotation in Semantic Web of Things, this paper comprehensively uses formal concept analysis, variable precision rough set, semantic similarity technology, and information extraction technology to solve the key problems in semantic annotation. This paper presents application of the rough concept lattice model in construction of ontology and semantic annotation in Semantic Web of Things. According to ontology structure based on rough concept lattice, this paper's objective is to obtain the sensor ontology in Semantic Web. Aiming at the two subontology pairs in the ontology system, this paper proposes a multi-strategy attribute joint distribution mapping method. In this paper, the multi-dimensional weighted vector analysis method is used to identify sensor entities in the Internet of Things and form a semantic comparison rule database. Finally, a similarity calculation method based on the combination of features and information content is proposed for semantic annotation. The future research work is to use big data mining technology to enable the Internet of Things to provide personalized intelligent services [14].

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This study was supported by the National Natural Science Funds of China (61272015) and 2022 Henan Province Science and Technology Research Project (Construction and Application of Intelligent Ontology in Internet of Things Based on Semantic Concept Model) (222102210316).

References

[1] F. Ganz, P. Barnaghi, and F. Carrez, "Information abstraction for heterogeneous real world internet data," *IEEE Sensors Journal*, vol. 13, no. 10, pp. 3793–3805, 2013.
[2] J. Jason, "Exploiting semantic annotation to supporting user browsing on the web," *Knowledge-Based Systems*, vol. 5, pp. 373–381, 2007.
[3] V. Janev and S. Vraneš, "Applicability assessment of semantic web technologies," *Information Processing & Management*, vol. 47, no. 4, pp. 507–517, 2011.
[4] P. Barnaghi, W. Wang, C. Henson, and K. Taylor, "Semantics for the internet of things," *International Journal on Semantic Web and Information Systems*, vol. 8, no. 1, pp. 1–21, 2012.
[5] X. Kang, D. Li, S. Wang, and K. Qu, "Rough set model based on formal concept analysis," *Information Sciences*, vol. 222, pp. 611–625, 2013.
[6] B. Han, J. Li, J. Su, M. Guo, and B. Zhao, "Secrecy capacity optimization via cooperative relaying and jamming for WANETs," *IEEE Transactions on Parallel and Distributed Systems*, vol. 26, no. 4, pp. 1117–1128, 2014.
[7] M. Compton, P. Barnaghi, L. Bermudez et al., "The SSN ontology of the W3C semantic sensor network incubator group," *Journal of Web Semantics*, vol. 17, pp. 25–32, 2012.
[8] A. A. Estaji, M. R. Hooshmandasl, and B. Davvaz, "Rough set theory applied to lattice theory," *Information Sciences*, vol. 200, pp. 108–122, 2012.
[9] J. J. Jung, "Semantic annotation of cognitive map for knowledge sharing between heterogeneous businesses," *Expert Systems with Applications*, vol. 39, no. 5, pp. 5857–5860, 2012.
[10] G. Wang, J. Du, B. Wang, and J. Zhang, "A new approach for ranking non-normal trapezoidal fuzzy number," *International*

Journal of Innovative Computing, Information and Control, vol. 9, no. 8, pp. 3173–3184, 2013.

[11] B. Han, J. Li, J. Su, and J. Cao, "Self-supported cooperative networking for emergency services in multi-hop wireless networks," *IEEE Journal on Selected Areas in Communications*, vol. 30, no. 2, pp. 450–457, 2012.

[12] M. Dahab, H. Hassan, A. Rafea, and TextOntoEx, "TextOntoEx: automatic ontology construction from natural English text," *Expert Systems with Applications*, vol. 34, no. 2, pp. 1474–1480, 2008.

[13] Q. Xiao, Q. Li, and L. Guo, "Rough sets induced by ideals in lattices," *Information Sciences*, vol. 271, pp. 82–92, 2014.

[14] H.-Z. Yang, L. Yee, and M.-W. Shao, "Rule acquisition and attribute reduction in real decision formal contexts," *Soft Computing*, vol. 15, no. 6, pp. 1115–1128, 2011.

[15] B. Wu, M. F. Liu, and Z. Wang, "Efficiency evaluation in time management for school administration with fuzzy data," *International Journal of Innovative Computing, Information and Control*, vol. 8, no. 8, pp. 5787–5796, 2012.

[16] D. Pfisterer, K. Romer, D. Bimschas et al., "SPITFIRE: toward a semantic Web of things," *IEEE Communications Magazine*, vol. 49, no. 11, pp. 40–48, 2011.

[17] H. Xu, R. Zhang, C. Lin, and W. Gan, "Semantic annotation of ontology by using rough concept lattice isomorphic model," *International Journal of Hospitality Information Technology*, vol. 8, no. 2, pp. 93–108, 2015.

Hindawi
Scientific Programming
Volume 2022, Article ID 3125414, 9 pages
https://doi.org/10.1155/2022/3125414

Research Article

Land Use Classification Using Improved U-Net in Remote Sensing Images of Urban and Rural Planning Monitoring

Xiaoling Xie, Lin Ye, Xueqin Kang, Lei Yan, and LiQin Zeng

School of Architecture and Urban Planning, Lanzhou Jiaotong University, Lanzhou, Gansu 730070, China

Correspondence should be addressed to Xiaoling Xie; xiexl@mail.lzjtu.cn

Received 27 January 2022; Revised 11 March 2022; Accepted 21 March 2022; Published 12 April 2022

Academic Editor: Ahmed Farouk

Aiming at the problem of low accuracy and efficiency of existing land use classification methods for high-resolution remote sensing image segmentation, a land use classification method using improved U-Net in remote sensing images of urban and rural planning monitoring is proposed. First, taking the high-resolution remote sensing images of different remote sensing satellites as the data source, the remote sensing images in the data source are registered and cropped so that the pixels at the corresponding positions represent the same geographical location. Then, the encoder of the U-Net model is combined with the residual module to share the network parameters and avoid the degradation of the deep network. The dense connection module is integrated into the decoder to connect the shallow features with the deep features, so as to obtain new features and improve the feature utilization rate. Finally, the depthwise separable convolution is used to process the spatial and channel information of the convolution process separately to reduce the model parameters. Experiments show that the pixel accuracy, recall rate, precision rate, and average intersection-over-union ratio of the proposed land use classification method based on improved U-Net are 92.35%, 80.56%, 83.45%, and 86.75%, respectively, which are better than the compared methods. Therefore, the proposed method is proved to have good land use classification ability.

1. Introduction

Human beings' excessive demand and consumption of land resources have brought various problems, such as land degradation, land desertification, sharp reduction of forest land and grassland area, soil erosion, serious land pollution, and so on. These problems directly lead to the paralysis of some systems and the extinction of rare species [1]. If human beings create value without paying attention to the protection of nature and blindly destroy it, the living conditions will be greatly reduced and the future development will be limited. Therefore, it is necessary to reasonably classify and use land [2–4].

With the rapid development of high-speed imaging sensors and remote sensing technology, the resolution of remote sensing image can be as high as 0.41 m. On the one hand, the maturity of high-resolution remote sensing image technology provides accurate information for understanding the world; on the other hand, it brings great challenges to the automatic and intelligent interpretation of remote sensing image. How to make full use of these high-quality data is an important research direction [5–8]. High-resolution remote sensing images contain rich and complex surface information and record more ground object details. They are widely used in agriculture, industry, military, and other fields. The study of ground information through high-resolution remote sensing images can not only facilitate resource survey, disaster monitoring, urban planning, and military defense but also contribute to the improvement of intelligent technologies such as unmanned driving, crop planting statistics, remote sensing mapping, and so on [9–12].

Deep learning has strong feature fitting ability, so it is widely used in remote sensing image scene classification. This method extracts image features layer by layer in an end-to-end way, fuses them to form high-level features, and finally generates the semantic description of the image, that is, category label [13–17]. Due to the use of real semantic labels, deep learning can extract feature representations highly related to image categories and achieve high classification accuracy [18].

The widely used land use classification methods mainly include visual interpretation, supervised classification, unsupervised classification, and so on [19]. In recent years, with the development of artificial intelligence, the deep learning method has been gradually introduced into land use classification [20]. Zhang et al. [21] combined the advantages of convolutional neural network and Markov random field and proposed a variable precision rough set (VPRS) model to quantify the uncertainty in the classification of VFSR image by convolutional neural network (CNN). Maggiori et al. [22] proposed a CNN model for remote sensing image classification. CNN was used to learn the contextual features of image labels on a large scale. This network was composed of four stacked convolution layers. The image was downsampled, and the relevant features were extracted. In order to overcome the shortcomings of large-scale labeled remote sensing image datasets, Scott et al. [23] proposed a method of combining transfer learning with deep convolutional neural network (DCNN), which used TL to guide DCNN. This method retained the depth visual features learned from image corpora in different image domains, so as to improve the robustness of DCNN to remote sensing image data. Mou et al. [24] proposed a full Conv-Deconv network for unsupervised spectral spatial feature learning of hyperspectral images, which could be trained end-to-end. Mou et al. [25] proposed a hyperspectral image classification method based on recurrent neural network, which used the newly proposed activation function Pre-tanh to replace the traditional tanh function for hyperspectral sequence data analysis. Naushad et al. [26] proposed a land classification method combining VGG16 and wide residual network and fine-tuned the model with transfer learning. Considering pixel-level classification and boundary mapping, Dong et al. [27] proposed a new feature integration network (FE-Net), which included two stages: multi-scale feature encapsulation and enhancement. However, in the face of high-resolution remote sensing images, the above methods are difficult to effectively mine data features, and there are many model parameters, which have the problems of low accuracy and efficiency.

Aiming at the problem of low accuracy and efficiency of existing land use classification methods for high-resolution remote sensing image segmentation, a land use classification method using improved U-Net in remote sensing images of urban and rural planning monitoring is proposed. The innovations of the proposed method are as follows:

(1) The encoder is combined with the residual module to share the network parameters and avoid the degradation of the deep network. The dense connection module is used to cascade the upper features with the deep features.

(2) The convolution modules in the model are replaced by depthwise separable convolution. The spatial and channel information of the convolution process are processed separately. The direct correlation between spatial and channel is removed, so the amount of parameters of the model is effectively reduced.

2. Construction of Dataset

2.1. Overview of Satellite Information Used in Datasets. The multi-temporal remote sensing images in the dataset used in this paper come from different remote sensing satellites. QuickBird series satellites were launched by American company DigitalGlobe in 2001. It is one of the first commercial satellites in the world to provide sub-meter resolution. Its orbital altitude is about 450 km, its mass is about 1018 kg, the regression cycle is 1 to 6 days, and the corresponding actual area of a single image is about 272.25 km^2. The provided resolutions include panchromatic 0.61 to 0.71 meters and multi-spectral 2.44 to 2.88 meters. The sensor can detect four different bands: 450–520 nm blue band, 520–600 nm green band, 630–690 nm red band, and 760–900 nm near-infrared band.

Landsat series satellites are led by NASA in the United States to observe and study global change. At present, only Landsat7 and Landsat8 are in service. Landsat7 satellite carries enhanced thematic plotter sensors. Compared with the original sensor device, the device significantly improves the image resolution and positioning quality by setting absolute calibration on the satellite. A single image covers an area of 32375 km^2. Landsat8 has an orbital height of about 705 km, an orbital period of 99 minutes, and a revisit period of 16 days. The satellite is mainly equipped with two different sensors, namely, land imager and thermal infrared sensor. The two sensors provide 11 different bands, which can provide richer synthesis schemes through different combinations. The effects of different band combinations are shown in Figure 1, from which it can be clearly seen that the natural color map is closer to the daily images, while the vegetation analysis map focuses on the plant color, which can clearly distinguish vegetation from the surrounding environment. The atmospheric penetration map can shield some highlights to reduce the impact of light.

2.2. Detailed Introduction of Dataset. Most remote sensing images in the dataset are central and eastern China and contain a wide variety of changes, such as bare land changing into roads, farmland changing into high-speed rail tracks, wasteland changing into factories, urban building demolition, new buildings, mountain reclamation, river diversion, ore mining, and so on. The dataset contains 13680 pairs of multi-temporal remote sensing images with a resolution of 256×256, and the corresponding area of each image is about 2.5 km^2. Some images do not come from the same satellite, so first, each pair of images need to be registered and cropped so that the pixels at the corresponding positions represent the same geographical location. However, even so, there is still the problem of angle deviation caused by different satellite shooting angles of some buildings. For example, Figure 2 shows images of the same building obtained by different remote sensing satellites at the same location. It can be seen from the figure that these buildings

(a) (b) (c)

Figure 1: Composite maps of different band combinations of Landsat8 satellite. (a) Natural color. (b) Extraatmospheric view. (c) Vegetation analysis.

Figure 2: Comparison of angle deviation of buildings at different times.

only have some angular deviation, but in fact, there is no change in ground features. However, these deviations cannot be adjusted by simple image registration and can only be solved by using the recognition ability of the algorithm itself.

3. Land Use Classification of Remote Sensing Images Based on Improved U-Net

3.1. Technical Roadmap. Typical CNN models include AlexNet, VGG, GoogleNet, etc., all of which contain the most basic hierarchy. The development of these networks is characterized by complex networks, increasing parameters and deepening layers. However, there is no evidence that the number of layers of the network is directly proportional to the accuracy of the model, nor it is directly related to the image, region, and classification requirements. Therefore, blindly deepening the network is not desirable. Moreover, the deep layers of the network have high requirements for hardware, which directly affects the efficiency. It is the best situation to achieve a certain balance.

However, these networks are suitable for image recognition. During the test, a picture is input into the network and then a category label value is output, which cannot classify each pixel. The goal of this paper is to classify remote sensing images at pixel level.

U-Net is the optimization of FCN, and the extraction effect is significantly improved compared with FCN. Both U-Net and FCN have encoder-decoder structures, which are simple but effective. The encoder is combined with the residual module to share the network parameters and avoid the degradation of the deep network. The dense connection module is used to cascade the upper features with the deep features, which is conducive to extracting new features and improving the reuse rate of feature information. Therefore, the improved U-Net is used to classify land use. This paper first preprocesses the remote sensing image data and then classifies the study area by deep neural network, including sample making, model training, prediction, and classification, as shown in Figure 3.

3.2. Improved U-Net Model

3.2.1. Basic U-Net Model. The most noticeable feature of U-Net is the integration of low-dimensional features and high-dimensional features, making full use of the semantic features of images. Figure 4 shows the schematic diagram of U-Net structure. The U-Net structure is symmetrical left and right, and the images are input into the U-Net structure. First, the high-dimensional feature map with low resolution is obtained after several convolution downsampling operations through the encoder, i.e., compression channel on the left side of the network. The network structure on the left side is a Gaussian feature pyramid structure from low dimension to high dimension; then, enter the decoder on the right side of the network, i.e., the expansion channel, and the input feature maps are subjected to a series of deconvolution upsampling operations to generate the feature maps of the corresponding size with the original pyramid step by step. Finally, a prediction result map at the same pixel level as the input image is output. The biggest difference between U-Net and FCN structure is that when decoding, the high-dimensional features of this layer are fused with the low-dimensional features in corresponding pyramid layer for upsampling, which considers both the high-dimensional and low-dimensional features in the image.

3.2.2. Improved U-Net Model. The proposed model consists of an encoder, decoder, and connection block. The encoder is composed of 8 residual modules, 2 residual modules constitute a network layer, and each residual module is composed of two 3×3 convolution layer and quick

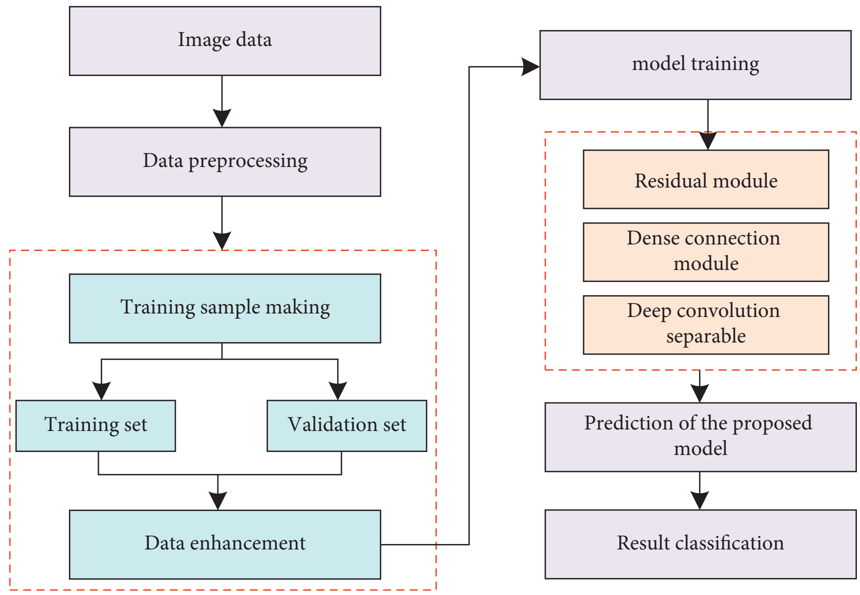


Figure 3: Proposed technology roadmap.

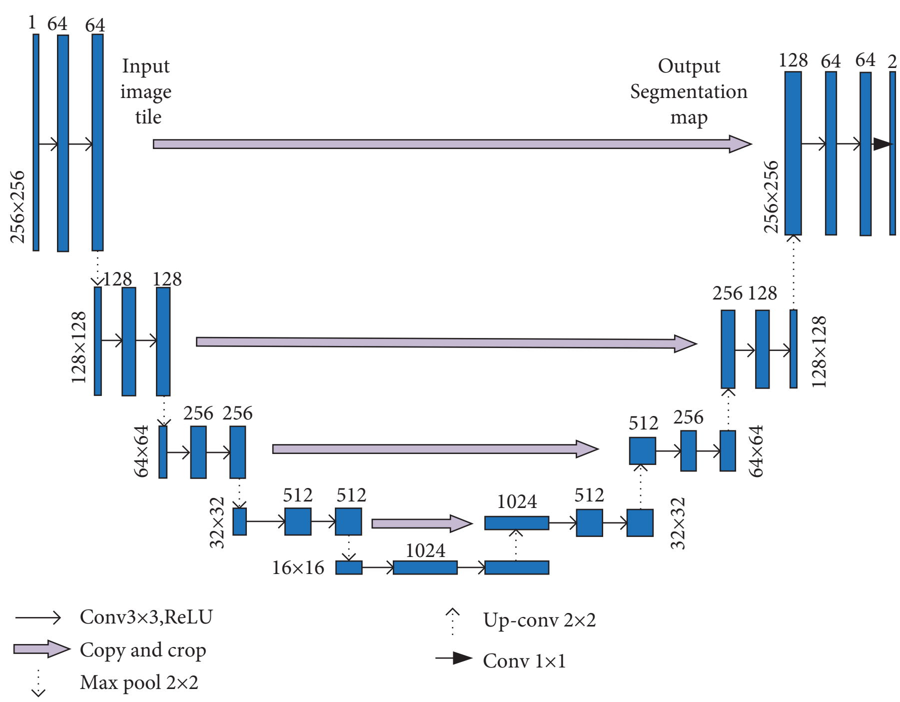


Figure 4: Schematic diagram of U-Net structure.

connection. Each network layer of the encoder is connected through the convolutional and max-pooling layers with step of 2 and convolutional kernel size of 2×2. The image information is convoluted to extract local features, and the quick connection operation of the residual module fuses the input global information with local features, so that the model can capture more abundant feature information, and the network is not easy to degrade. Each layer of the decoder consists of a dense connection module, which uses layer to layer connection by transpose convolution with step of 2 and convolutional kernel size of 3×3. The dense connection module consists of four 3×3 convolution layers. In addition, the output of the residual module is combined with the relatively symmetrical dense connection module by cascading, so that the model integrates more shallow features. The connecting block consists of four 3×3 convolution layers. The encoder output is connected to the decoder. In order to obtain a lighter network model, less convolution kernels than U-Net are used in each layer, and batch normalization and ReLU activation functions are added after each convolution layer to prevent overfitting. The model structure is shown in Figure 5.

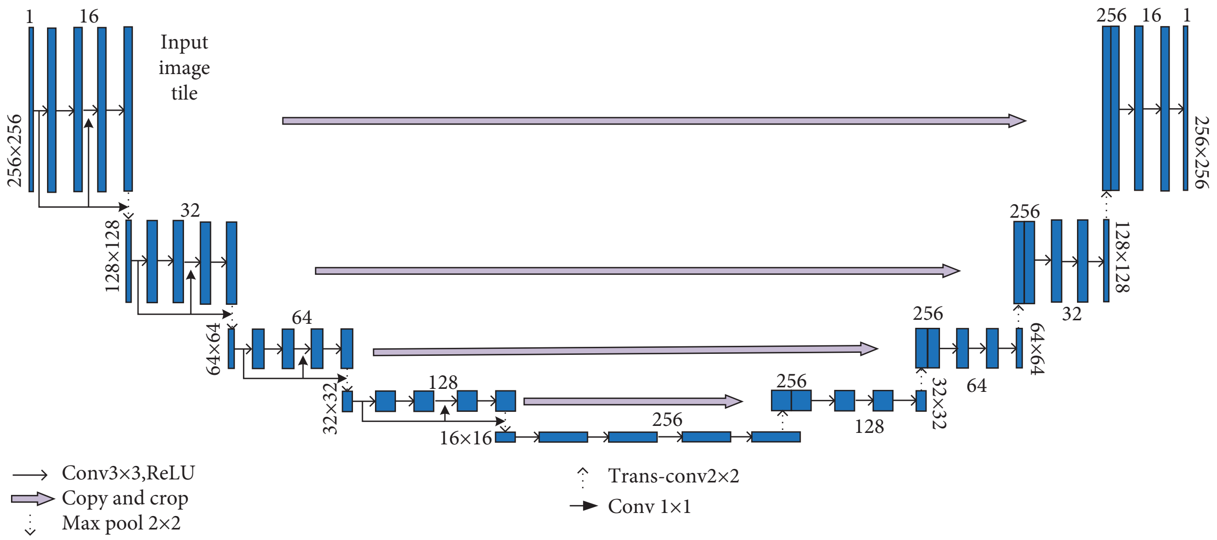


Figure 5: Improved U-Net model.

3.2.3. Depthwise Separable Convolution. The general convolution is replaced by depthwise separable convolution to reduce the amount of U-Net parameters. In Xception structure, the convolution kernel is three-dimensional, including width, height, and channel dimensions. The traditional convolution process is the unified processing of spatial and channel information, and the depthwise separable convolution processes the spatial and channel separately to remove the direct correlation between them. In this way, the redundant processing process is removed, the model parameters are reduced accordingly, the network becomes simpler, and the universality is strengthened. The operation of depth separable convolution includes first performing spatial convolution in the depth direction (convolution on each input channel, respectively), followed by a pointwise convolution mixing of the output channels together. The pointwise convolution is with convolutional kernel size of 1×1, which is applied to the second step of depth separable convolution to expand the depth of the image.

Supposing that the size of convolution kernel is $D_k \times D_k$, the size of input data is $D_f \times D_f \times M$ and the size of output data is $D_f \times D_f \times N$, and the parameter quantity of general convolution is

$$D_k \times D_k \times M \times N \times D_f \times D_f. \tag{1}$$

The depth separable convolution parameters are obtained by adding the parameter quantities of pointwise convolution and depth separable convolution:

$$D_k \times D_k \times M \times D_f \times D_f + M \times N \times D_f \times D_f. \tag{2}$$

Using the property that depthwise separable convolution can reduce the parameter quantity, some traditional convolutions are replaced by depthwise separable convolution on the basis of U-Net. The parameter quantity is reduced to about 1/3 of the original parameter quantity, and the model inference time is about 5/6 of the original time.

3.3. Loss Function Design. The fundamental principle of the design criterion of loss function is to directly reflect the network model according to the characteristics of function. In the field of deep learning, the loss functions commonly used include Euclidean loss function, hinge loss function, softmax cross-entropy, and contrastive loss function. In order to be applicable to the proposed improved U-Net structure as much as possible, log loss function is used as the loss function in the experiment. The log loss function is the loss function corresponding to sigmoid, and its formula is

$$L(Y, P(Y|X)) = -\log P(Y|X), \tag{3}$$

where L is the value of cross-entropy, X is the value of sample data, and Y is the value of predicted data. In order to facilitate network calculation, the log loss function is mainly used for maximum likelihood estimation. Because the derivation of maximum likelihood is very cumbersome, the logarithm is first calculated, and then the derivative and extreme points are calculated. As the name suggests, the loss function is the sum of the losses of each type of sample. If the result is negative, it is the minimum loss of maximum likelihood estimation.

4. Experiment and Analysis

4.1. Experimental Setup and Evaluation Index. The computer system of the experimental environment is Windows 10, and the programming language used is Python. The deep learning framework used in the experiment is TensorFlow, and the high-level neural network API-Keras is used in the construction of deep learning network (graphics card: NVIDIA GeForce GTX 1060 6 GB; memory: 16G).

In this paper, pixel accuracy (PA), recall (RC), precision (PR), and mean intersection over union (MIoU) are used as evaluation indexes. PA is the most commonly used evaluation index, which indicates the proportion of correctly predicted pixels in all pixels. MIoU calculates the proportion between the intersection and union of two sets. In the remote sensing image change detection task, these two sets represent the changed region and the unchanged region. The formulas are shown in (4) and (5):

$$\mathrm{PA} = \frac{\sum_{i=0}^{k} p_{ij}}{\sum_{i=0}^{k}\sum_{j=0}^{k} p_{ij}}, \tag{4}$$

$$\mathrm{MIoU} = \frac{1}{K+1}\sum_{i=0}^{k}\frac{p_{ij}}{\sum_{j=0}^{k} p_{ij} + \sum_{j=0}^{k} p_{ji} - p_{ii}}, \tag{5}$$

where k represents the number of object categories; p_{ij} represents the number of pixels that belong to the category i but are recognized as the category j; and p_{ii} indicates the number of pixels correctly identified.

Recall represents the proportion of the change area correctly recognized by the algorithm in the change area of the original image, and precision represents the proportion of the number of pixels in the correct change area predicted in the prediction map to the number of pixels in all the real reference change areas. The calculation methods of these two indicators are shown in formulas (6) and (7).

$$\mathrm{RC} = \frac{\mathrm{TP}}{\mathrm{TP}+\mathrm{FN}}, \tag{6}$$

$$\mathrm{PR} = \frac{\mathrm{TP}}{\mathrm{TP}+\mathrm{FP}}, \tag{7}$$

where TP represents the pixel marked as the change region in the reference image, and the recognition result of the algorithm for the region is also the pixel of the change region; FP represents a pixel marked as an unchanged region in the reference image, and the recognition result of the region by the algorithm is a changed region; FN represents a region marked as a change region in the reference image, and the recognition result of the region by the algorithm is an unchanged region; and TN represents the unchanged region marked in the reference image, and the recognition result of the region by the algorithm is also the unchanged region.

4.2. Loss Curve and Accuracy of Network Training Process. The loss function is used to evaluate the difference between the predicted value and the real value of the model. The better the loss function, the better the performance of the model. Figure 6 shows the loss curve and accuracy diagram of the experimental training process of the proposed method, including the loss curve and accuracy diagram of the training set and the verification set. When the epoch is 20, the loss value and accuracy are stable, Train_loss and Val_loss have converged, and the difference between them is very small. Finally, Train_loss is stable at about 85, Val_loss is stable at about 82, and accuracy is stable at about 0.74.

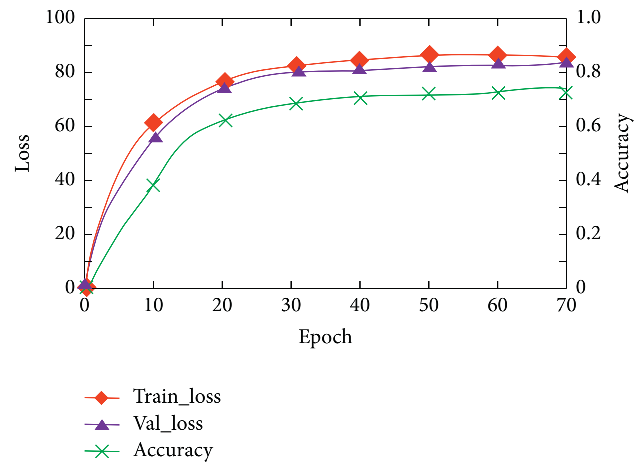


Figure 6: Loss curve and accuracy during training.

4.3. Comparative Experiments of Different Models. In order to prove the performance of the proposed algorithm, the methods in [26, 27] are compared with the proposed method under the same experimental conditions. The experimental results are shown in Figures 7 and 8.

By observing the experimental results, the PA of the method in [26] is only 91.24%, the RC is 65.33%, and the PR is 72.76%. The PA of the method in [27] is 91.87%, the RC is 71.24%, and the PR is 92.35%. The PA, RC, and PR of the proposed method are 92.35%, 80.56%, and 83.45%, respectively. Compared with other methods, it can be seen that the proposed method is the only model with more than 80% in PA, RC, PR, and MIoU indexes. MIoU is 86.75%, 10.16% higher than that in reference [26] and 4.30% higher than that in reference [27]. This is because the proposed method combines the residual module with the encoder to share the network parameters and avoid the deep network degradation. In addition, by combining the output of the residual module with the relatively symmetrical dense connection module in a cascade way, the model integrates more shallow features and improves the ability of the model to mine data features. The core of the comparison method is to optimize the model parameters, which cannot extract the deeper information from the remote sensing image data. Therefore, when dealing with the remote sensing image classification task, the values of each index are lower than those of the proposed method.

Figure 9 shows the comparison diagram of different methods for land change detection and plant change detection. Because the two models in [26, 27] cannot fully and effectively integrate the information of different depths, the edge information noise shown on the prediction map is serious. Although the approximate change region can be extracted, there is an obvious gap compared with the proposed method. The proposed improved U-Net model is superior to the other two models in terms of edge information and recognition integrity. This is mainly due to the residual module and dense connection module in the model, which improves the ability of the model to mine data features. In addition, the depth separable convolution is used to process the spatial and channel information of the

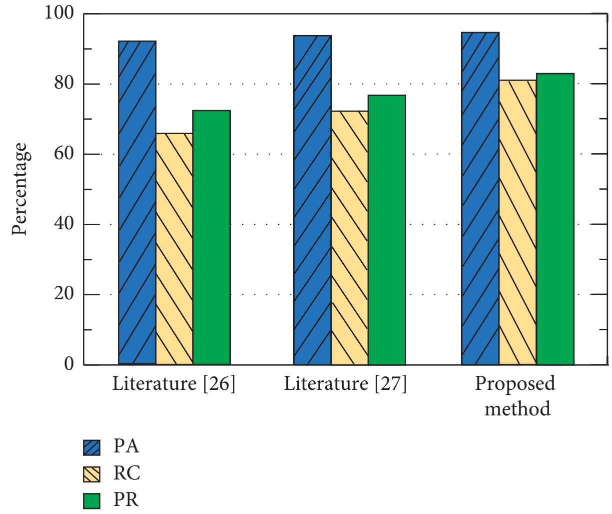


Figure 7: Comparison of PA, RC, and PR indexes of different methods.

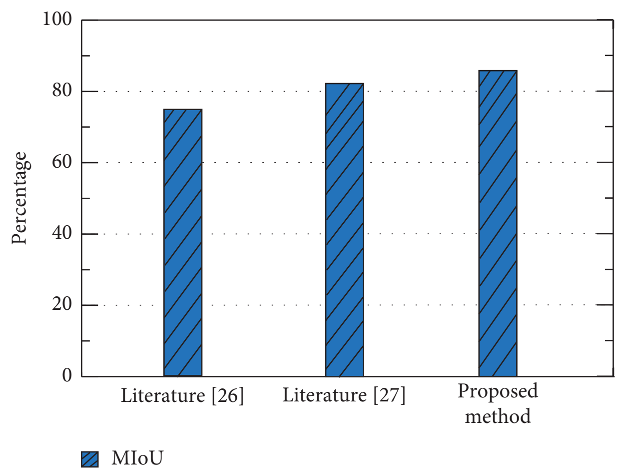


Figure 8: Comparison of MIoU indexes of different methods.

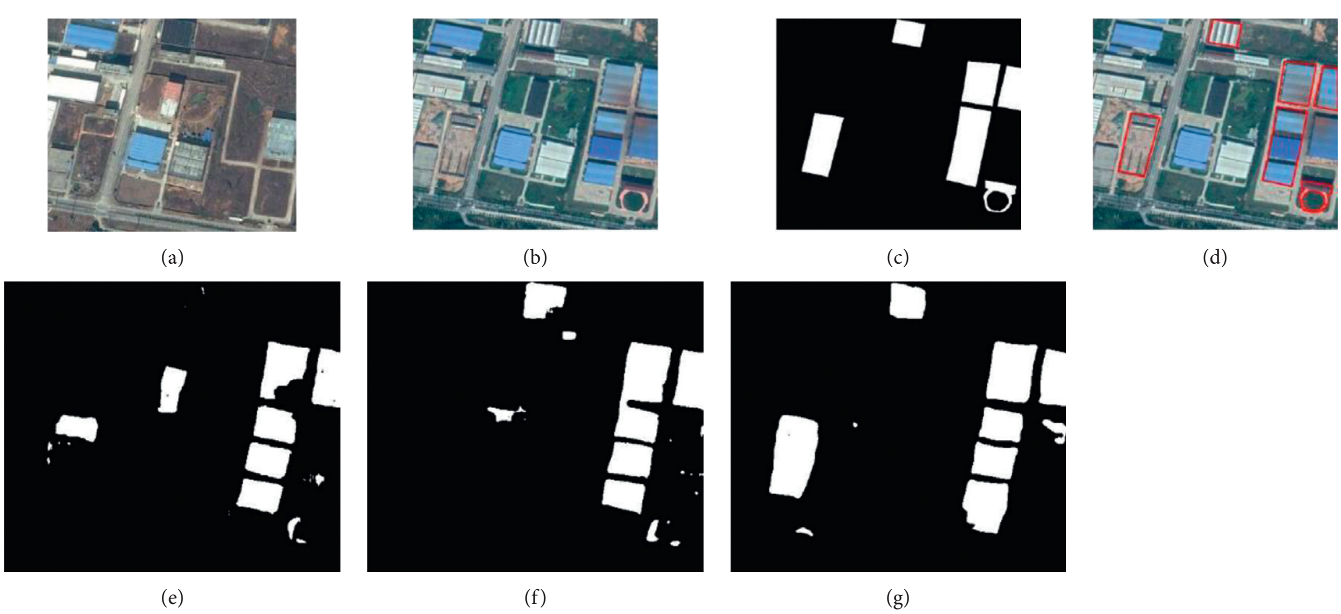


Figure 9: Comparison of different methods for change detection. (a) T1 time image. (b) T2 time image. (c) Reference change area. (d) Change area range. (e) Literature [26]. (f) Literature [27]. (g) Proposed method.

convolution process separately to remove the direct correlation between them, which can provide relatively independent shallow information for fusion with the main module while completing their respective tasks. Therefore, experiments show that the proposed method is feasible and efficient for land use classification in remote sensing images.

5. Conclusion

In view of the low accuracy and efficiency of existing land use classification methods for high-resolution remote sensing image segmentation, a land use classification method using improved U-Net in remote sensing images of urban and rural planning monitoring is proposed. By combining the encoder and residual module of U-Net model and integrating the dense connection module into the decoder, the data mining ability of the model is improved, and the depthwise separable convolution is used to process the spatial and channel information of the convolution process, respectively, so as to reduce the model parameters. Compared with other methods, it can be seen that the proposed method is the only model with more than 80% in PA, RC, PR, and MIoU indexes. The classification system in this paper is not detailed enough and does not involve secondary classes. In the future, a variety of data types can be integrated for more detailed classification. In addition, how to use multiple GPUs to train the network model at the same time is also one of the focuses of future research.

Data Availability

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

Conflicts of Interest

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

Acknowledgments

This study was supported by the National Natural Science Foundation of China (Research on rural planning in Northwest China from the perspective of smart contraction: a case study of Gansu Province) (no. 51968037).

References

[1] K. Jia, X. Wei, X. Gu, Y. Yao, X. Xie, and B. Li, "Land cover classification using Landsat 8 operational land imager data in Beijing, China," *Geocarto International*, vol. 29, no. 8, pp. 941–951, 2014.

[2] Y. Jia, H. T. Li, H. Y. Gu, and Y. S. Han, "Study on the technology and method of land cover classification for geographic national conditions surveying," *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. 3, no. 2, pp. 61–66, 2013.

[3] S. Paul, J. Li, and R. Wheate, "Application of object oriented image classification and Markov chain modeling for land use and land cover change analysis," *Journal of Environmental Informatics*, vol. 31, no. 1, pp. 30–40, 2018.

[4] L. Ma, M. Li, X. Ma, L. Cheng, P. Du, and Y. Liu, "A review of supervised object-based land-cover image classification," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 130, no. 5, pp. 277–293, 2017.

[5] K. M. Bergen, D. G. Brown, J. F. Rutherford, and E. J. Gustafson, "Change detection with heterogeneous data using ecoregional stratification, statistical summaries and a land allocation algorithm," *Remote Sensing of Environment*, vol. 97, no. 4, pp. 434–446, 2005.

[6] T.-A. Teo and C.-H. Huang, "Object-based land cover classification using airborne lidar and different spectral imagesTerrestrial," *Atmospheric and Oceanic Sciences*, vol. 27, no. 4, pp. 491–498, 2016.

[7] D. Phiri and J. Morgenroth, "Developments in Landsat land cover classification methods: a review," *Remote Sensing*, vol. 9, no. 9, pp. 967–976, 2017.

[8] D. Yemshanov, D. W. McKenney, and J. H. Pedlar, "Mapping forest composition from the Canadian National Forest Inventory and land cover classification maps," *Environmental Monitoring and Assessment*, vol. 184, no. 8, pp. 4655–4669, 2012.

[9] H. Yang, S. Li, J. Chen, X. Zhang, and S. Xu, "The standardization and harmonization of land cover classification systems towards harmonized datasets: a review," *ISPRS International Journal of Geo-Information*, vol. 6, no. 5, pp. 154–160, 2017.

[10] R. Khatami, G. Mountrakis, and S. V. Stehman, "Predicting individual pixel error in remote sensing soft classification," *Remote Sensing of Environment*, vol. 199, no. 7, pp. 401–414, 2017.

[11] Y. Wang, M. Y. He, J. Xiang, and Z. M. Zhou, "Review of land cover classification based on remote sensing data," in *Proceedings of the 3rd International. Conference. Wireless Community. Sensor Network*, pp. 69–78, Wuhan, China, December 2016.

[12] M. S. Regasa, M. Nones, and D. Adeba, "A review on land use and land cover change in Ethiopian basins," *Land*, vol. 10, no. 6, pp. 585–593, 2021.

[13] R. Khatami, J. Southworth, C. Muir et al., "Operational large-area land-cover mapping: an Ethiopia case study," *Remote Sensing*, vol. 12, no. 6, pp. 954–964, 2020.

[14] R. Lucas, N. Mueller, A. Siggins et al., "Land cover mapping using digital earth Australia," *Data*, vol. 4, no. 4, pp. 143–156, 2019.

[15] L. Peng, X. Wang, and T. Chen, "Multifunctional land use value mapping and space type classification: a case study of Puge County, China," *Natural Resource Modeling*, vol. 32, no. 4, pp. 2012–2020, 2019.

[16] B. Stelmach-Fita, "European land use spatial data sources and their role in integrated planning: opportunities and challenges for Poland," *Land*, vol. 10, no. 11, pp. 1138–1148, 2021.

[17] K. Tatsumi, Y. Yamashiki, M. A. Canales Torres, and C. L. R. Taipe, "Crop classification of upland fields using Random forest of time-series Landsat 7 ETM+ data," *Computers and Electronics in Agriculture*, vol. 115, no. 14, pp. 171–179, 2015.

[18] W. Chen, X. Li, H. He, and L. Wang, "A review of fine-scale land use and land cover classification in open-pit mining areas by remote sensing techniques," *Remote Sensing*, vol. 10, no. 1, pp. 15–24, 2018.

[19] W. Y. Yan, A. Shaker, and N. El-Ashmawy, "Urban land cover classification using airborne LiDAR data: a review," *Remote Sensing of Environment*, vol. 158, no. 3, pp. 295–310, 2015.

[20] M. M. Mishaa, A. D. Andrushia, and T. M. Neebha, "Image based land cover classification for remote sensing applications-A review," in *Proceedings of the 2021 3rd International Conference on Signal Processing and Communication (ICPSC)*, pp. 152–155, Coimbatore, India, May 2021.

[21] C. Zhang, I. Sargent, X. Pan, A. Gardiner, J. Hare, and P. M. Atkinson, "VPRS-based regional decision fusion of CNN and MRF classifications for very fine resolution remotely sensed images," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 56, no. 8, pp. 4507–4521, 2018.

[22] E. Maggiori, Y. Tarabalka, and G. Charpiat, "Fully convolutional neural networks for remote sensing image classification," in *Proceedings of the 2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, pp. 5071–5074, Beijing, China, July 2016.

[23] G. J. Scott, M. R. England, W. A. Starms, R. A. Marcum, and C. H. Davis, "Training deep convolutional neural networks for land-cover classification of high-resolution imagery," *IEEE Geoscience and Remote Sensing Letters*, vol. 14, no. 4, pp. 549–553, 2017.

[24] L. Mou, P. Ghamisi, and X. X. Zhu, "Unsupervised spectral–spatial feature learning via deep residual Conv–Deconv network for hyperspectral image classification," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 56, no. 1, pp. 391–406, 2017.

[25] L. Mou, P. Ghamisi, and X. X. Zhu, "Deep recurrent neural networks for hyperspectral image classification," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 55, no. 7, pp. 3639–3655, 2017.

[26] R. Naushad, T. Kaur, and E. Ghaderpour, "Deep transfer learning for land use and land cover classification: a comparative study," *Sensors*, vol. 21, no. 23, pp. 8083–8089, 2021.

[27] S. Dong, Y. Zhuang, Z. Yang, P. Long, C. He, and L. Teng, "Land cover classification from VHR optical remote sensing images by feature ensemble deep learning network," *IEEE Geoscience and Remote Sensing Letters*, vol. 17, no. 8, pp. 1396–1400, 2019.

Hindawi
Scientific Programming
Volume 2022, Article ID 2978460, 9 pages
https://doi.org/10.1155/2022/2978460

Research Article

Cultivation of Teenagers' Digital Media Literacy and Network Legal Literacy in the Era of Digital Virtual Technology

Yipin Lv

School of Finance and Economics, Xinyang Agriculture and Forestry University, Xinyang 464000, Henan, China

Correspondence should be addressed to Yipin Lv; 2007220023@xyafu.edu.cn

Received 12 January 2022; Revised 28 January 2022; Accepted 19 March 2022; Published 12 April 2022

Academic Editor: Ahmed Farouk

Digital virtual technology with media survival as an important representation, with the rapid development of the new media technology represented by the Internet, digital virtual technology with its entertainment, personalized service, open sharing of content, form of real-time interaction and other characteristics strongly attract the young group. In the digital virtual era, teenagers' digital media literacy has not only become one of the essential qualities for them to cope with global competition, but also an essential quality for college students to realize lifelong learning. Therefore, it is not only necessary but also urgent to carry out systematic digital media literacy education for adolescent groups. This study first discusses that the typical illegal phenomenon in the network is the problem caused by the lack of network legal awareness, and analyzes the level of media literacy of the subject media in these cases and whether the network legal awareness is weak. Finally, from the perspective of school education, social publicity and national system support, this paper puts forward some Suggestions on how to improve teenagers' media literacy and cultivate their network legal literacy, so as to create a harmonious network environment. Establish a scientific and reasonable indicator system of youth network literacy, and build a youth network literacy training mechanism.

1. Introduction

At present, the network media is affecting people's life all the time. On the one hand, at the same time, with the development of digital virtual technology, the negative information in network media communication also causes a great impact on people. Many teenagers have formed some bad network media complex; On the other hand, although the legal management in the real society is comprehensive and popular with citizens, the legal mechanism under the new media environment is still relatively imperfect. The network information is complicated, true and false, and the transmission speed is fast. The rapid development of the Internet has brought human beings into the age of network information [1]. As an important subject of the Internet, young people are of great significance to network security. The level of teenagers' network ethics literacy directly affects the quality of the network order, and is also a decisive factor for the healthy growth of teenagers in the network society. Teenagers' cyberethical literacy is mainly reflected in their awareness of cyberethics, knowledge and ability of cyberethics, and practice of cyberethics. The "double-edged sword" effect of technology also requires people to seek advantages and avoid disadvantages, so that the network can serve people better. Different from traditional ethics, network ethics has some unique characteristics. Only by combining traditional ethics and network ethics well, can we find a way suitable for the development of network ethics [2, 3]. The purpose of this thesis is to find a feasible way to improve adolescents' network ethics literacy. Facing this problem, we must seek effective ways to educate teenagers to correctly understand and use Internet media, and scientifically guide them to transform their complex of Internet media into their literacy of Internet media.

The generation of teenagers' network media complex is largely based on the recognition of network media and the resulting emotions [4]. The network media complex is dependent on the update and development of network virtual technology and network auxiliary equipment, which provides people with modern thinking and survival mode, and is a dynamic media culture that is constantly developing [5, 6]. Network media complex is often manifested as an intricate psychological state [7]. Along with the demand and use of the network, as well as the network emotion continuously strengthened in this process [8–10]. Based on their dependence and persistence on the Internet, teenagers form a collection of network needs, network emotions and network consciousness in their subconsciousness, which has an influence and control effect on their thoughts, wills and behaviors [11]. Digital media literacy is characterized by the increasing immediacy of network information, the equality and non-centrality of network culture, the high degree of openness and freedom, the personalization and popularization of network participants, the interaction between subjects and the sharing of network resources, as well as the authenticity of network virtuality and communication [12, 13]. Nots allow to ignore the influence of network culture brings to teenagers, it changed the thinking and way of life of teenagers, may make some thinking and behaviour of the teenagers at odds with reality, and most teenagers are in growth stage, the mind is not mature, not very correct judgment standard, lack of self-control ability [14]. Therefore, it is particularly important to strengthen the network media literacy education for teenagers.

Compared with western countries, China has relatively late access to media literacy education, so it is an important issue that needs to be urgently solved under the current network environment to cultivate the legal awareness of the public media literacy and effectively regulate the virtualized cyberspace [15]. As a normative basic research, related issues such as the structure and attributes of the network society, the characteristics of network social communication behavior and the current issues of network ethics have attracted the attention of domestic scholars; more research tends to be discussed within the discipline. Or speculative and abstract research and empirical research are mainly based on the intuitive description of the current situation, and lack of in-depth analysis of the influencing factors of current network social behavior. Based on the social changes caused by digital virtual technology, this study conducted a questionnaire survey on some teenagers in our province according to the research needs. This study focuses on the objective, content, implementation and evaluation of media literacy education for young people, and tries to construct the implementation system of digital media literacy education for young people. In the implementation process, it is required that each adolescent education unit independently develop and provide all-round information environment support, and at the same time, corresponding educational evaluation must be carried out, with emphasis on an evaluation system that combines authentic evaluation and traditional evaluation [16, 17]. Through the analysis and induction of the result data, the current situation of media literacy of teenagers is not optimistic, and there are many problems to be solved including "network media complex," which has become urgent for the media literacy education of teenagers. In the past, related research, especially the domestic research on network ethics, was mostly carried out by age groups, such as "research on network ethics of middle school students," "research on network ethics of college students," and research on primary school students. I am not denying this. A refined age study. In a big way, teenagers are also divided into age groups. The research in the scope of learning stage also has its rationality, it can better reflect the ethical situation of students at each stage, and there are many researches in this area to discover their common problems.

2. Research Overview

2.1. Connotation of Network Media Literacy. After decades of development, network media literacy has developed into a concept with multiple dimensions, perspectives and meanings, so there is no clear definition [18]. Some scholars believe that Internet media literacy is an expanding information and communication skill that is born in response to the changes of social information. This view is based on the fact that teenagers must have the ability to be educated in life in the 21st century and global economic challenges. Teenagers' Internet literacy is a concept put forward for the needs of research. This concept has not been directly used by researchers, so it can be said to be a new concept. However, there have been many studies on the perspectives related to adolescents' cyber ethics literacy, and the research results are also quite abundant, such as the research on "information literacy," "computer literacy," "media literacy," "information ability," "digital literacy" and "electronic literacy." In fact, these are different names for network literacy in foreign countries. The connotation of information literacy includes four aspects: information attitude and emotion, information knowledge, information ability and information morality. There are also some scholars who believe that media literacy is a child with a thousand names. They believe that the cultivation of critical use of media and cognition of media information are the core contents of the cultivation of media literacy for teenagers. More scholars generally believe that network media literacy refers to users' correct use and effective use of network media to create and disseminate information on the basis of certain network knowledge, so as to achieve the purpose of serving individuals. These foundations can be understood as the ability to deal with various aspects of the media. These abilities include not only the cognition of media use technology, but also the critical cognition of media content and the mastery of media information transmission channels.

After sorting out the existing studies, it can be found that the existing research results show the understanding of network media literacy from two categories. The first group believes that the ability to distinguish and analyze information in network media literacy is very important, and this kind of research focuses on the ability to analyze media information. The classification of the main characteristics of the dynamic performance for the media literacy, standing on the position of protectionism, content and medium for the culture of the vulgar bad for preventing violence, pornographic content or resist, these research basic media literacy is treated as a protection way of culture, but this kind of idea started in recent years were replaced by a more realistic and objective concept, namely the role of the media literacy in the positioning of the media information comprehension and participation of media information dissemination; Another point of view emphasizes the role of network media literacy in the audience's access to and use of network information. It believes that network media is different from traditional media in that it has more professional means of obtaining information and needs special learning. Therefore, how to get information from the network becomes the most basic problem of using network media.

In combination with the attributes of this study, the concept of network media literacy is redefined. It is believed that media literacy education refers to an individual's acquired ability to deal with various kinds of media through training, cultivation and practice, and it is a systematic process of the research on media literacy cultivation of teenagers from the digital virtual perspective. "Morality is a special social phenomenon, a kind of spiritual life unique to human beings, and it is produced by adapting to the inevitable requirement of human social life to deal with the relationship between individual interests and the common interests of society. The formation and development of society are inseparable, and the formation and development of human social relations are the objective premise and direct basis for the emergence of morality." The author believes that the basic connotation of network media literacy should include the ability to obtain network media information: the ability to correctly interpret, criticize information and the ability to produce and disseminate information. Network media literacy includes two aspects: first, the cultivation of the ability to use known information. The current social media has extended to all aspects of life, and the cultivation of media literacy is a basic ability needed to survive in this era; Second, the cognitive ability of media, including the use of media, media communication information collection, analysis and evaluation.

2.2. Necessity of Cultivating Teenagers' Internet Legal Literacy in the Internet Era. Under the background of the development of society and the deepening of legal system reform, people have gradually reached consensus on the concept of the rule of law [19, 20]. The higher the recognition degree of teenagers to network law, the closer the realization of network legalization will be. The rapid development of the Internet has an increasingly important impact on all aspects of human social life. In today's information age, Internet access has become a must and a fashion. Among the huge network groups, teenagers account for a large proportion. And it is gradually increasing. The openness of the Internet has greatly helped the improvement of young people's learning efficiency, but also brought risk factors. The influence of the Internet on young people is profound, both beneficial and bad. The network society formed by the network ultimately shapes the youth. Therefore, the cultivation of network legal literacy has become an inevitable expectation for the management of young people from all walks of life [21].

2.2.1. Practical Need of Cyberspace Governance in the Internet Era. The Internet is an extension of the real society, but it does not exist independently of the real world. The network society also needs the rule of law, and the network society is also an important content and aspect of the rule of law [22, 23]. With the rapid popularization of the Internet, teenagers can transcend the constraints of time and economy, obtain the ever-changing information of The Times and humanistic scientific and technological information, absorb the essence and absorb all kinds of nutrition to develop and strengthen themselves, and also provide an important way for teenagers to obtain legal information [24]. Under the background of network informatization, all kinds of hot events provide richer and more convenient ways for college students to obtain information [25]. As the common spiritual home of hundreds of millions of people, cyberspace enables every Internet user to become a publisher of legal news and provides an important platform for teenagers to widely discuss legal issues [26]. In recent years, many of the cases that have drawn public attention have been widely known through Internet channels and triggered a large number of young people to participate in the discussion. Therefore, the cultivation of young people's Internet legal literacy has become a necessary prerequisite for the smooth development and implementation of the rule of law [27].

2.2.2. Objective Requirements of Running the University According to Law. Running schools in accordance with the law is an inevitable requirement of promoting the basic strategy of comprehensively governing the country by law and an important content of promoting the construction of education in accordance with the law. To advance the rule of law in an all-round way, we must make it specific to the schools where young people live and comprehensively promote the rule of law in schools [28]. In accordance with the requirements of the basic strategy of comprehensively implementing the rule of law, we must accelerate the process of building the educational legal system and improve the laws and regulations on socialist education with Chinese characteristics. In 2013, the competent education authorities also issued a document to clarify the objectives, requirements and main tasks of promoting school administration in accordance with the law, and put forward systematic requirements for schools to transform their management concepts, means and methods in accordance with the spirit and principles of the rule of law, which is of great significance for promoting the reform of China's school administrative management system and internal governance mechanism [29, 30].

To train the vast number of young people to form a good habit of knowing, abiding by the law, using and protecting the law in the process of using the Internet, the premise is to realize the legalization of the Internet management work for young people, so that young people clear their own obligations, rights and responsibilities should be performed. To achieve these goals, it is necessary to adopt the network service real-name system and legal management mode among the youth group.

2.2.3. Strategic Arrangements for the Rule of Law. China has clearly put forward the legal goal of "governing the country by law and building a socialist country under the rule of law" at many important meetings, which indicates the country's determination to implement the rule of law. Moreover, the CPC Central Committee has repeatedly taken the "rule of law" as the theme in the form of plenary sessions, which shows that China's national governance level has fully realized the advantages of such a management system, and will continue to carry it forward in the concept of national governance. In particular, in the report to the 19th National Congress of the COMMUNIST Party of China, "upholding the rule of law in all respects" was included in the basic strategy of upholding and developing socialism with Chinese characteristics in the new era. This indicates that theoretical exploration and practical development in building a China under the rule of law have reached a new height.

2.3. Research Ideas and Methods. There are a large number of research works on media literacy both at home and abroad, and the research on media literacy has been very mature. However, due to the relatively short emergence of the Internet, the research on network media literacy is still incomplete. This study discusses and evaluates the development of digital media literacy through a two-line parallel research approach to study the content and path of media literacy cultivation in the digital environment, so as to provide a theoretical basis for the cultivation of media literacy for teenagers in the future. In addition, the research on the status of network media literacy carried out in this research is an empirical research, which starts from the analysis of survey data. Therefore, the research attribute is to put forward Suggestions on the improvement of teenagers' network media literacy from the whole social level.

2.3.1. Literature Research Method. The sources of literature research mainly include Chinese journal full-text database journal resources, CNKI, Chinese Weipu and foreign university website literature, and through the in-depth analysis and summary of the content of the literature to form a cognitive approach to the research content. By analyzing, summarizing and synthesizing the Chinese and foreign literature and periodical data, the author studies and draws lessons from the research results of legalization of adolescent Internet behavior in various disciplines at home and abroad, and puts forward targeted Suggestions for the cultivation of adolescent media literacy in combination with their psychological characteristics.

2.3.2. Interdisciplinary Comprehensive Research Method. The research on the cultivation of digital media literacy and network legal literacy of teenagers covers education, management, law, communication, psychology, sociology and other disciplines. The research on the legalization of young people's online behavior should also pay attention to the different focuses of various disciplines and integrate the research results of various disciplines to further realize the legalization of young people's online behavior management.

2.3.3. Case Questionnaire Analysis. This study randomly selected several teenagers in our province, conducted a comprehensive analysis of the status of their network media literacy through questionnaire survey, and proposed feasible countermeasures for improvement on this basis. The biggest advantage of questionnaire survey is that it can obtain the relevant psychological and behavioral information of the subjects to the greatest extent and provide objective and accurate data for the study. This study through the medium of youth network, pay attention to the investigation of the use of time, contact information and the choice of the digital resource and so on the content of the information to the analysis of current teenagers use of network media, and on the basis of this puts forward the specific content of teenagers' media literacy cultivation and guidelines, and make specific instructions to improve youth media literacy intervention.

2.3.4. Comparative Research Method. This paper collects western articles on the relationship between youth training and network ethics, conducts comparative research on Western analytical theories, in order to draw the analysis related to this article, and finds the training path of youth network ethics literacy from the comparison between China and the West, and points out my country's youth network ethics literacy in China. Inadequate cultivation.

2.3.5. Mathematical Statistics. In this study, SPSS 23.0 sociological statistical software was used to describe and analyze the data obtained from the questionnaire, and various types of data were compared and comprehensively analyzed to understand the status of the surveyed teenagers' Internet media literacy.

3. Survey on Internet Media Literacy Education for Teenagers

3.1. Purpose and Form of Investigation. The purpose of this survey is to improve the media literacy of teenagers, so that they can make more reasonable use of Internet media, thus setting up a correct world outlook, outlook on life and values, so that they can have a clearer understanding of Internet media and grow up healthily and happily under the background of Internet culture. At present, the current situation of adolescents' online ethics literacy is not optimistic. The phenomenon of adolescents' online behavior anomie is more common, and it is also reflected in the gender difference between men and women. Girls perform better than boys. This paper uses a descriptive exploratory research method to propose a feasible path choice for solving the problems existing in the cultivation of young people's Internet literacy, and build its corresponding cultivation mechanism. This research is mainly to analyze and grasp the real status of the current network media literacy of teenagers through the form of questionnaire, and then to study and analyze the existing problems and causes of the media literacy of teenagers, so as to put forward more practical countermeasures and Suggestions.

3.2. Selection of Survey Objects. According to the "Medium- and long-term Youth Development Plan (2016–2025)" initiated by the CPC Central Committee and the State Council, the age range of young people is limited to 14 to 35. According to academic tradition and actual research needs, the lower limit is 18 years old and the upper limit is 30 years old. In this study, 315 people and 225 social youth, a total of 540 people, were randomly selected from major universities in Our province, and this was taken as the survey sample to try to understand the actual situation of the media literacy of teenagers at present. At the same time, some respondents were interviewed randomly in the process of the survey, so as to better analyze the current status of media literacy of teenagers and the respondents' understanding and thoughts on media literacy with better auxiliary data. The basic information of the respondents is shown in Table 1.

3.3. Survey Implementation. Questionnaires were distributed through the combination of online questionnaires and offline questionnaires. Off-line questionnaires were distributed and collected on-site by the executive staff of this study. Online questionnaires were conducted in the form of "star questionnaire," expressing gratitude to the respondents who answered the questions carefully, in exchange for the quality of the answers meeting the research standards. After all questionnaires were recovered, quality inspection was carried out on the recovered questionnaires. It was found that 37 questionnaires were excluded due to logic errors and missing selection, etc. The effective number of the final questionnaires was 503, and the overall recovery rate was 93.15%. In general, the sample in this survey has a relatively comprehensive coverage of age level and knowledge structure background. The sample structure is relatively scientific and reasonable, and the data in the research report has authenticity and reliability.

4. Survey Results and Analysis

4.1. Survey Results. This paper will analyze the current situation of media literacy of teenagers from four dimensions, namely, the popularity, purpose, duration and abstinence of digital media.

4.1.1. Popularity of Digital Media among Young People. The results of the survey on the usage preference of digital media are shown in Table 2 and Figure 1. According to the feedback data from the questionnaire results, 42.94% of teenagers choose to use mobile phones and 34.19% choose to use computers and tablet computers in their choice of media. The total number of newspapers, magazines and extra-curricular books is only 3.98%. This situation shows that teenagers tend to use paper media far less than digital media. Externalization is reflected in their desire to use digital media more in their daily lives, which is also the driving force to cultivate their media literacy.

Table 1: Basic information of respondents.

Item	Options	Sample size
Age	18–20	112
	21–23	154
	24–26	172
	27–30	102
Gender	Male	296
	Female	244
Education background	Senior high school and below	127
	Junior college	225
	University degree	165
	Postgraduate and above	23

Table 2: Survey results of digital media usage preference.

Product category	Frequency	Proportion (%)
Mobile phone	216	42.94
TV	41	8.15
Computers, tablets	172	34.19
Newspaper, magazine	20	3.98
Extracurricular books	29	5.77
Other	25	4.97

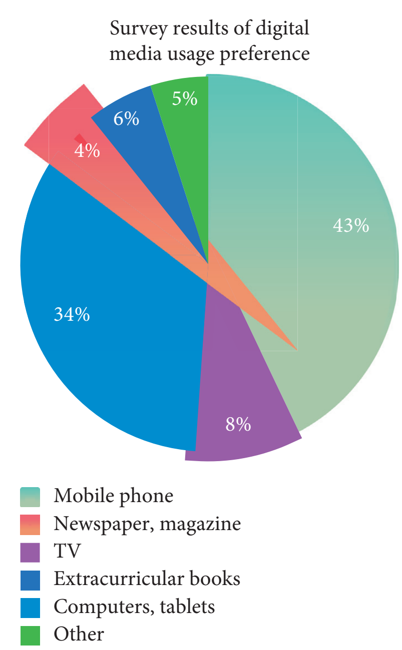


Figure 1: Survey results of digital media usage preferences.

4.1.2. Purpose of Accessing the Internet. The results of the survey on teenagers' Internet usage are shown in Table 3 and Figure 2. As can be seen from the figure, the most common purpose of the survey respondents is to search for information, and 42.94% of college students do so. Then there's chatting, gaming, and browsing in general, and we found that 5% of people do it for blogging, which is unusual in previous data. People's access to Internet media is based on certain needs. For example, looking up information, chatting and making friends, playing games and entertainment, etc., so this is also true for teenagers who are the majority of today's Internet users.

Table 3: Results of the survey on teenagers' Internet usage.

Application aim	Frequency	Proportion (%)
Data access	102	20.28
Chat with friends	112	22.27
Receive mail	51	10.14
Browse video	104	20.68
Play a game	132	26.24
Blogging	2	0.40

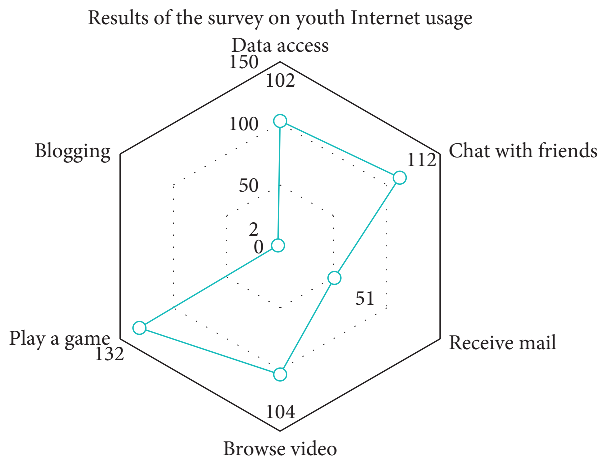


Figure 2: Results of the survey on teenagers' Internet usage.

4.1.3. Survey Results of Daily Usage Hours. The results of the survey on daily usage time of adolescents are shown in Table 4 and Figure 3. As can be seen from the chart, the number of teenagers who spend 1–3 hours in daily media exposure is the highest, accounting for 47.91%. The second was 4–6 hours, accounting for 32.01%; Very close to the proportion of less than 1 hour is more than 6 hours, accounting for 12.33% and 7.75% respectively. It can be seen that most teenagers use media for 1–3 hours a day, which is within a reasonable range.

4.1.4. Teenagers' Restrained Use of Virtual Network. The results of the survey on whether teenagers have enough self-control to refrain from using virtual network are shown in Figure 4. It can be found from the figure that, regardless of the total number of people, or stratified by age, nearly 70% of the teenagers fail to have access to the Internet and mobile phones except for normal study and use. This shows that virtual network has become an important part of teenagers' life. They have entered the normal life of teenagers and are still developing in an orderly way. If used properly, it can guide people to learn and lead young people to grow up more healthily. But if addicted to the network, it will have a strong attraction to the youth, and even cause the youth to degenerate.

To sum up, a considerable number of teenagers have a certain degree of network literacy, they have a good subject consciousness, have a basic understanding of bad information, can identify bad information and the ability to prevent deception, and can recognize that network literacy is important in personal growth. It is hoped and actively used

Table 4: Survey results of daily hours used by adolescents.

Duration of use	Frequency	Proportion (%)
Less than 1 hour	62	12.33
1–3 hours	241	47.91
4 to 6 hours	161	32.01
Over 6 hours	39	7.75

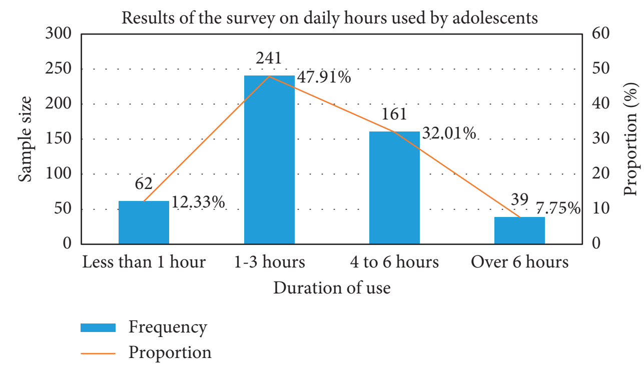


Figure 3: Survey results of daily hours used by adolescents.

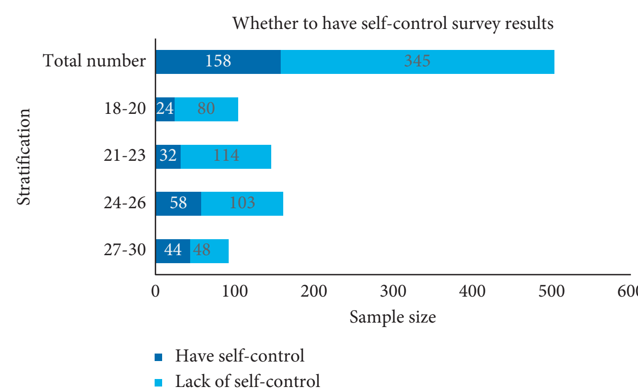


Figure 4: Survey results on whether adolescents have adequate capacity for self-restraint.

to improve their network literacy through various means. However, many young people have a vague understanding of the Internet and hold an indifferent attitude. The lack of knowledge is obvious, and there are also shortcomings in the practice of Internet ethics. They have not yet formed an attitude to actively learn Internet literacy knowledge. The authors must attach great importance to this reality, recognize the necessity and urgency of cultivating young people's Internet literacy, and then consciously improve the consciousness of young people's Internet education, and give full play to the leading role of school education in cultivating young people's Internet literacy, so as to help them in the future. A solid foundation is laid for healthy growth and success in the online world.

4.2. Analysis of the Current Situation of Teenagers' Internet Media Literacy. Through the above analysis and summary of the questionnaire results, we have a clearer and deeper understanding of the state of Internet media literacy of teenagers, and this situation also points out the specific direction for our further development of Internet media literacy education.

According to the data obtained from the survey, although the main source of information received by teenagers is the virtual network, their trust in the virtual network content is lower than that of traditional media. When judging information from different sources, teens were more likely to believe information published by the government or the news media. The revelation of unknown persons can also be treated with an objective and rational attitude. Thus it can be seen that most of the teenagers know how to choose and judge when facing the network information.

As a large audience group of network media, young students have frequent contact with network media and long time of using network media. When they get in touch with Internet media, most teenagers basically have a clear purpose. Some of them look up information, some chat, play games, and some write blogs. In addition, in the interview process, I learned that many teenagers play online games, chat and make friends, post blogs and other behaviors in contact with the Internet. They are ambivalent and very entangled. Hate and love the network media, can not get rid of and do not want to get rid of, always unconsciously. The existence of everything has two sides, the influence of the network on people is no exception, there are positive and negative. However, due to the immature psychology and physiology of teenagers, sometimes they cannot avoid the negative impact brought by the Internet. Young people have low social experience, imperfect will, poor ability to distinguish right from wrong, and are easily affected by unhealthy things on the Internet media. Young people are the future of the motherland, are the builders and successors of socialism, strengthen their education is particularly important. Then choosing the appropriate educational content is a very important issue. The content of the moral education curriculum in the past is too outdated, lacks a sense of the times, and cannot respond to the new situations and new problems in the network society in a timely manner, and sometimes even causes students' resentment and resistance., thus making them lose interest in learning. With the further impact of informatization on traditional morality, more and more obvious changes have taken place in the field of youth network literacy. Therefore, according to the changes of the situation, when the school adheres to the principle of pluralistic education in the aspect of online ethics education, it should also teach some basic and universal things to the young people, and keep the same as the original.

According to the survey data, more than a quarter of respondents believe that Internet media has a great influence on their life and study, and mobile phones account for more than a sixth. With the promotion and popularization of 5G wireless network, the number of people using mobile phones to surf the Internet will increase day by day. Internet media provides a free field for expression of opinions, but the freedom of cyberspace also gives rise to problems such as cyber violence. It can be seen from the study that the Internet has become a place for some teenagers to express their emotions, but most of them say that although they can express their emotions, they will not attack others and participate in online violence at will. It can be seen that teenagers enjoy greater freedom in online media, but most of them have certain self-restraint ability.

In general, most teenagers have basic network media literacy skills, but they better understanding is not enough for the content of the network media literacy, the former youth media literacy status quo is not optimistic, are worth pondering, necessary to have further study, the teenagers' media literacy education is urgent. In such an open online world, teenagers should strengthen the cultivation of online ethical literacy. Only in this way can they not follow the trend. The way is to form correct values. With the guidance of correct values, can they not lose themselves in the virtual online world. There is not only one correct value, all roads lead to Rome, there may be multiple judgments when faced with ethical dilemmas, and they may all be correct, but there is only one core value, people live in a specific environment, a country The basic national conditions of a person are the soil in which a person's correct values are formed. The national spirit with patriotism as the core and the spirit of the times with reform and innovation as the core are our correct core value pursuit, because it can best reflect the spiritual state of the era we live in.

4.3. Analysis of the Cultivation Mode of Legal Consciousness in Media Literacy. At present, the problems and deficiencies of young people in our country in terms of Internet literacy mainly include the following aspects: young people lack the intrinsic motivation of self-cultivation; the teaching conditions for Internet ethics literacy are not perfect; Internet laws and regulations are not perfect; family, as the carrier of inheriting the essence of traditional ethics, Failed to play the role of cultivating the basic ethics of young people.

In order to make judgments, there must be corresponding judgment standards. A good evaluation standard not only has a guiding role, but also reflects the effect of things. In order to better serve the improvement of young people's Internet literacy, corresponding network literacy should also be established. The purpose of the index system is to judge and measure its value and merit with a value evaluation standard that can be recognized by the public. The establishment of the index system must follow certain principles to organize and select, so as to make it more scientific and rational.

4.3.1. Cultivate Young People's Critical Attitude Towards Digital Media. Information is an important resource for the existence and development of individuals, organizations and society in the era of virtual network. The producers and disseminators of information often inject their own will and subjective views, which affect the comprehensiveness and objectivity of media citizens' information acquisition. When it comes to the core competence needed in the digital media era, the surveyed teenagers can also realize that critical inheritance is the key to the cultivation of media literacy among them.

The development of critical skills can not only help teenagers to view the messy digital information objectively, but also help them to solve practical problems. Therefore, teenagers should enhance in the selection of media information, the judgment and recognition ability, pay attention to cultivate their critical thinking of the new media information, learn to look at the view of media information, it seems to most teenagers to question, critical thinking and problem solving are inseparable, and add up to is in the new era of global knowledge economy for the first key ability, this is youth to actively participate in the key to education reform.

4.3.2. Colleges and Universities shall Establish Law Enforcement Mechanism for Juvenile Management. All kinds of colleges and universities are the key stage for teenagers to consolidate and finalize their world outlook, outlook on life and values. The internal educational administrative law enforcement in the management of college students is an internal administrative function department in colleges and universities, which manages student affairs in accordance with the statutory and prescribed powers and procedures. It has its own particularity, which comes from the autonomy of colleges and universities. Therefore, the administrative law enforcement of higher education should form its own law enforcement characteristics under the basic principles and requirements of the rule of law. As the implementers of online ethics education for teenagers, teachers themselves must have a deep understanding of the content and characteristics of online quality education, carry out teaching in a way suitable for teenagers, continuously improve teenagers' online literacy, and internalize this literacy into their inner literacy. Action guide.

The construction of law enforcement mechanism mainly focuses on educational administrative law enforcement, which includes the following four aspects: First, law enforcement is an administrative act that influences the rights and obligations of relevant subjects; Second, the process of law enforcement is the implementation and implementation of national laws and regulations and school rules and regulations. Third, law enforcement activities and procedures must be strictly implemented in accordance with legal procedures, and in accordance with the provisions of state laws and regulations; Fourth, from the perspective of colleges and universities to explore the construction of educational administrative law enforcement mechanism.

4.3.3. Carry Out in-Depth Publicity within the Social Scope. In the theoretical framework of sociology, people communicate with each other in a certain group, that is, the way people interact with each other guides people's behaviors. Then in the network society this large group, the lack of network legal consciousness norms. The more effective way to cultivate the social network legal consciousness is publicity, which is inseparable from the government's leading and support, especially the operation supported by the government or political groups.

When the society undertakes propagandize, want to notice the task of two points at the same time. First, it requires people to respond to and criticize the received information, and at the same time according to their own needs, rather than blindly following. Second, the free and personalized platform provided by the network society does not mean that people can do whatever they want in the network society. The legal system and norms in the real society should be equally useful in the network society. In addition, the cultivation of network legal awareness in the society should take into account the overall social environment and the nature of groups and other factors, and implement targeted cultivation methods in order to achieve the predicted effect.

4.3.4. The Government should Create a Good Network Media Education Environment. From the perspective of political structure, China is a society with relatively concentrated power, and governments at all levels have great power, while media literacy education is just a social system project, which needs the cooperation and support from all aspects of society. Therefore, the government is the key to promoting media literacy education in China. The government with public power can undertake the task of effectively allocating, integrating and utilizing social resources to carry out network media literacy education. In most countries with more developed media literacy, the importance of government as the leading force in media literacy education is obvious. Therefore, the Chinese government should also put the Internet media literacy education into the agenda of the work of the Party and government, supervise and summarize its development in a planned way to ensure its development effect.

5. Conclusion

This study first discusses that the typical illegal phenomenon in the network is the problem caused by the lack of network legal awareness, and analyzes the level of media literacy of the subject media in these cases and whether the network legal awareness is weak. The current situation of young people's network literacy is not optimistic, and it is necessary to strengthen the cultivation of this aspect. According to statistical analysis, a large number of teenagers have a weak awareness of Internet literacy, such as a negative and indifferent attitude towards hacking and bad information on the Internet, and many people use their own behavior to explain their lack of Internet literacy. A person's literacy is the internal driving force of his judgment, that is to say, what kind of literacy will make what kind of moral choice. From this point of view, there is sufficient practical and theoretical basis for strengthening the cultivation of young people's network ethics. Finally, from the perspective of school education, social publicity and national system training, this paper puts forward some Suggestions on how to improve teenagers' media literacy and cultivate their network legal literacy and create a harmonious network environment. It is found that teenagers, with low social experience, imperfect will and poor ability to distinguish right from wrong, are easily affected by unhealthy things on the Internet media. Young people are the future of the motherland, are the builders and successors of socialism, strengthen their education is particularly important. Based on this, this study points out that the cultivation of critical teenagers for digital media, law enforcement mechanism of management in colleges and universities to establish teenagers, propaganda on the society within the scope of the Internet concept of rule of law and the government and create a good environment for the network media education of corresponding measures, the strategies for cultivating network provides structural specifications to ensure that legal literacy.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

[1] M. Adil, M. A. Jan, S. Mastorakis et al., "Hash-MAC-DSDV: mutual authentication for intelligent IoT-based cyber-physical systems," *IEEE Internet of Things Journal*, 2021.

[2] A. Farouk, A. Alahmadi, S. Ghose, and A. Mashatan, "Blockchain platform for industrial healthcare: vision and future opportunities," *Computer Communications*, vol. 154, pp. 223–235, 2020.

[3] A. Farouk, J. Batle, M. Elhoseny et al., "Robust general N user authentication scheme in a centralized quantum communication network via generalized GHZ states," *Frontiers of Physics*, vol. 13, no. 2, pp. 1–18, 2018.

[4] M. Ranieri, I. Bruni, and A. C. O. D. Xivry, "Teachers' professional development on digital and media literacy. Findings and recommendations from a European project," *Research on Education & Media*, vol. 10, no. 2, p. 1, 2017.

[5] C. B. Meyers, "Social media influencers: a lesson plan for teaching digital advertising media literacy," *Advertising & Society Quarterly*, vol. 18, no. 2, p. 1353, 2017.

[6] D. Peicheva and V. Milenkova, "Knowledge society and digital media literacy: foundations for social inclusion and realization in Bulgarian context," *Calitatea Vietii*, vol. 28, no. 1, pp. 50–74, 2017.

[7] P. P. Pascual, "Mobile Learning through Digital Media Literacy," *Calico Journal, by Belinha S. de Abreu, B: Peter Lang, US $53.00*, vol. 35, no. 2, pp. 200–203, 2017.

[8] I. Yuliana, L. P. Octavia, and E. Sudarmilah, "Computational thinking digital media to improve digital literacy," *IOP Conference Series: Materials Science and Engineering*, vol. 821, no. 1, Article ID 012032, 2020.

[9] M. Adil, H. Song, J. Ali et al., "EnhancedAODV: a robust three phase priority-based traffic load balancing scheme for internet of things," *IEEE Internet of Things Journal*, 2021.

[10] H. Abulkasim, H. N. Alsuqaih, W. F. Hamdan et al., "Improved dynamic multi-party quantum private comparison for next-generation mobile network," *IEEE Access*, vol. 7, pp. 17917–17926, 2019.

[11] A. M. Guess, M. Lerner, B. Lyons et al., "A digital media literacy intervention increases discernment between mainstream and false news in the United States and India," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 117, no. 27, pp. 15536–15545, 2020.

[12] A. Rogers, "Global media literacy in a digital age: teaching beyond borders," *International Review of Education*, vol. 63, no. 1, pp. 137–139, 2017.

[13] S. Waters, "Movie-making apps and media literacy," *Journal of Adolescent & Adult Literacy*, vol. 61, no. 1, pp. 109–111, 2017.

[14] B. S. K. Chan, D. Churchill, and T. K. F. Chiu, "Digital literacy learning in higher education through digital storytelling approach," *Journal of International Education Research*, vol. 13, no. 1, pp. 1–16, 2017.

[15] E. Mansour, "A survey of digital information literacy (DIL) among academic library and information professionals," *Digital Library Perspectives*, vol. 33, no. 2, pp. 166–188, 2017.

[16] H. Burkhardt and G. Zwerger, "Use of digital media and technology in the ries geopark and their limits in practice," *Schriftenreihe der Deutschen Geologischen Gesellschaft*, vol. 94, no. 1, pp. 36–39, 2019.

[17] L. S. Connaway, H. Julien, M. Seadle, and A. Kasprak, "Digital literacy in the era of fake news: key roles for information professionals," *Proceedings of the Association for Information Science and Technology*, vol. 54, no. 1, pp. 554-555, 2017.

[18] M. H. Yi, M. J. Lim, H. Ko, and J. Shin, "Method of Profanity Detection Using Word Embedding and LSTM," *Mobile Information Systems*, vol. 2021, pp. 1–9, 2021.

[19] J. K. Malik and S. Choudhury, "Privacy and surveillance: the law relating to cyber crimes in India," *Journal of Engineering, Computing and Architecture*, vol. 9, no. 12, pp. 74–98, 2019.

[20] P. Tanodomdej, "The tallinn manuals and the making of the international law on cyber operations," *Masaryk University Journal of Law and Technology*, vol. 13, no. 1, pp. 67–86, 2019.

[21] M. Parasol, "The impact of China's 2016 Cyber Security Law on foreign technology firms, and on China's big data and Smart City dreams," *Computer Law & Security Report*, vol. 34, no. 1, pp. 67–98, 2018.

[22] A. Qi, G. Shao, and W. Zheng, "Assessing China's cybersecurity law," *Computer Law & Security Report*, vol. 34, no. 6, pp. 1342–1354, 2018.

[23] D.-K. Kipker, "Chinese Cybersecurity Law: update zu den aktuellen Entwicklungen," *Datenschutz und Datensicherheit—DuD*, vol. 43, no. 9, pp. 583–586, 2019.

[24] L. Huang, D. Lang, K. M. Arroll, and Z. Hou, "Understanding the impact of China's far-reaching new cybersecurity law," *Intellectual Property and Technology Law Journal*, vol. 30, no. 2, pp. 15–23, 2018.

[25] R. Weber, "DOD IG examines adequacy of info-sharing under cyber law," *The Pentagon*, vol. 34, no. 45, p. 11, 2018.

[26] C. Li, "A repeated call for omnibus federal cybersecurity law," *The Notre Dame Law Review*, vol. 94, 2019.

[27] D. K. Kipker, "VPN-Tunnelabschaltung and, Chinese Cybersecurity Law," *Datenschutz und Datensicherheit—DuD*, vol. 42, no. 9, pp. 574-575, 2018.

[28] A. Daniel, "Chinese cybersecurity law compared to EU-NIS-directive and German IT-security act," *Computer Law Review International*, vol. 19, no. 1, pp. 1–5, 2018.

[29] R. Weber, "FBI cites China's cyber law to stress implications of Huawei indictments," *The Pentagon*, vol. 35, no. 5, pp. 11-12, 2019.

[30] S. D. Jayasekara and I. Abeysekara, "Digital forensics and evolving cyber law: case of BIMSTEC countries," *Journal of Money Laundering Control*, vol. 22, no. 4, pp. 744–752, 2019.

Hindawi
Scientific Programming
Volume 2022, Article ID 3789810, 9 pages
https://doi.org/10.1155/2022/3789810

Research Article

A Bibliometrics Analysis on Teacher's Feedback Research Based on CiteSpace through Data Visualization

Wanji Xie

Foreign Language Department, Xi'an Jiaotong University City College, Xi'an 710018, Shaanxi, China

Correspondence should be addressed to Wanji Xie; 2030301029@st.btbu.edu.cn

Received 25 February 2022; Revised 19 March 2022; Accepted 21 March 2022; Published 12 April 2022

Academic Editor: Ahmed Farouk

Teacher feedback has played a pivotal role in students' foreign language learning. This article aims to gain a more comprehensive insight into the current situation and development trend of teacher feedback in core leading Chinese Academic Journal within the last decade using both CiteSpace and narrative analysis. Results show that (1) research on teacher feedback has undergone a dynamic increase in the past 10 years, with 2013 the summit; (2) research subjects have become more diversified rather than focusing only on undergraduates learning English; written and oral feedback are still two major research classifications; (3) empirical studies still dominates the field while theory exploration still employs nonempirical research. Future research should emphasize more on sustained development of authors and explore this field using more cross-discipline theories and taking multiple theoretical perspectives.

1. Preface

Feedback has been an important part in teaching and learning, be it from teachers or learner's peers. Research on feedback has always been a hot topic. Since a more well-developed notion of student feedback literacy came up in Carless' article in 2018 [1], how well students understand the feedback and what factors will influence students' perception of feedback has been "under scrutiny as never before" [2]. On the contrary, less attention has been paid to the feedback giver–teachers. Carless has proposed the interplay between teacher-student feedback literacy [3]. Han discussed the influences of teacher feedback on peer feedback [4]. More articles emphasized students' feedback literacy, using teacher feedback as one of the variables. Only a handful of research focuses on teachers and their perception of feedback, such as Boud et al. [2, 5].

Teacher feedback refers to teachers giving targeted recommendations or suggestions based on the understanding of students' current learning so that different aspects of their learning can be improved. Although it is not the leading research topic in recent years,with the rise of research on student feedback literacy, similar attention should be given back to teacher feedback practice so as to further deepen feedback research. Therefore, it is necessary to review previous research to know what aspects have been researched more thoroughly before and what new directions can be sought in the future.

For years, Chinese researchers are trying to follow and develop international research trends. However, due to the language barrier, most research articles are published in Chinese journals. With a large number of articles providing potential research subject and data, there is a need to review important articles on this topic in Chinese and hopefully shed some light on new research directions. In view of the above, this article intends to provide a review of teacher feedback study published in Chinese core journals, summarizing the developing process and results while discussing existing problems and future prospects.

2. Theory Basis of Teacher Feedback

Teacher feedback can be divided into instant oral feedback in class and written feedback focusing on writing, each with a different theoretical basis: Typical Communication Pattern in ESL Classroom Discourse (I-R-F), Process Approach, and Output Hypothesis.

2.1. Typical Communication Pattern in ESL Classroom Discourse. Classroom discourse is the language used by both teachers and students based on their own characters and needs in classrooms. The typical pattern in this discourse is I-R-F: teacher's questions (initiation), students' answers (response), and teachers' feedback (feedback) [6]. In this discourse pattern, the teacher dominates the process, controlling what to ask and what to answer; students are participants and passively engaged in the classroom activity. In this discourse pattern, teacher feedback has two characteristics: both evaluation and discourse. Its evaluative aspects focus on language quality, expecting students to pay attention to linguistic form to trigger self-correction. Its discourse aspect separates from linguistic form, focusing on the contents, which can better promote teaching contents, enrich student's knowledge bank, and represent a natural communication in the classroom.

2.2. Process Approach. Traditional writing class often employs a product approach, eyeing the completed text. Whereas students are limited by their own linguistic ability, they cannot achieve the final text in one go so they need an external push, teacher feedback being one of the most important approaches. Writing is a dynamic process, so focusing only on the result will lead to ignoring the process [7]. During the writing process, brainstorming, planning, multiple drafting, and revising are all indispensable. Teachers can be involved in each of the steps in different forms, communicating with students about their language, contents, or strategy. Based on students' individual characters, making sure students hold the responsibility of writing will help them improve writing quality and become better writers.

2.3. Output Hypothesis. Swain had proposed the Output Hypothesis: learners' output can promote them using the language more fluently and accurately [8]. However, a fundamental prerequisite of this hypothesis is to consciously pay attention to the linguistic form. Confined by their own language level and cognitive ability, students cannot realize their errors by themselves. External feedback from teachers will timely provide their use to the utmost, helping students focus on errors, test their own linguistic hypothesis, and enhance their language capacity.

3. Research Method

More and more empirical studies provide research data; therefore, meta-analysis has become a rising research method for overview articles [9], and the development of technology has offered more data analyzing methods. Zhang and Lin have used CiteSpace as a tool for quantitative analysis of research articles and provided a model for using such software for bibliometrics analysis [10]. Thus, this article employs the same tool for analyzing a different research area.

Nevertheless, nonempirical studies still account for part of all research, such as theory exploration, model building, and research overview. Since a narrative overview can cover more extensive research and explore each article at a deeper level, this article also employs a narrative method.

The data used in this article come from a Chinese research database -- China National Knowledge Infrastructure (CNKI). "Teacher feedback," "Teaching feedback" and "classroom feedback" are used as keywords, and all selected articles must meet the following requirements:

(1) Journals should be core journals or CSSCI (expanded included), based on the day when the article was published.
(2) Articles should include discussions on teacher feedback, and those only mentioning the topic are excluded.
(3) Articles should be research-based, excluding book reviews.
(4) Articles should be published between January 2011 and December 2020.

In total, 57 articles were finally chosen and coded to ease discussion, including author, publishing time, source, research topic, research subjects, and research methods.

4. Results

4.1. Publishing Time. It can be seen from Figure 1, the numbers between 2011 and 2013 are comparatively higher than the following years, with 2013 being the highest year: 19 articles were published within this year in core journals. From 2014 to 2020, the number fluctuated but remained at the low end with a total number of 20 articles, less than half of all articles selected. The rise and fall of article numbers demonstrate that this field has attracted less and less attention. New research angles or questions should be explored, or more cross-discipline research should be conducted.

4.2. Frequency of Authors. In CiteSpace author mapping, the bigger the names, the more articles this author published. The authors are also mapped based on whether they collaborated with other authors or worked independently. It can be seen from Figure 2, within the 57 articles; only Shulin YU has written three articles represented by the biggest font. All the other authors only published one article in this domain. Most authors write on their own, with only a few choosing to collaborate. This suggests that authors may not have sufficient follow-up studies and cannot provide focused research in this area. It is beneficial to have a large number of researchers on this topic, but it is against further development of this field to have very few authors persisting in this field. More collaborations are expected.

4.3. Publishing Sources. In total, 57 articles come from 34 journals, 10 of which have published two or more articles on teacher feedback. Details are presented in Figure 3.

Foreign Language World and Journal of PLA University of Foreign Language published the most articles on teacher

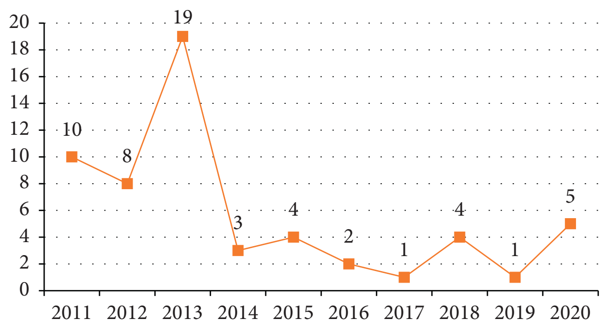


FIGURE 1: Numbers of articles on teacher feedback between 2011 and 2020.

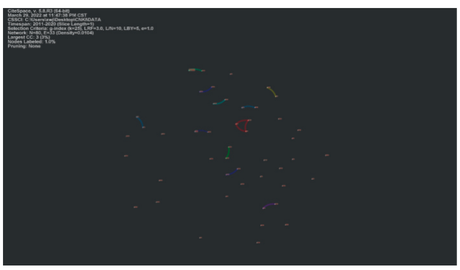


FIGURE 2: Author mapping of core articles on teacher feedback published from 2011 to 2020.

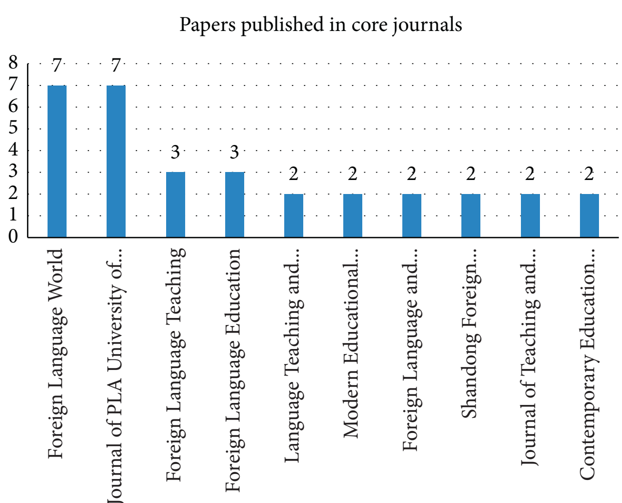


FIGURE 3: Numbers of articles published on teacher feedback from 2011 to 2020.

feedback, whereas Foreign Language Teaching and Foreign Language Education come third and fourth. This figure indicates the research on teacher feedback is mainly conducted in the foreign language teaching field. Although foreign language journals make up the majority of publishers in this field, journals from other fields also published relevant articles, such as Journal of Mathematics Education, Studies in Ideological Education, and Studies in Early Childhood Education, which shows a wide range of research topics and subjects.

4.4. Research Subjects. Dividedbased on their education level, most of the subjects are undergraduates, with 43 articles focusing on them. Other subjects include postgraduates (1 article), secondary education (3 articles), and preelementary and elementary education (4 articles). Most researchers are from higher education institutions, which means that undergraduates are convenient research subjects. However, students are engaged in feedback activities since they started being educated. Their experience of feedback and the environment where they receive feedback will exert an impact on how they view future feedback from teachers; therefore, it is important to further expand the range of research subjects to compare if students behave differently in different stages and possibly guide them better receive feedback.

Categorized by students' majors, research on teacher feedback in the last decade has been focused on languages: 29 articles on undergraduate English major and 18 articles on non-English major undergraduates. These articles provide a reasonably comprehensive understanding of students' reception of teacher feedback with different educational backgrounds. Three articles discussed relevant questions in Teaching Chinese as a Foreign Language (TCFL), and five more articles focused on how efficient teacher feedback is in mathematics, Chinese, physical education, and ideological and political lessons, showing that other majors have been paying attention to teacher feedback other than English language teaching field.

4.5. Research Keywords and Timeline View. CiteSpace provides a mapping function of the keywords of selected articles (see Figure 4) with a timeline view (see Figure 5). In the key words mapping, each node represents a keyword, and its size shows how frequently the words are used. Links between nodes represent their cooccurrence. The tighter they are clustered, the hotter the topic is [11]. As seen in Figure 4, "teacher feedback" is most frequently used as it is the research field. Other than "teacher feedback," "teacher discourse," "English writing," and "Interpretation teaching" are some of the more frequent keywords.

In Figure 5, CiteSpace provides a timeline view of all the selected articles. The articles are divided into four clusters with a timeline showing when it became a hot topic. Teacher oral feedback has been a focused topic in the first half of the last decade. Interest in written feedback on English writing also started at around the same time but lasted longer than oral feedback. Interpretation teaching only enjoyed a very brief focus in 2011 and 2012. Although it is hard to tell from the figure which aspect of teacher feedback won researcher's attention in the last five years, it can also be argued that the research interests are more varied and do not cluster together, which is a good indication that the field has been widened.

4.6. Research Questions. Teacher feedback research can be divided into the following five categories: overview, efficacy studies, comparative studies, theory/model building studies,

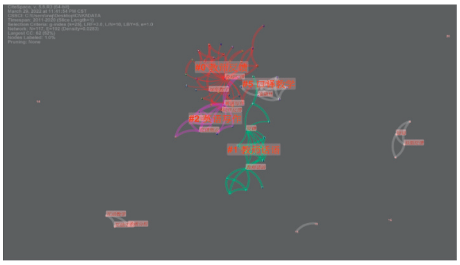


Figure 4: Keywords mapping of articles published on teacher feedback from 2011 to 2020.

and cross-discipline studies. The numbers of each category and main questions are illustrated in Table 1.

Almost half of the articles chosen are concerned with efficacy studies, followed by comparative studies with 21%. Cross-discipline studies account for 12% of all studies, and theory/model building and overviews take up 9% and 4%, respectively. This indicates that efficacy and comparative studies have always been the research focus in recent years, while less attention is paid to theory exploration and cross-discipline studies still have plenty of room for development.

4.7. Overview Studies. Over the decade, there have been few systematic overview studies on teacher feedback. Wang and Li put their emphasis on three modes of feedback using the latest technology and discussed the convenience and challenge brought by a revolution in the feedback model [12]. Zhai started from constructivism teaching and introduced the relevant theory, the conception of conversational teaching overseas, quoting several studies to prove its significance in the classroom for inquiry learning [13]. Wang et al. reviewed domestic and international studies on oral feedback given by teachers in classrooms [9, 14]. The former article used meta-analysis to review related empirical studies, pointing out that Chinese studies in this area could be deepened and widened in their choice of research subjects and research method in intervention studies. The latter article looked back on international studies on the research topic, methods, and trends, suggesting that Chinese researchers can focus on interactions among different factors and broaden the research scope. Among the four review articles, three articles were published before 2015, and the latest article is from 5 years ago. More research has been done since then, so there is a need for a more updated review.

4.8. Efficacy Studies. Efficacy studies mainly refer to the efficiency and effect brought by teacher feedback in classroom activities or homework, including oral and written feedback. Different feedback approaches are discussed in their impact on students' language ability and contents, and some research also commented on feedback skills and strategies.

In total, 14 articles investigated oral feedback, mainly on observation in the classroom about how teachers give real-time feedback or correct students' response. Lin extracted 9 Middle school English video classes. After transcription and coding, Lin discovered that teacher's feedback dominates classroom conversation, focusing more on linguistic form rather than contents [15]. Teng observed how college English teachers used feedback language in the classroom and transcribed what she observed--teachers had a preference for using positive feedback, and therefore she advised teachers to use different styles of feedback according to students' performance. Some articles made a parallel comparison between different teachers [16]. Lv discussed how male teachers and female teachers differ in their choice of feedback. Female teachers prefer to give more positive feedback and wait longer for students' responses, while male teachers tend to use more negative feedback and referential questions [17]. Wang compared how teachers give feedback in traditional classrooms and teaching competition showcases. She found that in competition showcases, teachers focus more on displaying their own teaching ability than what the students learn. Ending the turn-taking quickly means that the teacher cannot achieve meaningful communication with students, which is adverse to student's improvement [18].

Among the 14 articles, several articles are concerned about students in primary and secondary education or classes other than English. Dong thought teachers should use more positive feedback in teaching deaf children, giving them more confidence [19]. Li et al. study the relationship between teacher's questions and feedback, recommending teachers raise their question quality and pay more attention to students' way of thinking rather than their correctness [20]. Liu and He explored the question and answer in ideology and politics classes in college [21]. Li and Li reflected on how teachers use feedback in Chinese classes in primary schools [22]. Students in primary and secondary education often have less or more formatted homework, which is not easy for teachers to give in-depth feedback. Classroom teaching is still the main approach for students to acquire knowledge, and teaching efficiency is teacher's main concern. Therefore, research in these periods concentrates on classroom oral feedback, and conclusions often revolve around suggestions for teacher feedback practice and strategy.

Written teacher feedback is mainly focused on L2 writing text, and the efficacy study is about the improvement of students' language ability and richness in contents. Yang used a qualitative case study, discovering that a certain teacher concentrated highly on students' linguistic errors and little on text organization and contents. Even so, students still report being greatly helped in L2 writing ability and positively impacted on writing attitudes [23]. Wang and Liu studied whether teacher's written feedback can influence how students' texts meet assessment criteria. The study proves if students take feedback seriously and revise their text accordingly, their writings will greatly improve in language accuracy and organization [24]. Li did thorough research on teacher's feedback script, thinking corrective feedback should be used mainly for linguistic errors, and other feedback can be used to improve writing ideas and other aspects. Students' individual differences should also be taken into consideration so that more effective feedback can

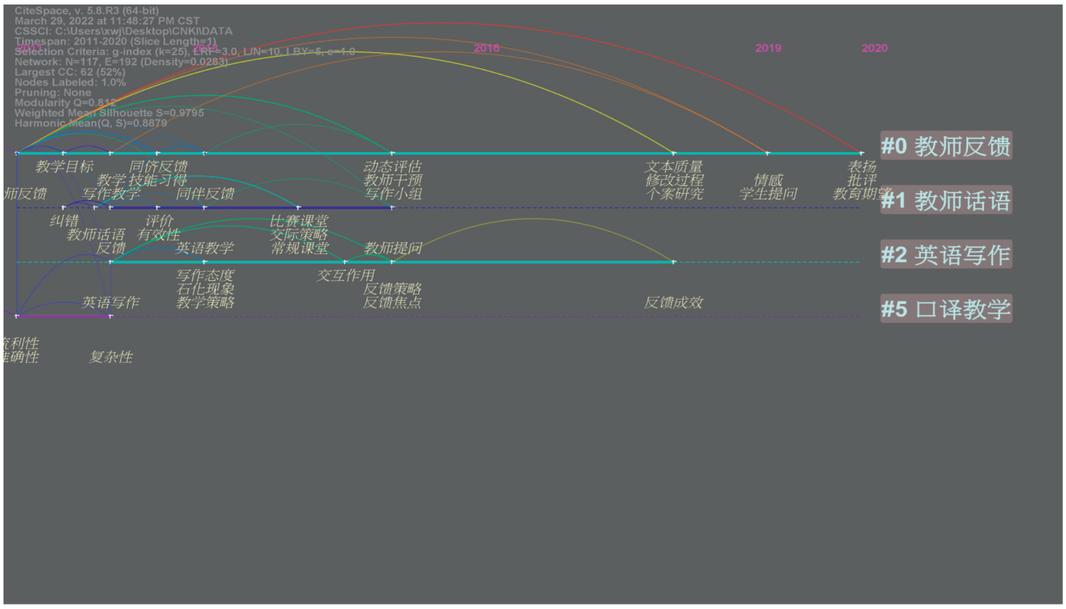


Figure 5: Timeline view of articles published on teacher feedback from 2011 to 2020.

Table 1: Categories of research topics on teacher feedback from 2011 to 2020.

	Main research question	Numbers	Percentage (%)
Overviews	Reviews on national and international research on teacher feedback theory, empirical studies, providing new research ideas	4	7
Efficacy studies	Efficacy of oral and written teacher feedback in classroom teaching, writing, and translation	26	46
Comparative studies	Comparison between teacher feedback with peer feedback, automatic feedback	12	21
Theory/model building	Discussion on feedback theory or buildup of a new theoretical model	5	9
Cross-discipline studies	Using teacher feedback as variables to discuss its relation with nonlinguistic skills	7	12
Others	Unable to be categorized	3	5
Total		57	100

be provided [25]. Niu and Zhang came to a similar conclusion [26]. Yu examined how teachers use Chinese as a medium for giving written feedback, providing a theoretical view on the interrelationship between teacher feedback and code-switching [27].

4.9. Comparative Studies. In total, 30% of all articles selected are concerned with comparative studies. In this area, researchers mainly compare the efficacy of teacher feedback with peer feedback or automated feedback, including how they impact L2 writing differently and how good is students' acceptance.

Many of the comparative studies focus on students' attitudes towards teacher feedback in comparison with other feedback modes. Ge et al. reported data on feedback acceptance [28–32]. All the above studies indicate students highly respect and accept teacher feedback, normally higher than peer and automated feedback. This can be attributed to the Chinese tradition of honoring the teacher and respecting his teaching, showing that students have full confidence in their teachers. Ge compared students' attitudes towards accepting written and face-to-face teacher feedback. She believed that the face-to-face mode is better than the written one, using face theory to explore the difference in students' acceptance in more detail [28]. Wang et al. thought different cognition styles will impact how well students accept different modes of feedback. Indirect feedback leads to a greater improvement in students' writing, and field-independent students are more prone to improve with teacher feedback [32].

In this research field, some researchers also compare the efficacy of different modes of feedback on L2 writing. Wang and Liu used a control and experimental group to find teacher feedback group has a significant improvement in language quality in their final L2 writing [24]. Sheng and Yu made a comparison between online automated feedback and teacher feedback and came to the conclusion that online automated feedback can further increase students' writing interest and improve language quality [33]. However, the research does not provide a full picture of the data, it is unclear what the teacher feedback is and if it had any impact on student's writing. Bai and Wang also compared automated feedback with teacher feedback but focused more on a different angle. The article concludes that teacher feedback can bring more progress in text contents and writing as a whole; automated feedback only concerns linguistic errors [34]. Thus, teacher feedback has an irreplaceable position in improving student's writing logic and organization. Liu compared teacher feedback only and teacher feedback plus peer feedback, thinking the latter had a better result in raising writing motivation and cultivating self-study ability [31].

In comparative studies, Yan used a delayed test of the same writing passage to explore the difference between student-initiated notice and feedback-initiated notice [35]. He concluded that only when students and teachers have an overlap in the notice, can long-term and effective improvement be achieved.

There are very few comparative studies on oral feedback. The main reason could be oral feedback is an instantaneous action and that a real-time environment is hard to replicate; therefore, it is very difficult to conduct comparable studies. Still, there are researchers who try to start from a bigger category: Lv compared the difference between genders and Wang found the difference in oral feedback in different settings [17, 18].

4.10. Theory/Model Building Studies. Not many articles have explored the theory related to teacher feedback. Yang proposed an error-correction strategy model, including participant, error types, timing, mode, and results [36]. Although this model is targeted at Interpretation class, there are still lessons to be learned by L2 writing. Qiao proposed the interaction hypothesis and communication factor in an authentic context and built an interactive spoken English teaching model, with teacher feedback as one important section [37]. Yu based his discussion on activity theory and proposed the L2 writing feedback model. The article suggests that teachers should maximize the combined effort of teacher feedback and peer feedback so that students enjoy the most improvement [38]. Hu and Zhang built an English writing feedback model and brought technological element to traditional model [39]. Huang constructed a "feedback for learning" model for vocabulary based on L2 writing vocabulary studies [40]. Further studies could refer to this paper and build relevant model for other L2 writing aspects. From the above discussion, it can be seen that future research should dig deeper into the underlying theory to form a more profound understanding and build a solid theoretical foundation for present and future research.

4.11. Cross-Discipline Studies. With the rise of cross-disciplinarity research, teacher feedback is not only confined to teaching and learning tasks. Some articles use teacher feedback (mainly oral feedback) as a variant to discuss student differences in nonlinguistic aspects. Guo and Shi used the structural equation model to compare course evaluation by undergraduates, trying to find a correlation between students' learning process and their academic achievement [41]. They discovered that teacher feedback has the biggest impact on the learning attitudes of students from humanity majors. Yao et al. analyzed whether the praise and criticism from teachers will influence students' self-expectation on academic achievement [42]. They discovered what the teacher expects from giving feedback does not always provide a positive stimulus. Tang and Luo studied when and how teachers give oral feedback in the classroom and analyzed its effect on students' confidence [43]. However, the article is more of a voice of experience rather than scientific research. Chen started with teacher feedback on "students initiated question," analyzed the value behind such phenomenon, and hoped "students initiated question" not only solves their confusion but also cultivates a correct learning attitude [44]. Wang and Liu found both low and high frequency of teacher feedback will affect students' goal orientation ability. Only with medium frequency of feedback, can students achieve a balance between pressure and motivation so as to obtain their goals [45]. Li and Liu used critical thinking theory to classify and analyze five dissertations of English major undergraduates [46]. Though each feedback has a different focus, they still exert a positive influence on student's critical thinking overall.

4.12. Research Methods. Scientific research methods can lead to reliable research results. In total, 57 selected studies can be divided into empirical studies and nonempirical studies. Former studies include using observation, questionnaires, interview transcription, and text study and often employ quantitative, qualitative, or a combination of the two methods. The latter studies include experience sharing, theory building, and overviews.

It is obvious from Figure 6 that empirical studies have always been the dominant research methods, which are employed by three-quarters of all studies. Nonempirical studies are more often seen in the early years, from 2011 to 2013. Analysis of objective data gives empirical studies the advantage of providing more scientific results. However, some research questions can only be answered by nonempirical methods, such as narrative overviews, theory or model building, and discussion. A combination of two research methods can complement each other to give a more comprehensive understanding of this field.

Different empirical studies use video/audio transcription, text study, questionnaires, and personal interviews. Teacher oral feedback often employs video/audio transcription because it is easier to study an instantaneous action at a later time. Text studies are widely used by L2 writing studies. Questionnaires and interviews have been the most commonly used approach. The former is often used for students' attitude research and interviews are mainly for case studies or small samples.

5. Retrospect and Prospect

Through a thorough review of studies on teacher feedback published in Chinese core journals from 2011 to 2020, it can be seen that research in this field has witnessed rapid

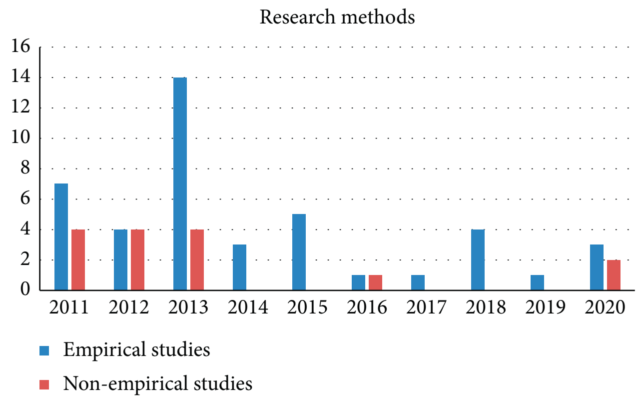


FIGURE 6: Categories of research methods on teacher feedback from 2011 to 2020.

development, with breakthroughs in both quantities and qualities. However, there are still some deficiencies and room for further investigation.

5.1. Studies on Efficacy Improvement. Existing research mainly focuses on how teacher feedback can affect students or a parallel of feedback modes in the same context. There are very few longitudinal researches in this field. Yan conducted the only research that discussed how one teacher used different modes of feedback in different situations [35]. Most oral feedback research provides suggestions on practice and strategy, but there are no follow-up studies exploring if these changes will lead to an increased efficacy or acceptance.

5.2. Teacher as Research Subject. Research paid much more attention to the practice of teacher feedback but ignored teachers as conscious participants who will be affected by their own identity and experience. Only Dong provided a relevant discussion. At the same time, establishing evaluation criteria is also an important factor in raising efficacy. There are reasonably well-developed theories and research groups on student feedback literacy [47], but few are about teacher feedback literacy. Carless and Winstone have provided a rudimentary model, which can be applied to Chinese educational settings after further research [3].

5.3. Diversification Studies. With the development of online technology, automated writing feedback is becoming more and more enriched. There are articles comparing automated online feedback and traditional teacher feedback, such as Cai et al. [29, 48]. Wang also introduced international online feedback research in the form of reviews [12]. The two feedback modes are not contradictory but rather complementary. Exploring how teachers can use AI or online platforms to increase feedback efficacy is also an area future research can tap into.

6. Conclusion

This article provides a bibliometrics analysis of teacher feedback published in Chinese core journal from 2011 to 2020, summarizing current research status and deficiency to discover new research interests with the help of CiteSpace. In the last decade, studies on teacher feedback display the following characteristics: (1) 2011 to 2013 is the ascent stage with most articles published in these years, and since 2014, research interest cooled down and fluctuated at the low end; (2) research questions are divided into oral and written feedback, and efficacy studies are dominant in both fields; (3) most research is done in higher education institutions and related to English, while a small number of studies are in primary and secondary education or non-English areas; (4) majority of studies are empirical and a few are nonempirical studies.

Several possible future research can also be found: (1) researchers should be encouraged to persist in this domain to conduct more profound research so as to promote further development; (2) improvement on feedback efficacy, teacher as research subject, and different modes of feedback giving can all be a new engine for research; (3) cross-discipline studies can be a new force to drive in-depth development in this field.

Data Availability

No data were used to support this study.

Disclosure

The author received no financial support for the research, authorship, and/or publication of this article.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this article.

References

[1] D. Carless and D. Boud, “The development of student feedback literacy: enabling uptake of feedback,” *Assessment & Evaluation in Higher Education*, vol. 43, no. 8, pp. 1315–1325, 2018.
[2] D. Boud and P. Dawson, “What feedback literate teachers do: an empirically-derived competency framework,” *Assessment & Evaluation in Higher Education*, pp. 1–14, 2021.
[3] D. Carless and N. Winstone, “Teacher feedback literacy and its interplay with student feedback literacy,” *Teaching in Higher Education*, pp. 1–14, 2020.
[4] Y. Han and Y. Xu, “The development of student feedback literacy: the influences of teacher feedback on peer feedback,” *Assessment & Evaluation in Higher Education*, vol. 45, no. 5, pp. 680–696, 2020.
[5] C. K. Y. Chan and J. Luo, “Exploring teacher perceptions of different types of ’feedback practices’ in higher education: implications for teacher feedback literacy,” *Assessment & Evaluation in Higher Education*, vol. 47, no. 1, pp. 61–76, 2022.

[6] Y. Chen, “Analysis of the typical communication pattern in ESL classroom discourse – the I-R-F chains,” *Shandong Foreign Language Teaching*, vol. 3, pp. 52–54, 2004.
[7] N. A. Chenoweth and J. R. Hayes, “Fluency in writing,” *Written Communication*, vol. 18, no. 1, pp. 80–98, 2001.
[8] M. Swain, “Output hypothesis: its history and its future,” *Foreign Language Teaching and Research*, vol. 01, pp. 45–50+81, 2008.
[9] W. Wang, “Twenty-five years' empirical research on L2 teachers' oral corrective feedback in China: a quasi meta-analysis,” *Foreign Language Learning Theory and Practice*, vol. 3, pp. 64–71, 2017.
[10] Y. Zhang and X. Lin, “A bibliometric analysis of China's peer feedback researches based on CiteSpace,” *Technology Enhanced Foreign Language Education*, vol. 196, no. 6, pp. 113–120, 2020.
[11] J. Li and C. Chen, *CiteSpace: Technological Text Digging and Data Visualization”*, Publishing House of Capital University of Economics and Business, Beijing, China, 2016.
[12] Y. Wang and Z. Li, “A critical review of electronic feedback in second language writing,” *Technology Enhanced Foreign Language Education*, vol. 4, pp. 11–16, 2012.
[13] J. Zhai, “Towards dialogic teaching: strategies and functions of teacher follow-up moves in classroom discourse,” *Primary & Secondary Schooling Abroad*, vol. 252, no. 12, pp. 39–43, 2013.
[14] Y. Fan and J. Xu, “Overviews on oral corrective feedback research in foreign language classrooms,” *Journal of PLA University of Foreign Languages*, vol. 39, no. 5, pp. 121–128, 2016.
[15] Z. Lin and S. Zhou, “A study of teacher feedback types and characteristics in Middle school English classes,” *Foreign Language Teaching Theory and Practice*, vol. 135, no. 3, pp. 15–22, 2011.
[16] B. Teng, “A survey in teacher feedback in college English classroom interaction,” *Journal of the Chinese Society of Education*, vol. 247, no. S4, pp. 46-47+50, 2013.
[17] C. Lv, “On gender differences manifested in college English teacher talk,” *Journal of PLA University of Foreign Languages*, vol. 35, no. 2, pp. 66–70, 2012.
[18] R. Wang, “Interactive strategy of feedback turn-taking of college English teachers: comparing teaching competition class and ordinary class,” *Journal of PLA University of Foreign Languages*, vol. 37, no. 4, pp. 74–83, 2014.
[19] B. Dong, “Studies on positive teacher feedback in deaf children education,” *Social Science Front*, vol. 216, no. 6, pp. 266–268, 2013.
[20] N. Li, Y. Mo, and L. Wu, “Types of mathematics teacher's feedback to students' mistakes in secondary school,” *Journal of Mathematics Education*, vol. 25, no. 5, pp. 55–60, 2016.
[21] X. Liu and Y. He, “Observation of questioning and answering in classroom,” *Studies in Ideological Education*, vol. 224, no. 7, pp. 57–60, 2013.
[22] X. Li and R. Li, “Teacher's teaching feedback: recognition, perspective and reflection – taking Chinese class in primary school as an example,” *Journal of Shanghai Educational Research*, vol. 393, no. 2, pp. 63–67, 2020.
[23] L. Yang, “A case study of the impact of teacher written feedback on Chinese EFL university students,” *Shandong Foreign Language Teaching*, vol. 34, no. 5, pp. 12–18, 2013.
[24] Y. Wang and Z. Liu, “A study of the effects of teacher feedback on accuracy, fluency, complexity and quality of EFL writing,” *Foreign Language Education*, vol. 33, no. 6, pp. 49–53, 2012.
[25] J. Li, “Case study of teacher written feedback and student response in Chinese students' writing,” *Foreign Language World*, vol. 147, no. 6, pp. 30–39, 2011.
[26] R. Niu and R. Zhang, “A case study of focus, strategy and efficacy of an L2 writing teacher's written feedback,” *Journal of PLA University of Foreign Languages*, vol. 3, pp. 91–99, 2018.
[27] S. Yu, “Understanding the mediating role of L1 in teacher written feedback: a sociocultural activity theory perspective,” *Foreign Language World*, vol. 155, no. 2, pp. 77–86, 2013.
[28] L. Ge, “On the effects of feedback from teacher assessment and peer assessment in English writing,” *Shandong Foreign Language Teaching*, vol. 32, no. 3, pp. 54–57, 2011.
[29] J. Cai, “A contrastive study of online peer feedback and online teacher feedback on Chinese college students' English writing,” *Foreign Language World*, vol. 143, no. 2, pp. 65–72, 2011.
[30] Y. Li, “Comparative studies on EFL writing feedback based on dynamic assessment,” *Foreign Language World*, vol. 3, pp. 59–67, 2015.
[31] Y. Liu, “A comparative study of teacher feedback and peer feedback in writing groups of English major,” *Foreign Language World*, vol. 1, pp. 48–55, 2015.
[32] L. Wang, F. Zhang, and Y. Wu, “The effects of different feedbacks in translation teaching,” *Shanghai Journal of Translators*, vol. 150, no. 1, pp. 82–87+95, 2020.
[33] R. Sheng and J. Yu, “A comparative study of online automated feedback and teacher feedback on L2 writing,” *China Adult Education*, vol. 307, no. 18, pp. 134–136, 2012.
[34] Y. Bai and J. Wang, “Effects of feedback modes on EFL students' revision process and text quality,” *Journal of Northeast Normal University*, vol. 2, pp. 134–139, 2018.
[35] R. Yan, “Learners' spontaneous and teacher's feedback-initiated attention in writing: relations and their effects on revision,” *Journal of PLA University of Foreign Languages*, vol. 34, no. 3, pp. 46–50+127, 2011.
[36] L. Yang, “Error correction strategy in Chinese-English interpretation class,” *Foreign Language Research*, vol. 128, no. 4, pp. 67–74, 2011.
[37] Y. Qiao, “Interactive oral English teaching in non-English majors,” *Journal of Southwest Minzu University(Humanities and Social Science)*, vol. 32, no. S2, pp. 128–131, 2011.
[38] S. Yu, “Revisiting teacher feedback and peer feedback: a sociocultural activity-theory perspective,” *Contemporary Foreign Language*, vol. 36, no. 1, pp. 70–76+110, 2013.
[39] C. Hu and Y. Zhang, “A study of college English writing feedback system based on M-learning,” *Modern Educational Technology*, vol. 24, no. 7, pp. 71–78, 2014.
[40] A. Huang, “Feedback for learning: the construction of mode of multi-feedback based on writing tasks,” *Foreign Language Education*, vol. 41, no. 6, pp. 67–71, 2020.
[41] F. Guo and J. Shi, “Study on the relationship between curriculum-based assessment and undergraduate learning of academic disciplines,” *The Journal of Higher Education*, vol. 35, no. 5, pp. 63–70, 2014.
[42] D. Yao, Y. Xu, and P. Zhang, “Teachers' feedback and students' educational expectations: heterogeneous impacts of praise and criticism on students' educational expectations,” *Economic Science*, vol. 239, no. 5, pp. 111–123, 2020.
[43] T. Tang and M. Luo, “A study on the establishment of students' confidence through error corrections,” *Foreign Language and Literature*, vol. 28, no. 4, pp. 136–138, 2012.
[44] Q. Chen, “Discussion on feedback of “student-initiated questions”: analysis of phenomenon and value,” *Contemporary Educational Science*, vol. 12, pp. 3–7, 2020.

[45] X. Wang and J. Liu, "Effects of teacher feedback frequency on students' goal orientation in physical education class," *Journal of Shenyang Sport University*, vol. 30, no. 3, pp. 61–63, 2011.
[46] L. Li and X. Liu, "Effects of teacher feedback on critical thinking cultivation: a case study," *Foreign Language World*, vol. 06, pp. 20–27, 2018.
[47] Y. Dong, "A synopsis of student feedback literacy: connotation, model and development," *Open Education Research*, vol. 26, no. 5, pp. 26–39, 2020.
[48] F. Yang and Q. Hu, "Reform of college English writing teaching based on bingo grading system – cooperative group writing model combining peer feedback and teacher's feedback," *Journal of Zhejiang SCI-TECH University*, vol. 30, no. 6, pp. 951–955, 2013.

Hindawi
Scientific Programming
Volume 2022, Article ID 8197740, 12 pages
https://doi.org/10.1155/2022/8197740

Research Article

Network Accounting Model in Intelligent Internet of Things Network Computing and Multimedia Environment

Shu Chen

College of Accounting, Zhanjiang University of Science and Technology, Zhanjiang 524000, Guangdong, China

Correspondence should be addressed to Shu Chen; 31415425@njau.edu.cn

Received 5 January 2022; Revised 24 January 2022; Accepted 28 February 2022; Published 4 April 2022

Academic Editor: Ahmed Farouk

This article focuses on the network charging model in the intelligent Internet of Things network computing and multimedia environment. The current human world has entered a century of economic development. The greatest feature of this century is knowledge economy. With the development of society, the importance of accounting has gradually increased. If accounting is better developed, education should be the basis. How to make students more systematically grasp the basic knowledge of accounting and the corresponding accounting methods is the focus of accounting education nowadays. In this paper, a new teaching model of network accounting under multimedia environment is proposed. On the basis of traditional teaching, multimedia technology is introduced. Through network technology, the platform of network accounting education under multimedia environment is designed to better realize the teaching of accounting course. Firstly, according to the specific teaching needs of students, the relevant functions are designed; secondly, B/S architecture mode is used in combination with database development technology to achieve the teaching system; finally, according to the user survey, the rationality and practicability of the system are analyzed. This article starts with the research status of science and technology and accounting informatization, analyzes the impact of the development of IoT technology on accounting theory and accounting work, and then discusses the promotion of these technologies to accounting informatization. The model proposed in this paper realizes the informatization of accounting and is bound to promote the informatization of accounting and realize the third leap of accounting informatization.

1. Introduction

Since the middle of the last century, with the development of the social science and technology revolution, the development of the information industry, and its industrialization in recent decades, an economic form that uses knowledge and information instead of old production factors, knowledge economy, is gradually taking shape on a global scale.

The growth of the IoT has become another force behind the Internet technology to promote the social process. The Internet of Things refers to the real-time collection of any information that needs to be monitored, connected, and realized between objects and objects, and objects and people through various devices and technologies such as various information sensors, radio frequency identification technology, global positioning system, infrared sensors, and laser scanners ubiquitous connection. The IoT is having an impact on human social life and production methods. Research on the impact of the Internet of Things on corporate management, especially on the construction of corporate accounting information, is of great significance.

First of all, college accounting undergraduate education is the main channel to train accountants. Apprentices should master the necessary professional knowledge of accountants in schools. In addition, due to the rapid changes in the environment, it is impossible for students to master all the rules within four years of the undergraduate course, and rote-learning knowledge cannot adapt to the complex and changeable environment. This requires colleges and universities to change the teaching content and structure, change examination-oriented education to quality-oriented education, and cultivate students' ability to adapt to the environment and innovation.

Secondly, information and network have changed the traditional teaching methods. Multimedia teaching is full of pictures and texts, which improves the learning fun for beginners and activates the scope of the classroom. Teachers do courseware well before class, which greatly saves the time of writing in class, makes use of classroom time more fully, and allows more effective time for imparting knowledge.

However, from the feedback from the talent market and various large-scale talent exchanges in recent years, we can see that the market demand for "accounting talents" has been saturated. However, the supply is expanding. The fundamental reason for this phenomenon is the blind development of accounting education. Taking higher education as an example, we find that almost all of the existing 1,000 universities in China have accounting majors, including teachers, engineering, agriculture, and forestry. There are also various colleges, secondary vocational schools, vocational high schools, and self-taught examinations, and various private schools are training "accounting talents." In a short period of more than ten years, the demand for accounting talents has changed from "tight demand" to "surplus." At present, accounting professionals account for more than one percent of the total population of the country, making China a unique "super accounting power" in the world. However, high-level, highly educated, and high-quality accounting talents, such as masters of accounting and doctors, are scarce. Although the demand for undergraduate accounting students is not small, because of the large graduate group, it is difficult for them to find employment, and it is even more difficult for junior accounting students to find jobs. Some employers say that they do not want graduates. They think that graduates have poor hands-on ability, practical ability, and innovative ability. They have a lot of problems in dealing with people and other things. Enterprises need to spend considerable energy on training after they are recruited, hence the general recruitment of college students with more than two years of work experience.

The educational situation in China is that the educational objectives are not clear and the educational boundaries at all levels are blurred. Although computers and networks have been basically popularized in China, the teaching methods in colleges and universities representing the advanced culture of the country are still mostly blackboard and chalk. In the era of information development, teachers still rely mainly on the short classroom time to teach students the contents of textbooks, and some of these contents have become obsolete.

From the above analysis, it can be seen that social needs have been changing and the economy has developed rapidly, but the school's accounting education has not changed. Undergraduate education is the main way to train accounting talents, so the reform is imperative.

In response to the new century, today, colleges and social education have conducted in-depth research on teaching concepts and teaching methods and constructed a diversified teaching model. Combining the application of the Internet of Things system and project display equipment, the use of advanced technologies such as informatization, digitization, and wireless to form network teaching has been comprehensively promoted.

At present, the research and application of China's online training platform lie in the promotion and use of online courseware. The apprentices learn on their own through online platforms and get advice from their instructors via e-mail or online chat. In addition, many online teaching systems provide functions such as online course selection, online grade examination registration, score query, and exchange forums.

Based on this, if we want to get close to the current era of knowledge economy, this article will study the accounting teaching mode, introduce the multimedia environment, design the online financial training mode in the new era, and realize the construction of online financial training. The system is realized through network technology in the new era.

2. The Underlying Logic of Accounting Training under New Technology

2.1. Concepts and Advantages of Information Technology Teaching. The term multimedia is composed of "multiple" and "media," usually understood as a composite of multiple media. The application fields of multimedia include education and training, e-commerce, information release, commercial advertising, film and television entertainment, and games. Multimedia is an artistic combination of words, graphics, images, audio, video, and animation transmitted to people by means of computer or other digital processing means, that is, the manifestation and transmission of various information carriers [1, 2].

Multimedia has the interaction [3], integration [4], real-time [5], multidimensional [6], and digital characteristics [7]. Interactivity enables students to have more participation and more active learning and helps students form new cognitive structures by creating an environment for reflection. Interactivity is the key feature of multimedia technology, which means that users can interact with various information media of computer, thus providing users with more effective means to control and use information. Integration refers to the computer-centric integrated processing of multiple information media, which includes the integration of information media and the integration of equipment handling these media. Multidimensionality is the diversification of computer computing media information. Digitization refers to the existence of media in digital form. Online response refers to the diversity of sounds and moving images (videos) over time.

New technology training means that the training content is taken from different purposes, after preparing lessons, reasonably applying advanced teaching technology, and effectively combining it with old teaching methods. Students use various information technologies to get better teaching results [8, 9]. That is to say, this kind of teaching mode is a theoretical teaching mode which takes multimedia technology as the medium, optimizes the teaching elements as the basis, uses different teaching methods and strategies to reflect the teaching content, and achieves the established teaching objectives.

2.2. The Significance of Multimedia Technology Applied to Teaching. Firstly, multimedia technology can arouse intellectual curiosity. Apprentices have weak economic accounting foundation, no good learning habits and methods, unclear learning objectives, and lack of interest in accounting professional knowledge learning. Multimedia technology can greatly enhance students' interest in learning knowledge. Multimedia has the characteristics of intuition, image, and richness. It has changed the single classroom mode of traditional teaching chalk plus blackboard and textbook plus teaching plan. Combining text, pictures, audio, video, etc. with vivid pictures, vivid colors, and rich language and cultural scenes presented to students realistically. This stimulates students' senses in many ways, adds interest and flexibility to classroom teaching, stimulates students' interest, and encourages them to learn with fun and curiosity.

Secondly, multimedia is conducive to creating communication situations. The purpose of accounting training is to improve students' ability to handle accounting-related business. This requires the instructor to focus on the explanation of processing skills and bring students into process thinking. Only when students are placed in a real environment and experience the process in an all-round way, can they learn relevant skills better. Multimedia can create a working environment and help apprentices to intuitively study accounting theory in the working environment.

Thirdly, multimedia technology can speed up training efficiency.

Fourthly, multimedia technology is conducive to improving teachers' quality. The application of multimedia technology can provide space for teachers to display their teaching ability. Teachers can combine teaching experience, reorganize teaching content, design rich and diverse classroom activities, and create a personalized teaching style. At the same time, multimedia teaching requires teachers to skillfully use a variety of media technologies and classroom teaching skills in teaching practice, so that boring book knowledge is transformed into vivid pictures, to enhance the interest of teaching, in order to stimulate students' thirst for knowledge.

2.3. The Theoretical Basis of Multimedia Teaching

2.3.1. Constructivist Theory. Constructivism [10] originated from the theory of Jean Piaget, a Swiss cognitive psychologist, including American psychologist and psychotherapist George Kelly's theory of "personal constructive psychology." This theory is the further development of behaviorism in learning theory after it develops to cognitivism. Constructivists believe that although the world exists objectively, people's understanding and giving meaning to the real world are determined by themselves; people construct and interpret the objective world on the basis of their own experience background. Because people have different experiences, there are also differences in their understanding of the outside world. They put forward a lot of their own opinions on education and summarize the existing experience into a new system [11].

The basic explanation of constructivism for learning is that education is a step by which researchers automatically construct mental representations. It has both theoretical information and a lot of nontheoretical information, that is, experience background. The knowledge construction of learners is not simply copying external information directly, but acquiring new information through their own cognitive structure. Therefore, knowledge cannot be acquired by external imparting. Constructivists put more emphasis on the role of informal experience background formed under the theory. They explained that the original teaching knowledge, concepts, and even the whole knowledge system can be transmitted from the speaker to the listener through words [12].

2.3.2. Dominant-Subject Teaching Theory. The "dominant-subject" teaching theory [13] adopts a relatively objective position and believes that the laws of the external world are objective and are not transferred by human will. The types of dominant teaching theories include knowledge-led teaching theories and development-led teaching theories. The process of people's understanding of the essential attributes of these objective things is the process of continuous learning. The learning process is not taught by teachers to these learners. It is the learners who interact and collaborate with the external environment according to their own life experience and original knowledge structure and explore, discover, and construct themselves. Because the learners' knowledge background and ability structure are different, and the depth, breadth, mode, and method of interaction with the environment are also different, this will inevitably lead to different learners' understanding of the same objective things at different levels, thus forming personalized knowledge. Therefore, the "dominant-subject" teaching theory emphasizes the importance of collaborative learning. Collaborative learning among different learners helps them to have a richer understanding of the same objective things, closer to objective facts.

2.4. Intelligent Internet of Things Based on BP Neural Network Algorithm. The learning rule of BP neural network is the generalized W-H learning rule. The BP network is used to add one or several layers of neurons between the input layer and the output layer. These neurons are called hidden units. They have no direct connection with the outside world, but their state changes can affect the relationship between input and output, and each layer can have several nodes. The target is approached gradually by calculating the change in the network weights and the deviation along the direction of decreasing relative error slope. The function used to calculate the error is defined as follows:

$$F(R,O) = \frac{1}{2}(P-H)^2 = \frac{1}{2}(K-RE-O)^2. \tag{1}$$

P is the target output, and H is the actual output. From the formula, it can be seen that the W-H rule is used to learn the desired output result by continuously updating the weights R and deviations O. In the learning process, for any ith output point, there are the following:

$$\Delta r_{ab} = -\theta \frac{\varepsilon Y}{\varepsilon y_{ab}} = \theta (p_a - h_a) w_b. \tag{2}$$

This can also be expressed as follows:

$$\begin{aligned} \Delta o_a &= -\varepsilon \vartheta_a, \\ \Delta r_{ab} &= -\varepsilon \vartheta w_b. \end{aligned} \tag{3}$$

ϑ_a is the error of the ath output point:

$$\delta_i = k_i - m_i. \tag{4}$$

ε is the learning rate. After extensive use by scholars in practice, it has been shown that it generally takes the value of 1.

$$\varepsilon = 0 \cdot 99 * \frac{1}{\max\left[\det\left(O * O^P\right)\right]}. \tag{5}$$

This time can improve the learning speed and can achieve good learning results.

A distinctive feature of BP neural networks is that their activation functions must be differentiable everywhere. An S-shaped logarithmic or tangential activation function is usually used. The Sigmoid logarithm is continuous and differentiable. The output layer uses a linear activation function to guarantee the output results of the network. Common types of activation functions include Sigmoid function, Tanh function, ReLU function, and Maxout function.

The BP neural network training process is divided into two steps: forward information transfer and backward error propagation. BP neural network has local minimization problems, slow convergence speed of algorithms, different configuration choices, and contradictory problems of prediction ability and training ability.

The output of any ath neuron in the hidden layer is as follows:

$$h1_a = g1\left(\sum_{b}^{r} t1_{ab} + o1_a\right) \quad (a = 1, 2, \ldots, n1). \tag{6}$$

The output of any pth neuron in the output layer is as follows:

$$h2_v = g2\left(\sum_{a=1}^{n1} t2_{va} h1_a + o2_v\right) \quad (v = 1, 2, \ldots, l2). \tag{7}$$

The error function is as follows:

$$F(R, O) = \frac{1}{2} \sum_{v=1}^{n2} \left(p_v - h2_v\right)^2. \tag{8}$$

If the output error of $h2_v$ is less than or equal to the set target error, $h2_v$ is output; if it is greater than the target error, the error is propagated backwards and the updated weights are modified.

Error backpropagation is as follows:

Updated output layer weights are as follows:

$$\Delta r2_{va} = -\varepsilon \frac{\theta F}{\varepsilon r2_{vb}} = -\varepsilon \frac{\theta G}{\varepsilon m2_h} \Delta \frac{\theta m2_h}{\varepsilon q2_{hi}} = \varepsilon \Delta \theta_{va} \Delta h1_a, \tag{9}$$

where

$$\begin{aligned} s_v &= p_v - h2_v, \\ \varepsilon_{va} &= s_v \Delta g2^{`}. \end{aligned} \tag{10}$$

By analogy, we can obtain the following:

$$\Delta O2_{va} = \varepsilon \left(p_v - h2_v\right) \Delta g2^{`} = \varepsilon \Delta \theta_{va}. \tag{11}$$

Implicit layer weights update is as follows:

$$\Delta r1_{va} = -\varepsilon \frac{\delta F}{\delta r1_{vb}} = \varepsilon \Delta \theta_{ab} \Delta o_b. \tag{12}$$

In the above equation,

$$\varepsilon_{ab} = s_a \Delta g1^{`}, \quad = p_v - h2_v, \tag{13}$$

and so on

$$\Delta o1_a = -\varepsilon \Delta \delta_{ab}. \tag{14}$$

The BP neural network algorithm can complete the training of the BP neural network model through the continuous iterative cycle through the above process.

In practical applications, a single hidden layer is generally used. Although multiple hidden layers can improve the accuracy of the network, they also increase the complexity and the training time of the network. The number of neurons in the hidden layer is usually determined by experience. In general, there are several commonly used empirical formulas for reference:

$$\begin{aligned} w &= \sqrt{tu}, \\ w &= \log_2 t, \\ w &= \sqrt{t+1} + n, \end{aligned} \tag{15}$$

where x is the number of neurons in the hidden layer, y is the number of nodes in the inflow layer, z is the number of nodes in the output layer, and a is usually a number between 1 and 10. Set the activation function of the network, and the S-type activation function is usually used. Set the output error of the network.

The adaptive degree based approach to complex Internet community research, such as the LFK algorithm, defines the adaptive degree function as follows:

$$b_R = \frac{K_{in}^R}{\left(K_{\text{in}}^R + K_{\text{out}}^R\right)^\beta}. \tag{16}$$

At the same time, R is a partitioned community. K_{in}^{R} represents the sum of the number of interconnected edges between each node in society R, i.e., twice the sum of the number of edges within the assigned society R. $K_{\text{out}}^{\text{R}}$ is the sum of the number of edges between nodes in society R that are connected to the outside of society R. ε is a social regulation parameter, which regulates the size of the community, but according to the thought experience, the value of ε is more reasonable between 1.0 and 1.6, and the value of ε chosen in this paper is 1.4. For any node O in the network, its adaptation to the community R is defined as the change of the community R joining and not adding the node O, and the amount of change is as follows:

$$b_R^O = b_{R+O} - b_R, \tag{17}$$

where b_{R+O} and b_R denote the adaptation degree of the community R containing node O and the original community R not containing node O, respectively. If $b_R^O > 0$, this means that the adaptation degree of node O increases after joining community R. If $b_R^O < 0$, this means that the adaptation degree of node O decreases after joining community R.

However, according to the adaptation formula, to determine whether a node can become a community, we must calculate the original communities $K_{\text{in}}^R + K_{\text{out}}^R$ to join the nodes, which greatly increases the computing time.

Therefore, the following improvements are made to the adaptation formula.

The community R after adding node O is given by (2).

$$b_{R+O} = \frac{K_{in}^{R+O}}{\left(K_{\text{in}}^{R+O} + K_{\text{out}}^{R+O}\right)^{\varphi}}. \tag{18}$$

The community R after joining node O can be obtained from (2). After joining node O, the edge k_O^R of the original community R connecting node O becomes an internal edge, the edge K_{in}^O of the node connecting community R also becomes an internal edge, and the edge K_{out}^O of node O connecting with the external node of the original community R becomes an external edge, so it can be obtained as follows:

$$\begin{aligned} K_{\text{out}}^{R+O} &= k_{\text{out}}^R + k_{\text{out}}^O - k_{\text{in}}^O, \\ K_{\text{in}}^{R+O} &= k_{\text{in}}^R + K_{\text{in}}^O + k_O^R. \end{aligned} \tag{19}$$

It can be shown that k_O^R and K_{in}^O are equal and can be equated as follows:

$$\begin{aligned} b_{R+O} &= \frac{K_{\text{in}}^{R+O} + 2K_{\text{in}}^O}{\left(k_{\text{in}}^R + K_{\text{in}}^O + k_{\text{out}}^R + k_{\text{out}}^O\right)^{\varphi}}, \\ K_{\text{in}}^{R+O} &= k_{\text{in}}^R + 2K_{\text{in}}^O. \end{aligned} \tag{20}$$

Therefore, only k_{in}^R and k_{out}^R of the initial community R need to be calculated once, and each time a new node is added in the future, only K_{in}^O and k_{out}^O need to be calculated to meet the requirements, thus greatly reducing the computing time consumption.

3. Design of Online Accounting Training Platform under New Technology Conditions

3.1. User Analysis. This article conforms to the theory of school entity online accounting teaching construction. This article mainly analyzes the needs of online accounting training management under new technical conditions from the perspective of new technology systems. The network accounting training management platform under the new technology has the following users:

3.1.1. System Administrator. The system administrator can handle various emergencies of the server and maintain the daily operation of the platform.

3.1.2. Teacher Users. Teacher users have the right to test, upload, and download teaching resources. In addition, they can use the function of communication and discussion to communicate with students or other teachers. Teachers can issue questions according to their own courses, publish them to the system, and notify the class students; after the students complete the test, teachers can grade papers and enter scores.

3.1.3. Student Users. Student users can modify part of their information and learn with the help of system resources. At the same time, after receiving the test notification, they can conduct online examination and query the results. Similarly, students can use the function of communication and discussion to discuss problems with other students or teachers.

3.1.4. Educational Administration Personnel. Education administrators need to summarize daily education work and also need to manage the information exchanged and discussed.

3.2. System Characteristics

(1) Having a clear and friendly user interface to facilitate user interaction can effectively attract the active participation of reviewers.

(2) Confirm user's permission clearly. For different users, different permissions should be granted, and different operation permissions should be exercised.

(3) Through the network, database maintenance and data statistics can be achieved.

(4) Provide useful help to enable users to familiarize themselves with the system and operate it as soon as possible.

(5) To maintain good compatibility between the educational administration system and the platform, the platform operation requirements must be compatible with daily work, and there are high requirements for normal and effective office operations.

(6) It has good data portability. Multiple evaluation rounds can be carried out in a certain time according to the need, and the specific time section of the corresponding rounds can be set by managers.

(7) Data resources, especially those required by the whole system, need to introduce management system module, encrypt the database, and centrally control all privileged operations.

(8) Provide language support in Chinese.

3.3. Basic Functional Module of the System. The services provided by the teaching system can be summarized into four main teaching components: demonstration, activity, communication, and management.

Demonstration is a practical application of the teaching platform. It is composed of textbooks of related courses and has the function of transmitting all related materials.

Activities include active and interactive learning materials with students participating in them. In most of the current network teaching systems, activities are evaluation-oriented, including exercises, tests, simulations, and experiments, and their main purpose is to evaluate the progress of students.

Administration contains all records related to the teaching system. These records preserve course information, teacher information, registered student status information, credit information, all behavior penalties of students in school, etc. The main purpose is to support the necessary management functions in the teaching process, such as student management and curriculum management.

Based on the ideas of Brusilovsky and Miller, online training platforms can enable all participants to communicate fully [14–16]. This kind of communication is particularly important. In addition, some key links to improve the quality of training in the traditional teaching process, such as homework and examination, should be well supported in the network teaching system, so that the network teaching can be transformed from a simple information dissemination system into a powerful, resource-rich, interactive, and communicative virtual learning community.

This article mainly studies the online financial training mode under the multimedia background. Based on the conditions of new technology, it provides a multifunctional teaching platform for training needs. The specific system design is shown in Figure 1.

4. Realization of Online Financial Training System under New Technology Conditions

4.1. Main Technology of the System. The technical framework of network accounting teaching system under multimedia environment will be based on B/S (browser/server) structure mode [17–19] multilayer architecture. The database server operating system will adopt Microsoft Windows Server 2003 operating system, the database management service will adopt Microsoft SQL Server 2005, the web client will adopt HTML [20–22] and JavaScript scripting language [23–25], and ASP.NET technology will be applied in the application server layer to process business logic data. The database types in the data server include Oracle, MSSQL, and MySQL. The hierarchical architecture of the system is shown in Figure 2.

The three-tier architecture is described in detail below.

User presentation layer: It is the program interface that the user sees and runs on the client computer. Through the browser, to complete the information release, participants pass their requests to the server by operating the business menu and display the returned result of the server. The user presentation layer does not perform actual data processing and only conveys the user's instruction to the business logic layer. The business logic is summed up by analyzing the application field of the software in the analysis phase. Its existence does not depend on the existence of the software. On the contrary, it exists before the software and limits the proper behavior of the software.

Business logic layer: After receiving the processing instructions from the initial layer, this layer transmits program files to complete business processing, generates a data processing request to the data access layer, and generates a user interface for the data returned by the database, and feeds it back to the user computer browser.

Data access layer: The database management system and database files are deployed on the database server. The data access layer responds to the data processing requests from program files; completes the operations of writing, reading, and deleting data of the database; and feeds back the data processing results to the business logic layer.

4.2. Operating Mode Selection. When designing the technical framework model of network accounting teaching system in multimedia environment, firstly, B/S mode is considered as the development model of network accounting teaching system in multimedia environment. The reason why the B/S mode is adopted is that the B/S mode has the following characteristics:

(1) The method is highly interactive and has a friendly interface. Universal browser runs applications designed for specific users and tasks, with online help, error prompts, and other functions.

(2) B/S mode is an open structure, facing a large number of users; even the use of firewall technology can not completely shield the network from hackers and malicious insiders of the system.

(3) B/S mode is a development mode for many users under the framework of web system. The communication HTTP used in the B/S mode can pass through the firewall system without too much consideration of the network restrictions. It has the characteristics of easy access. Logically, a three-tier structure is adopted. It establishes a webserver layer after browser and database server. All modules are installed in the webserver layer. In the browser, only general browser software is installed to access it, and it can be operated on the computer. The application is realized, and the use is simple. Therefore, the B/S mode simplifies the installation and deployment of users. Users can use browsers to complete operation access on any computer, which greatly reduces the operation complexity of users and administrators and also simplifies the cost and workload of maintenance, use, and upgrade of the system.

Selecting the financial comprehensive analysis function of the Harvard computing system can synchronize the output of the system content with the platform of the DuPont analysis system. The system is based on ROE as the leader, with net asset rate and equity multiplier as the core,

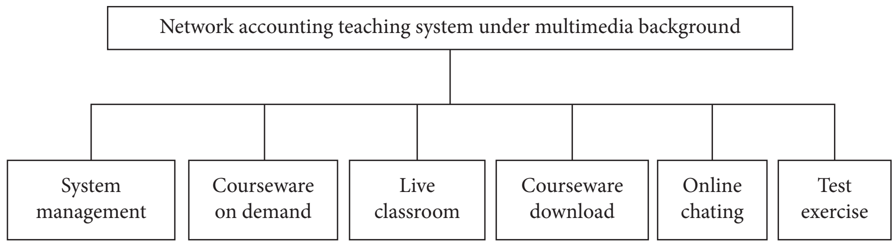


Figure 1: Design diagram of system function module.

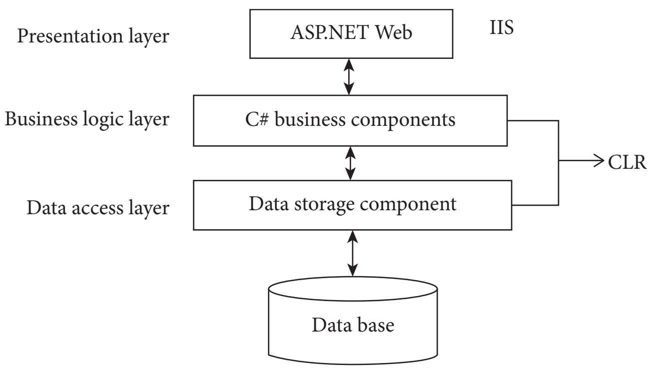


Figure 2: System layered architecture.

and focuses on revealing the impact of corporate profitability and equity multiplier on ROE, as well as the mutual influence of various related indicators. Besides, the platform provides a comparison of DuPont analysis results between S Group and the same industry's average value, median value, and other companies, as shown in Table 1.

Once it reaches 1.65, the system will automatically remind you. The financial early warning system must be highly sensitive, and it should predict the harbinger indicators when the crisis initially occurs, rather than the consequential indicators when it has fallen into a serious crisis state. It can be seen that the main influencing factors of the group's financial status are T4 and T5. Through financial early warning, you can focus on the main influencing factors in real time, as shown in Table 2.

Financial monitoring analysis includes monitoring of fund performance, accounts receivable monitoring, and sales budget completion monitoring. Check the overall sales budget and specific implementation progress of each agency in the sales monitoring analysis, as shown in Table 3.

4.3. Database System Selection. Considering the network operating environment and the cost of system deployment, the system uses SQL Server 2005, a large-scale network database of Microsoft Corporation in the United States. The selection basis of the database system is as follows:

(1) The data must support the relational network database system of standard SQL operation specification. Try to avoid large transaction operations, use the HOLDLOCK clause with caution, and improve the concurrency capability of the system; try to avoid repeatedly accessing the same table or several tables; try to avoid using cursors.

(2) It conforms to the system deployment environment in B/S mode.

(3) Program development solutions support ASP.NET, AJAX, and other technologies.

Table 1: S Group and DuPont analysis comparison table in the same industry.

Rank	Abbreviation	3-year average	2018	2019	2020
68	S Group	16.5	16.9	16.4	16.2
Industry average		18.6	18.2	19.4	18.2
Industry median		14.7	15.2	13.6	15.4
1	Can Qin Technology	60.1	64.4	61.2	54.8
2	Tengjing Technology	57.1	60.6	57.9	52.7

Table 2: System accounting forecast calculation table.

Quarter	T1	T2	T3	T4	T5	Z prediction	Actual monitering
2018-1	0.620	0.436	0.512	0.132	0.555	2.255	Risky
2018-2	0.580	0.165	0.373	0.555	0.622	2.295	Risky
2018-3	0.324	0.111	0.372	0.268	0.467	1.542	No risk
2018-4	0.090	0.363	0.086	0.600	0.635	1.774	Risky
2019-1	0.666	0.491	0.162	0.437	0.169	1.925	Risky
2019-2	0.404	0.597	0.464	0.185	0.163	1.813	Risky
2019-3	0.316	0.152	0.463	0.414	0.227	1.572	No risk
2019-4	0.464	0.36	0.173	0.341	0.371	1.709	Risky

The database management features of SQL Server 2005 are shown in Table 4.

4.4. System Implementation Effect Diagram. According to the above description, after designing the system function, this paper realizes the construction of the online accounting training platform through modern information technology and Internet of Things technology. The application fields of IoT technology include medical care, transportation, security, smart home, industry, and agriculture. The platform designed in this paper has various teaching-related functions. Among them, the platform management function can manage the user's basic information and select courses. Apprentices can preview and review the course through courseware on demand, so that they can learn the course better. The classroom live broadcast allows students to watch the teacher's classroom online and realize online teaching. The platform provides a button for caching class videos,

Table 3: The implementation and monitoring of platform financial budget.

Project		Budget	Reports	Offset	Statement	Schedule (%)
Commercial underwriting	Contractor A					
	Division a	30230.5	810.9	296.3	648.72	2.15
	Division b	42199.3	630.4	246.1	504.32	1.20
	Contractor B					
	Division c	33600	651.1	308.7	520.88	1.55
	Division d	43346.2	1126.5	243.8	901.2	2.08
	Subtotal	149376	3218.9	1094.9	2575.12	6.97
Factory-owned	Main plant					
	Branch 1	40083.7	1262.4	248.4	1009.92	2.52
	Branch 2	32022.6	606.6	213.8	485.28	1.52
	Branch 3	31876.5	895.4	221.9	716.32	2.25
	Subtotal	103982.8	2764.4	684.1	2211.52	6.28

Table 4: Characteristics of SQL Server 2005 database management.

Characteristic	Description
Database mirroring	The use of a new database calculation rule enhances the file transfer performance. This rule can make the server self-check and then self-repair when the server fails.
Online recovery	With the new version of the server, the database administrator can maintain the server without shutting it down, which improves the security of system operation.
Online retrieval operation	The latest data retrieval system can index more relevant data during server operation and can update the data on the basis of the original data.
Fast recovery	The database can flash some recent information to ensure that the data can be restored in the event of a server failure and ensure data security.
Improvement of safety performance	The server can use a more secure strategy to improve the efficiency of the firewall.
New SQL server management studio	The database is equipped with the latest toolkit, which expands the functions of the server.
Specialized administrator connection	The administrator can connect to the working server and diagnose fault types online in real time.
Snapshot isolation	The database can access any segment of data nodes through data isolation and improve retrieval efficiency.
Data segmentation	The database area division also has the function of improving the retrieval efficiency, which can effectively manage the server memory and ensure the service life of the server.
Enhancing replication function	The database designed in this paper shortens the decision-making time of the revised scheme and provides a variety of protocols for the transmission of various information.

which is convenient for students to use resources well. The online communication module provides a platform for communication between platform users. Students can search topics of interest on this platform or publish their own problems for help. The exercise and test module provides students with after-class exercises and the function of testing their own learning situation. In addition, teachers can also use the module to carry out ordinary tests and final examinations and keep abreast of students' learning situation at any time.

According to the above processing method, calculate the Eva forecast value of the sample enterprises in the extraordinary growth stage; see Table 5. Eva is a distributed database system that implements a time-aware, cumulative, and atomically consistent entity-attribute-value data model. Its API is generally compatible with Datomic's.

The two-stage growth model assumes that the company will enter a period of sustainable development after the extraordinary development stage. In this stage, the growth rate of the company will remain at a stable level for a long time.

The platform designed in this article will be described in detail below. After logging in to the platform, the login interface is shown in Figure 3. In this interface, users can log in by entering their user names and passwords. The system will jump to the page of the corresponding role according to the different roles of the user name in the user name database. If the user is using the platform proposed in this article for the first time, the user can log in to the system simply by registering.

Secondly, this paper introduces the courseware download module. When users select the module, they can see the interface shown in Figure 4. Users can download the courseware they are interested in in this module for review after class.

In addition, this paper introduces the exercise and test module, which can meet the students' need to test accounting-related knowledge, so as to better train students' accounting-related skills, so that students exercise knowledge and enhance their speed of processing information. The test interface is shown in Figure 5.

Table 5: Data processing in the extraordinary growth stage.

Listed company	NOPAT average	NOPAT Approximate growth rate (%)	WACC (%)
S group	43513446	56.9	29.7
Can Qin Technology	141583092	5.7	78.8
Tengjing Technology	152984355.5	31.0	76.1

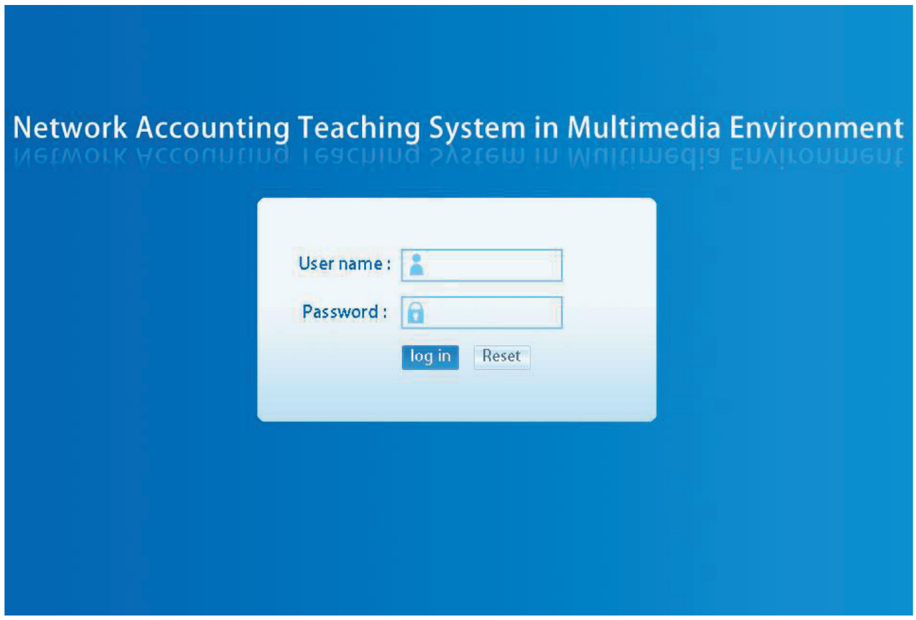


Figure 3: User login interface.

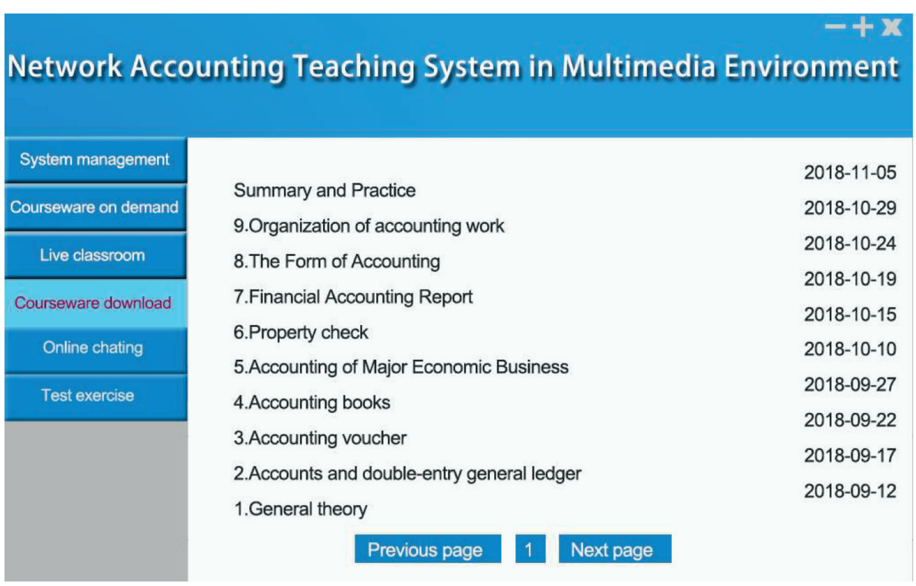


Figure 4: Courseware download interface.

In terms of corporate operations, after the application of the platform, S Group's capital utilization rate increased by 13%, profit margin increased by 9%, inventory turnover rate increased by 12%, problem handling time decreased by 18%, and inventory cycle decreased by 10%.

5. Test and Analysis of Platform Implementation Effect

For the practical performance and other functions of the platform proposed here, this article has conducted a number

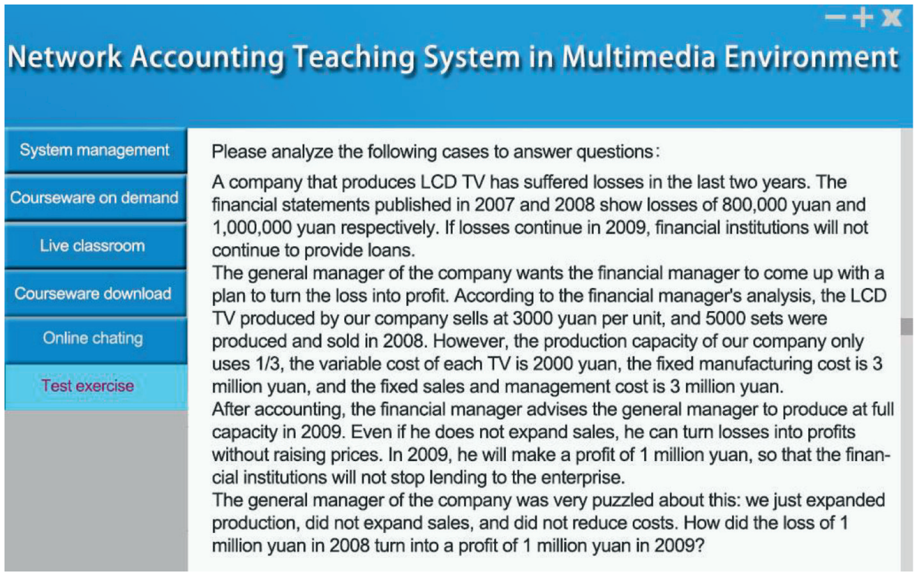


Figure 5: Test and exercise interface. S Group applied the Internet of Things accounting analysis platform constructed in this article, successfully tested it, and put it into use. The specific effects are shown in Table 6.

Table 6: Analysis table before and after platform application.

Analysis project		Comparative analysis		Conclusion
		Before building	After build	
Platform cost	Software development	43	24	49%
	Software maintenance	6	0	
Consolidated statement	Time (h)	360	1	
	Accuracy	75%	80%	20%
	Working saturation	85%	65%	
Financial analysis	Time (h)	120	1	
	Accuracy	85%	80%	20%
	Working saturation	80%	60%	
Financial monitoring	Time (h)	1650	1	
	Accuracy	75%	85%	25%
	Working saturation	85%	65%	
Financial decision	Time (h)	1580	1	
	Accuracy	85%	95%	30%
	Working saturation	90%	60%	

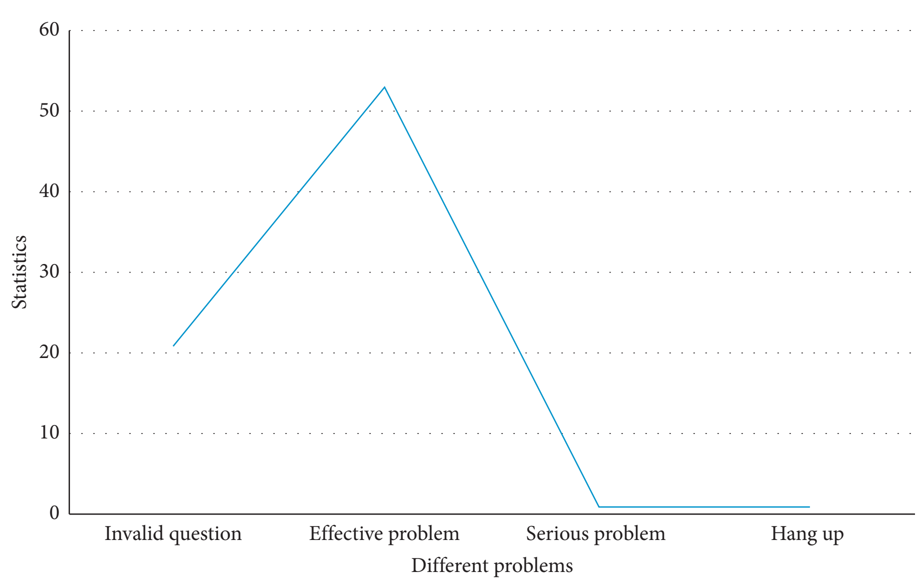


Figure 6: Statistical polygraph of defect problem.

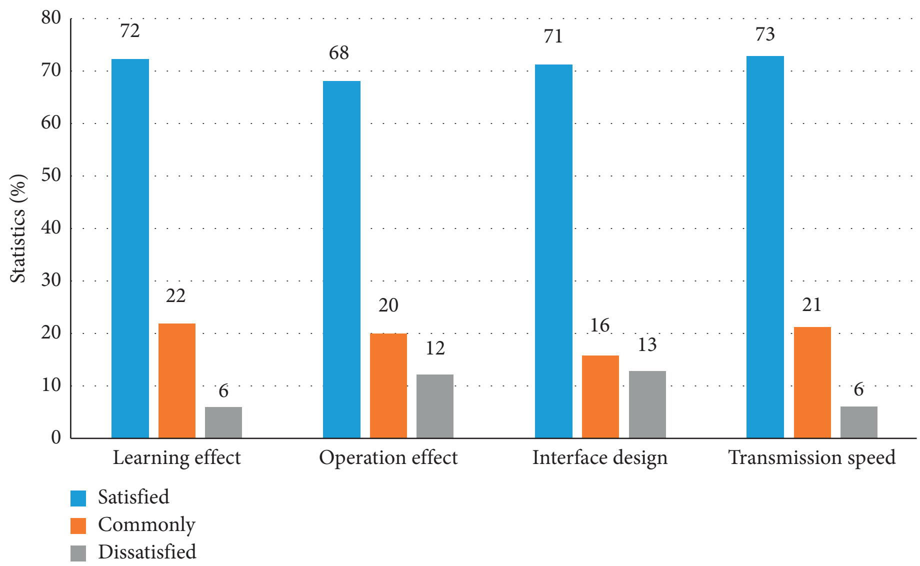


Figure 7: User experience questionnaire statistics.

of tests on it, and the specific test results can be found in the previous content of this paper.

Firstly, this paper takes two months as the testing cycle to test the system. In the testing process, the system will generate defect reports and record the specific content and time of the problem. In the two months of testing time, the statistics of defect problems generated in this paper are shown in Figure 6. As can be seen from the graph, 76 defects were found in the test time, including 21 ineffective problems, 53 effective problems, 1 serious problem, and 1 suspended problem. Among these problems, there is only one serious problem that causes the system to hang. Other problems do not have a great impact on the system. This shows that the system has good stability, reliability, and security. In addition, through statistics, this simple test system can effectively support 1000 users to operate online at the same time, and there is no abnormal phenomenon.

This article also selected a large number of users of this platform to conduct an experience survey. The statistical results are shown in Figure 7. It can be concluded that the contents of this survey are four aspects of teaching effectiveness. On the whole, users rate the system relatively highly. The abscissa of Figure 7 is the survey type.

6. Conclusion

Nowadays, as society enters the era of knowledge economy, accounting is becoming more and more important. The development of accounting based on education is a better solution to the country's talent gap for accounting personnel. The essence of the construction of accounting informatization under the IoT is the organic integration of the IoT and accounting work, and the core is the construction of an accounting information system. The model proposed in this article can realize the intelligence of accounting work and supervision work, accelerate the process of accounting informatization, and serve industrial management. On the basis of traditional teaching, we introduce multimedia technology, design corresponding functions according to students' specific needs, and use B/S architecture mode, combined with network technology such as database, to realize the construction of network accounting teaching system under multimedia background. Finally, a questionnaire survey on the performance and user experience of the system shows that the accounting training platform provided in this article can promote students' learning well.

Data Availability

The data that support the findings of this study are available from the author upon reasonable request.

Conflicts of Interest

The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Acknowledgments

This work was supported by Guangdong Province 2021–2022 Accounting Research Group Project (project no. 7-11); the research on the transformation and practice of accounting professional training in universities under the background of artificial intelligence in Zhanjiang—Taking Zhanjiang Institute of Science and Technology as an example (project no. 2021B01024); and Zhanjiang University of Science and Technology "Brand Promotion Program" School-Level Teaching Team Project: Accounting Professional Courses Ideological and Political Education Team (project no. PPJH202108JXTD).

References

[1] L. Gao, J. Song, X. Liu, J. Shao, J. Liu, and J. Shao, "Learning in high-dimensional multimedia data: the state of the art," *Multimedia Systems*, vol. 23, no. 3, pp. 303–313, 2017.

[2] R. Mohan, J. R. Smith, and C. S. Li, "Adapting multimedia Internet content for universal access," *IEEE Transactions on Multimedia*, vol. 1, no. 1, pp. 104–114, 2017.
[3] R. Moreno and R. E. Mayer, "Role of guidance, reflection, and interactivity in an agent-based multimedia game," *Journal of Educational Psychology*, vol. 97, no. 1, pp. 117–128, 2005.
[4] P. Hoschka, "An introduction to the synchronized multimedia integration language," *IEEE Multimedia*, vol. 5, no. 4, p. 84, 2002.
[5] L. Rui, S. Yang, and H. Huang, "A producer mobility support scheme for real-time multimedia delivery in named data networking," *Multimedia Tools and Applications*, vol. 77, no. 4, pp. 4811–4826, 2018.
[6] S. Abedi, "Efficient radio resource management for wireless multimedia communications: a multidimensional QoS-based packet scheduler," *IEEE Transactions on Wireless Communications*, vol. 4, no. 6, pp. 2811–2822, 2005.
[7] J. C. Mceachen, T. J. Cusack, and J. C. Mceachen, "A model for a PC-based, universal-format, multimedia digitization system," *Academic Radiology*, vol. 10, no. 8, pp. 914–918, 2003.
[8] M. Armenteros, S. S. Liaw, M. J. Sánchez-Franco, M. Fernanadez, and R. A. Sanchez, "Analysis of FIFA referees and assistant referees' motivational factors towards the Multimedia Teaching Materials," *Education and Information Technologies*, vol. 22, no. 3, 2017.
[9] C. Krstev and A. Trtovac, "Teaching multimedia documents to LIS students," *The Journal of Academic Librarianship*, vol. 40, no. 2, pp. 152–162, 2014.
[10] C. Tan, "Constructivism and pedagogical reform in China: issues and challenges," *Globalisation, Societies and Education*, vol. 15, no. 5, 2017.
[11] D. Alt, "Constructivist learning and openness to diversity and challenge in higher education environments," *Learning Environments Research*, vol. 20, no. 1, pp. 1–21, 2017.
[12] R. R. De Mello, "From constructivism to dialogism in the classroom. Theory and learning environments," *International Journal of Educational Psychology Ijep*, vol. 1, no. 2, pp. 127–152, 2012.
[13] A. W. K. Chow, "Teacher learning communities: the landscape of subject leadership," *International Journal of Educational Management*, vol. 30, no. 2, pp. 287–307, 2016.
[14] L. I. Fa-Chun, "Application and implementation of network teaching system using CallBack mechanism," *Computer and Modernization*, vol. 1, no. 6, pp. 151–155, 2013.
[15] X. Z. Sun, Y. L. Shangguan, and F. A. Wen, "Network teaching system based on lightweight J2EE framework," *Computer Engineering*, vol. 34, no. 6, pp. 266–268, 2008.
[16] Y. Li and E. Yani, "The research on learning behavior of Tibetan network teaching system," *IERI Procedia*, vol. 2, no. Complete, pp. 127–132, 2012.
[17] Y. Zhang, H. Liu, X. Su, P. Jiang, and D. Wei, "Remote mobile health monitoring system based on smart phone and browser/server structure," *Journal of Healthcare Engineering*, vol. 6, no. 4, pp. 717–738, 2015.
[18] Z. Y. Zhang and Y. Song, "A terahertz spectral database based on browser/server technique," *Guang Pu Xue Yu Guang Pu Fen Xi*, vol. 35, no. 9, pp. 2469–2472, 2015.
[19] X. Zhang, L. Cheng, and R. Zhong, "Implementation of multiarea-synchronous cooperative technology based on browser/server mode," *Computer Engineering*, vol. 31, no. 6, pp. 114–116, 2005.
[20] A. L. Sherter, "XML (hypertext markup language) makes the Web as easy as ABC," *Health Data Management*, vol. 6, no. 6, pp. 26–28, 1998.
[21] A. C. Schwickert, "Html - hypertext markup language," *Informatik-Spektrum*, vol. 20, no. 3, pp. 168-169, 1997.
[22] R. F. C. Internationalization, "Of the hypertext markup language," *Computer Science & Communications Dictionary*, vol. 42, no. 8, pp. 250-251, 1997.
[23] K. Chandra, S. S. Chandra, and S. Chandra, "A comparison of VBscript, javascript, and jscript," *Journal of Computing Sciences in Colleges*, vol. 19, no. 1, pp. 323–335, 2003.
[24] H. M. Kienle, "It's about time to take JavaScript (more) seriously," *IEEE Software*, vol. 27, no. 3, pp. 60–62, 2010.
[25] R. Toledo and E. Tanter, "Access control in JavaScript," *IEEE Software*, vol. 28, no. 5, pp. 76–84, 2011.

Hindawi
Scientific Programming
Volume 2022, Article ID 1118023, 10 pages
https://doi.org/10.1155/2022/1118023

Research Article

Financial Crisis Prediction Model of Listed Companies Based on Statistics and AI

Ying Wang

Department of Economics and Management, Luliang University, Lvliang 033000, Shanxi, China

Correspondence should be addressed to Ying Wang; wy2046@llu.edu.cn

Received 30 December 2021; Revised 12 February 2022; Accepted 28 February 2022; Published 31 March 2022

Academic Editor: Ahmed Farouk

In the fierce market competition, companies are constantly facing the threat of falling into GFC. A global financial crisis refers to a crisis in global financial assets or financial institutions or financial markets. However, the threat of a global financial crisis (GFC) is not helpless, but can be predicted in advance. Therefore, building a GFC prediction model is of great significance to the development of the company. This article mainly studies the GFC prediction model of listed companies based on statistics and AI methods. This paper chooses to determine the number of training samples and test samples as 40 and 16 respectively, that is, 8 companies are randomly selected as test samples from financial health companies and GFC companies respectively, and the remaining 40 become training samples. According to the primary selection of characteristic indicators, this paper adopts the frequency statistics method, that is, the higher frequency is selected through the previous research, and the indicator selection is made on this basis. This article will use the Kolmogorov–Smimov (K-S test) goodness-of-fit test method. Each of the early warning indicators selected in this article should be able to distinguish between GFC and non-GFC companies, so the selection should be made by indicators one by one. Bring the indicators of each year into the factor function formula obtained by factor analysis, and get a new variable group. Then SPSS16.0 was used for binomial logistic regression analysis for each year. This article uses KMO and Bartlett identification. The assumption of the sphericity test of the Bartlett test is that the correlation coefficient matrix is an identity matrix, and statistics are obtained according to the matrix formula of the correlation coefficient matrix. The prediction accuracy of the nonlinear combination discriminant method has been improved in the first three years of the GFC, and in the year ($t-3$), which is a little far away from the crisis time, the accuracy rate has reached 83%. The results show that the combination of statistics and AI has a significant effect on improving the prediction accuracy of the GFC prediction model of listed companies.

1. Introduction

With the active development of the capital market, companies can raise low-cost funds from the capital market to accelerate their development, and investors can use the operation of the capital market to invest and obtain higher returns. However, modern enterprises are facing an increasingly unlucky market environment, and risks always give operators a headache. The characteristics of the modern business environment are mainly reflected in economic globalization, rapid development of information technology, customer orientation, changes in business models and management methods. These factors are affected by politics, economy, society and technology. The survival process of a modern enterprise is a process in which various risks are continuously generated and resolved. When a GFC occurs in an enterprise, it will affect various degrees and seriously affect the interests of investors.

For investors, the establishment of an effective GFC early warning model helps corporate investors to correctly analyze, judge, and predict the financial status of the enterprise, establish correct investment concepts, and make correct investment decisions. Due to the asymmetry of information, most of the information obtained by investors will be delayed. If investors obtain information about abnormal corporate finances, losses are likely to occur. Therefore, being able to correctly judge the company's financial status and predict financial risks will help minimize the investment risks that are important to investors.

With the rapid development of financial integration, the financial security of various countries has seriously affected the pace of economic development of other countries. Konstantakopoulos et al. believes that the global financial crisis has had a significant impact on people's mental health, leading to an increasing incidence of mental disorders and suicide. Regarding the diagnostic classification rate of new CMHC cases each year, no significant difference was observed. Although his research has certain reference, it lacks some necessary data [1]. Motsi et al. studied the changes in bank competition behavior in sub-Saharan Africa after the 2007-2008 global financial crisis. He adopted the Panzar-Rosse competition model and found that the degree of competition among banks in sub-Saharan Africa has increased. Nevertheless, when the GFC broke out in 2007/2008, the success of the development of the banking system eased somewhat. Subsequently, as the regulator sought to restore system stability, the prudential policy underwent major adjustments, which once again had an impact on changing the competitive behavior of banks. Policymakers should continue to formulate and promote policies aimed at developing financial intermediaries and improving the competitive behavior of banks in sub-Saharan Africa. However, there is no specific experimental operation in his research [2]. Debunov believes that for companies under market conditions, not only the sum of profits is important, but also their financial capabilities. The ability of a company to resist the threat of bankruptcy is a necessary condition for its long-term operation and sustainable development. He proposed to use artificial neural networks to establish an economic mathematical model of corporate financial sustainability, remove human factors, and improve the speed and accuracy of corporate bankruptcy threat diagnosis. In the current conditions following the economic crisis of 2014-2015, an example of this model relates to Ukrainian companies. In order to establish a financial sustainability model, he constructed a three-layer artificial neural network for direct signal propagation. As an input factor, he suggested using 17 financial indicators to make the most comprehensive assessment of the company's financial sustainability. Although his model has certain reference value for financial institutions, investment funds, audit firms and enterprises themselves to predict corporate bankruptcy in time, it lacks specific experimental results [3].

In the construction of the indicator system, this article selects two aspects, financial indicators and nonfinancial indicators, to fully and accurately reflect the company's actual financial status and the company's overall picture. In the choice of the nonfinancial indicator system, the factors that have an impact on the company's financial goals are mainly considered, such as corporate governance factors, company ownership structure and auditing. This article analyzes the advantages and disadvantages of the model from three aspects: classification accuracy, two types of misjudgment costs, and operability, in order to find a model that is more suitable for enterprise GFC early warning research and has strong operability, and better help the relevant stakeholders of the enterprise avoid risks.

2. GFC Prediction Model for Listed Companies

2.1. Statistics and AI. Statistical data is a general term for the numerical data and other data related to the national economy and social phenomena obtained in the process of statistical work activities, and is the result of measuring the phenomenon. The Person χ^2 statistic is the sum of the relative square deviations between the actual observation frequency and the predicted frequency of the model. Then its calculation formula is [4]:

$$\chi^2 = \sum_{k}^{K} \frac{(O_k - E_k)^2}{E_k}. \tag{1}$$

Among them, K is the number of types of covariates, O_k represents the observation frequency of the k-th covariant type, E_k represents the prediction frequency of the k-th covariant type, and the degree of freedom is the difference between the number of covariate types and the number of parameters [5].

Let $\widehat{L}_s$ represent the maximum likelihood value estimated by the set model, which represents the degree to which the selected model fits the sample data, and $\widehat{L}_f$ represents the maximum likelihood value of the saturated model. $\widehat{L}_s/\widehat{L}_f$ is called the likelihood ratio [6]. Usually we use the natural logarithm of the likelihood ratio multiplied by −2 as the D statistic, then:

$$D = -2\ \ln\left(\frac{\widehat{L}_s}{\widehat{L}_f}\right) = -2\left(\ln\ \widehat{L}_s - \ln\ \widehat{L}_f\right). \tag{2}$$

The HL test data are arranged in ascending order of their predicted probabilities [7]. The statistical formula is as follows:

$$HL = \sum_{j=1}^{J} \frac{y_j - n_j\widehat{p}_j}{n_j\widehat{p}_j\left(1-\widehat{p}_j\right)}. \tag{3}$$

Among them, J is the number of groups, and $J \le 10$; n_j is the number of cases in the jth group; y_j is the number of observations of the jth group of events; $\widehat{p}_j$ is the predicted event probability of the jth group [8].

The empirical risk Remp (w) and the actual risk R (w) satisfy the following relationship with a probability of at least $1-\eta$ [9]:

$$R(w) \le \mathrm{Re}mp(w) + \sqrt{\frac{h(\ln(2n/h)+1) - \ln(\eta/4)}{n}}, \tag{4}$$

where h is the VC dimension of the function set, and n is the number of samples [10].

The classic radial basis function uses the following decision rules:

$$f(x) = \mathrm{sgn}\left[\sum_{i=1}^{l} a_i k_\gamma\left(|x - x_i|\right) + b\right]. \tag{5}$$

Among them, $k_\gamma(|x - x_i|)$ depends on the distance between the two vectors $(|x - x_i|)$ [11].

In general, a neuron is a multi-input, single-output nonlinear device, a neuron usually has multiple dendrites, which are mainly used to receive incoming information; while there is only one axon, and there are many axon terminals at the axon tail that can transmit information to other neurons. Axon terminals connect with the dendrites of other neurons to transmit signals. The location of this connection is biologically called a "synapse." and its expression is as follows [12]:

$$\begin{cases} \tau \dfrac{du_i}{d_t} = -u_i t + \sum w i_j x_j(t) - \theta_i, \\ \\ y_i t = f[u_i t]. \end{cases} \tag{6}$$

Among them, u_i is the internal state of the neuron, θ_i is the threshold, and wi_j represents the weight connected to the neuron i_j [13].

The output of the neuron is represented by the function f, and the S function is most commonly used to realize the non-linear characteristics of the network [14].

$$f(u_i) = \frac{1}{1 + \exp\left(-u_i/c\right)^2}. \tag{7}$$

Among them, c is a constant.

The network structure of Elman neural network is shown in Figure 1. Hidden layer neurons can use non-linear or linear transfer functions for transmission [15].

The non-linear state space expression of Elman neural network is [16]

$$\begin{aligned} x_c(k) &= x(k-1), \\ x(k) &= f(\omega x_c(k) + t\omega^2 n(u(k-1))), \\ y(k) &= g\left(\omega^3 x(k)\right). \end{aligned} \tag{8}$$

Among them, y, x, u, xc represent m-dimensional output neuron vector, n-dimensional hidden layer neuron vector, r-dimensional input vector and n-dimensional feedback state vector [17].

2.2. GFC Prediction Model. It is a gradual process for an enterprise to develop from the occurrence of financial risks to the GFC of the enterprise. Therefore, the GFC of the enterprise can be predicted. Therefore, the early warning of GFC is a very important part of the financial risk management of the entire enterprise, and it is effective. GFC early warning system can not only determine the status of corporate GFC, but also analyze the causes of corporate GFC, which can prompt companies to take corresponding countermeasures to avoid similar situations [18]. In addition, an effective GFC early warning system can issue early warning signals of corporate GFC in advance, so that companies can find financial risks in a timely manner and prescribe remedies, take relevant measures to control the spread of risks in a timely manner, and help companies return to normal financial status [19].

In a binary classification model with two situations in the dependent variable, in a binary classification model with two situations in the dependent variable, the dependent variable y is set to represent different results, and the dependent variable is the independent variable $x_1, x_2, \ldots, x_n$. When the error term μ_i exists, the regression model can be written as follows [20]:

$$Y_i = f(\alpha + X_i\beta) + \mu_i. \tag{9}$$

If the result value of the dependent variable y is 1, the probability is $p(y_i = 1 \mid x_i)$, then the probability that the result value of the dependent variable y is 0 is $1 - p(y_i = 1 \mid x_i)$, so that the value of the dependent variable is in the interval [0, 1], so write $F(X, \beta)$ into the following distribution function:

$$\begin{aligned} p(y_i = 0 \mid x_i) &= 1 - F(X, \beta), \\ p(y_i = 1 \mid x_i) &= F(X, \beta). \end{aligned} \tag{10}$$

Different prediction models correspond to different functional forms of $F(X, \beta)$. The logistic regression model is the prediction model when $F(X, \beta)$ takes the logistic function, namely $F(X, \beta) = \exp(X, \beta)/(1 + \exp(X, \beta))$, so the logistic regression model function form is as follows:

$$\begin{aligned} p(Y_i = 1 \mid X_i) &= \frac{e^{(\beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n)}}{1 + e^{(\beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n)}}. \\ \ln \frac{P}{1 - P} &= \beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n, \end{aligned} \tag{11}$$

When a GFC occurs, the financial risk early warning system can distinguish the causes of financial risks, and obtain the most likely causes of corporate financial risks and financial crises, so that the management can take effective measures in a timely and accurate manner to avoid the crisis. The financial risk early warning system can record the causes and roots of the crisis in detail, analyze the possible causes of the crisis in detail, and draw an analytical report, and formulate detailed measures and plans for the handling of such crises in the future. The loopholes in the existing management system and regulations can be remedied to improve the functions of the corporate financial early warning system and further reduce the potential hidden dangers of financial risks.

As a leader in the development of the market economy, listed companies have a relatively complete financial system. Facing the complicated and rapidly changing domestic and foreign economic situations, building a financial early warning model suitable for listed companies can enable management to detect abnormalities in financial operations early and prompt they adjusted their business strategies in advance to reduce the probability of deterioration in their financial situation. However, the financial early warning system cannot be widely used in my country's listed companies for some reasons. For example, the quality of accounting information affects the effectiveness of the financial early warning system, the decision-making level of listed companies lacks the awareness of actively using the financial early warning system, and the research on the practical application of the financial early warning system is not yet in place.

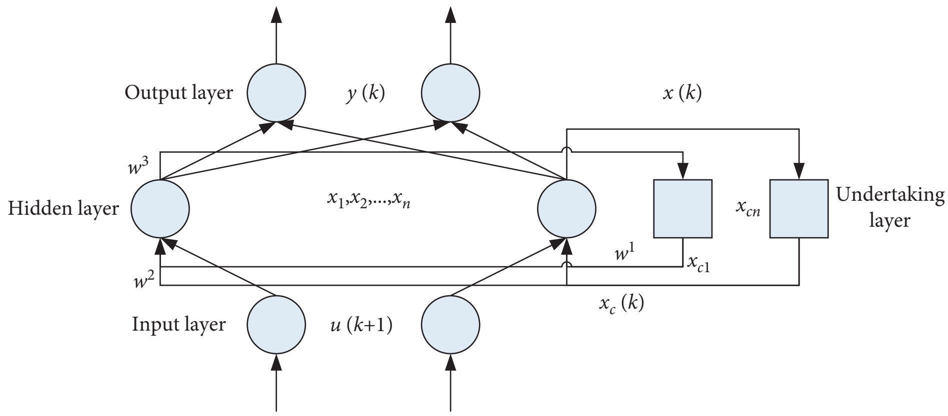


Figure 1: The network structure of the Elman neural network.

3. Simulation Experiment of the GFC Prediction Model of Listed Companies

3.1. Sources of Financial Data. The samples selected in this article involve various industries of listed companies in my country. This article mainly reflects the financial status of my country's listed companies from five indicators: solvency, profitability, operating ability, development ability and cash flow. Through the analysis of the significance of these indicators, 19 financial indicator systems were selected. When collecting and sorting out the data of 19 financial indicators, if there are missing data, the mean value of the nonmissing value closer to the missing value is used to fill it. Data with one-sidedness will not be selected. This paper finally chooses to determine the number of training samples and test samples as 40 and 16 respectively, that is, 8 companies are randomly selected as test samples from financial health companies and GFC companies respectively, and the remaining 40 become training samples. The sample grouping situation is shown in Table 1.

3.2. Selection of Financial Indicators. According to the primary selection of characteristic indicators, this paper adopts the frequency statistics method, that is, the higher frequency is selected through the previous research, and the guarantee is more general, and the indicator selection is carried out on this basis. This paper initially selects 23 financial indicators that reflect the five aspects of corporate profitability, debt solvency, operating capacity, growth capacity and cash flow, as shown in Table 2.

3.3. Normality Test of Early Warning Indicators. In statistics, there are two main types of normality tests for multivariate statistical analysis: one is to perform normality tests for each variable separately. If each variable conforms to normality, it is said that the multivariate conforms to the normal distribution; the second is to consider multiple variables at the same time and conduct a multivariate normality test. This article will use the Kolmogorov–Smimov (K-S test) goodness-of-fit test method. Each of the early warning indicators selected in this article should be able to distinguish between GFC and non-GFC companies, so the selection should be made by indicators one by one. In view of this, the normality test suitable for this article should be the first test method, that is, to verify whether each indicator conforms to the normal distribution.

3.4. Construction of GFC Prediction Model. Before creating and training the neural network, first initialize the neural network, the purpose is to prevent any remnants of previous values or operations from affecting the creation of the model. The initialization parameters of the neural network in this study are completely set according to the default values of the MALTAB software package. The larger the sample size of the neural network, the better it can be trained, and the higher the final training effect. Therefore, this article will divide all the samples into two parts based on the random selection method of the financial data of the first two years, the first three three years, the first four years of the crisis sample ST and the data of the corresponding years. A total of 415 sets of data are used as the input of the neural network to calculate the deviation between the output value and the expected value, and then calculated from the output layer to the input layer, adjusting each weight to reduce the deviation.

3.5. Test of Logistic Regression Model. Bring the indicators of each year into the factor function formula obtained by factor analysis, and get a new variable group. Then SPSS16.0 was used for binomial Logistic regression analysis for each year. The curve of the logistic regression model is S-shaped, and the predicted maximum value is close to 1, and the minimum value is close to 0. Usually, 50% is selected as the split point. In other words, if the value of the dependent variable calculated according to the model is greater than 0.5, it can be classified as a GFC enterprise. Otherwise, it can be regarded as a sound enterprise.

3.6. Factor Analysis. This article uses KMO and Bartlett identification. The KMO test statistic is an indicator used to compare simple and partial correlation coefficients between variables. The assumption of the sphericity test of the Bartlett

Table 1: Sample grouping situation.

	Training samples	Test sample	Total
Financial health company	20	8	28
GFC company	20	8	28
Total	40	16	56

Table 2: Financial indicators.

Evaluation content	Variable	Financial index	Evaluation content	Variable	Financial index
Profitability	X1	Return on assets	Operating capacity	X13	Accounts receivable turnover
	X2	Net profit margin of total assets		X14	Inventory turnover
	X3	Net profit margin of shareholders' equity		X15	Turnover of current assets
	X4	Gross profit margin		X16	Turnover of total assets
	X5	Operating income net profit margin	Growth ability	X17	Capital accumulation rate
	X6	Earnings per share		X18	Growth rate of total assets
	X7	Retained earnings ratio		X19	Net profit growth rate
Solvency	X8	Current ratio		X20	Growth rate of main business income
	X9	Quick ratio	Cash flow	X21	Ratio of cash flow to current liabilities
	X10	Ratio of working capital to total assets		X22	Cash ratio of main business income
	X11	Asset liability ratio		X23	Net cash flow from operating activities per share
	X12	Interest cover			

test is that the correlation coefficient matrix is an identity matrix, and statistics are obtained according to the matrix formula of the correlation coefficient matrix. If the value is large and the corresponding correlation probability value is less than the set validity level, the assumption is cancelled and the correlation coefficient matrix cannot be used as the identity matrix. In other words, there is a correlation between the original variables, which is suitable for factor analysis. In addition, it is not suitable for factor analysis.

4. Results and Discussion

The short-term solvency index variables selected in this article include: current ratio (X1), quick ratio (X2), working capital ratio (X3), cash ratio (X4) and working capital to total assets ratio (X5). The correlation analysis results between the variables X1, X2, X3, X4, and X5 are shown in Figure 2. From the results of the correlation analysis of the short-term solvency indicator variables, the correlation coefficient of the indicator variables X1 and X2 reached 0.9802, which is highly correlated. One of them should be removed, and the correlation between these two variables and other variables should be further analyzed. According to the principle of less correlation between the index variables, the index variable X1 is eliminated. According to the above method, the correlation between each index variable is compared one by one and eliminated one by one.

Taking $P = 0.5$ as the decision point, substituting the sample data of the training group to test the effect of the model, the results are shown in Table 3. For GFC companies, the forecast accuracy of $t-2$ year reached 89.8%, $t-3$ year reached 81.6%, and the forecasting ability declined sharply from $t-4$ year, and only 55.1% of GFC companies could be identified. In terms of reference to normal companies, the model maintained a relatively high recognition rate from $t-2$ to $t-4$, the lowest $t-2$ year also reached 81.6%, and the highest $t-3$ was 85.7%.

In order to explain these 8 factors, this paper uses the maximum variance method in the orthogonal rotation method to transform the factor loading matrix, as shown in Figure 3. The main variable of main component 1 is 0.887 expense and expense profit margin, which is much higher than other indicators. Explain the capital utilization efficiency of main component 1, and its representative index is the profit rate of expenses and expenses. The main variable of main component 2 is the total asset turnover rate of 0.830, which represents the equipment utilization rate of the asset. The factor load of the enterprise asset scale index of main component 3 is 0.713, which is significantly higher than other indexes, so the main component 3 can be interpreted as the asset scale factor, and its representative index is the total assets of the enterprise. The main factor load of main component 4's total asset growth rate is significantly higher than other indicators, so main component 4 can be interpreted as a growth factor, and its representative indicator is the growth rate of total assets. The main variable of main component 5 is the current ratio, which reflects the company's ability to pay. Therefore, the main component 5 can use the current ratio as a representative variable and summarize it as the debt repayment coefficient. In the main component 6, the main variable is the ratio of operating cash flow per share and the liquidity ratio of short-term loans, which reflects the company's ability to obtain cash. Therefore, the main component 6 can be summarized as cash flow factors and operating cash flow per share. In the main component 7 and the main component 8, the types of audit

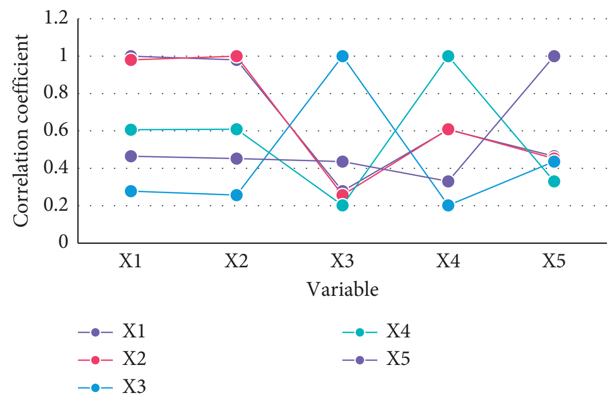


FIGURE 2: Correlation analysis results between variables X1, X2, X3, X4, X5.

TABLE 3: Sample model results of the training group.

$t-2$		Forecast results 0	Forecast results 1	Accuracy	Total accuracy
Original observations	0	44	5	0.89795918	0.857143
	1	9	40	0.81632653	
$t-3$		Forecast results 0	Forecast results 1	Accuracy	Total accuracy
Original observations	0	40	9	0.81632653	0.836735
	1	7	42	0.85714286	
$t-4$		Forecast results 0	Forecast results 1	Accuracy	Total accuracy
Original observations	0	27	22	0.55102041	0.693878
	1	8	41	0.83673469	

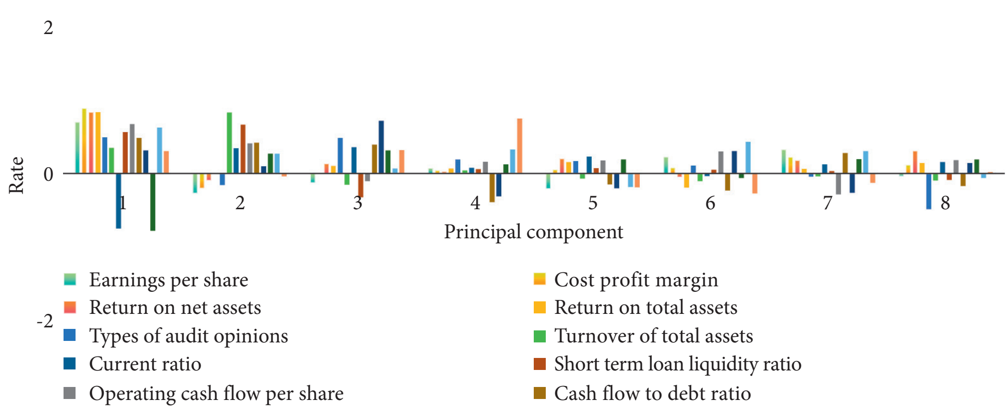


FIGURE 3: Factor load matrix.

opinions and the two indicators of profit per share have increased significantly compared with other indicators. The main variables of main component 7 are profit per share, return on net assets, and return on total assets.

The accuracy of the prediction model is shown in Table 4. In the three-category Logistic forecasting model, the rate of GFC companies being misjudged as non-GFC companies is 27.61%, the rate of non-GFC companies being misjudged as GFC companies is 7.14%, and the overall accuracy rate is 87.19%. The two-category logistic regression results show that the accuracy rate of companies in GFC is 62.70%, the accuracy rate of companies in non-GFC is 94.00%, and the total accuracy rate is 85.30%. From an overall point of view, the ordered three-catnon-financial crises, the accuracy of the former is 1.14% lower egory Logistic prediction model is better than the two-category Logistic prediction model, its accuracy rate is 1.89% higher, and the cost of misjudgment is relatively reduced. From the perspective of the accuracy of predicting than that of the latter, but from the accuracy of predicting financial crises, the accuracy of the former is higher than that of the latter 9.69%, which is of great significance in practical applications.

Table 4: Comparison of prediction model accuracy.

		Three classification logistic prediction model			Binary logistic prediction model	
		Non-GFC		GFC	Non-GFC	GFC
		(0)	2 (0)	3 (1)	0	1
Non-GFC	1 (0)	236	32	24	329	21
	2 (0)	18	39	13		
GFC	3 (1)	7	18	97	50	84
Miscalculation rate (%)		7.14		27.61	6.00	37.30
Accuracy rate (%)		92.86		72.39	94.00	62.70
Overall accuracy (%)		87.19			85.30	

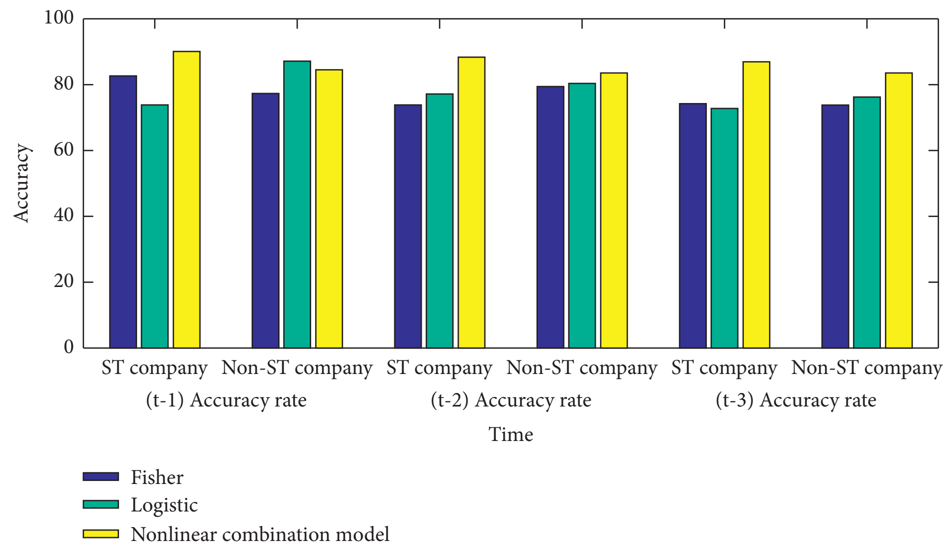


Figure 4: Comparison of prediction results of different models.

The empirical results of Fisher's two types of discriminant models, Logisic regression analysis model and nonlinear combination model based on BP neural network are compared as shown in Figure 4. It can be seen that the prediction accuracy of the nonlinear combination discriminant method has been improved in the first three years of the GFC, and in the year $(t-3)$, which is a little far away from the crisis time, the accuracy rate has reached more than 83%. This shows that the combined forecasting model can comprehensively consider the forecasting information of each individual model to a certain extent, thereby improving the forecasting accuracy.

The discrimination results of the BP neural network model are shown in Table 5. The results of the BP neural network's judgment and simulation of the control sample and the test sample respectively show that the control sample type I misjudgment (the GFC enterprise is misjudged as a financial health enterprise, that is, the number of false errors is 0, and the misjudgment rate is 0%, category II misjudgment (to judge a financial health company as a GFC company, that is, the number of true errors is 0, and the misjudgment rate is 0%. Therefore, the total number of misjudgments is 0, and the misjudgment rate is 0.0%. Therefore, the classification accuracy rate of the BP neural network for the control sample is 100%. The number of misjudgments for the test sample is 4, the misjudgment rate is 22.2%, and the misjudgment for the second type is 3, and the misjudgment rate The judgment rate is 16.7%, so the total number of misjudgments is 7, and the misjudgment rate is 19.5%. Therefore, the classification accuracy of the BP neural network on the test samples reaches 80.5%. In general, the BP neural network model has a good the forecast effect can be early warning of GFC three years in advance.

The comparison of the predicted value of the GFC early warning model is shown in Figure 5. The forecasting capabilities of the five GFC early warning models are all high. On the one hand, the accuracy of ST company's discrimination is higher than that of normal companies. It can be understood as: try to avoid misjudging ST company as a normal company in the experiment, meet the restriction of the first type of error in the statistical inspection, and reduce the inspection. On the other hand, the discriminant analysis model and regression analysis model are widely used, their prediction accuracy is very high, reaching 90%, its operation is simple, the requirements for samples are not harsh, and it reflects good predictive ability, which is most scholars why choose to use it. The overall prediction accuracy of the BP neural network is higher than that of the other two, which

Table 5: Discrimination results of BP neural network model.

Type of enterprise	Control sample			Test sample		
	0	1	Total	0	1	Total
0	28	0	28	15	3	18
1	0	28	28	4	14	18
Classification accuracy	100%	100%	100%	83.3%	77.8%	80.5%
Misjudgment rate	0%	0%	0%	22.2%	16.7%	19.5%

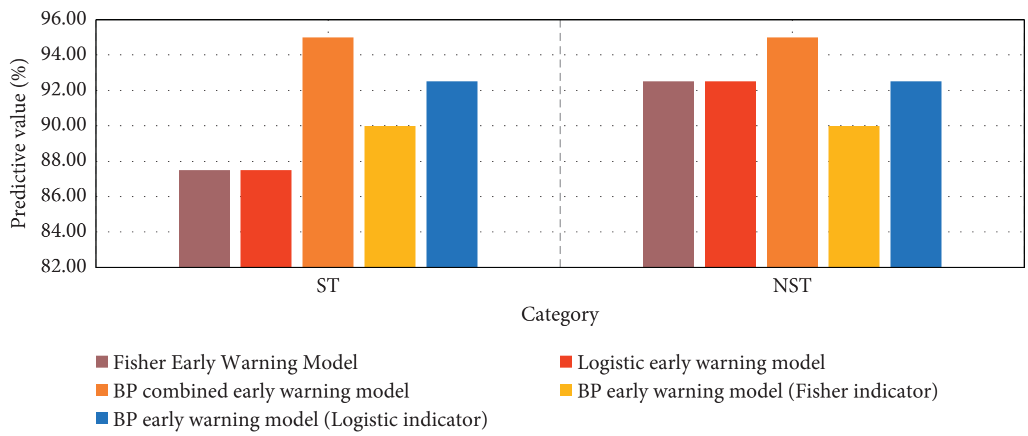


Figure 5: Comparison of prediction values of GFC early warning models.

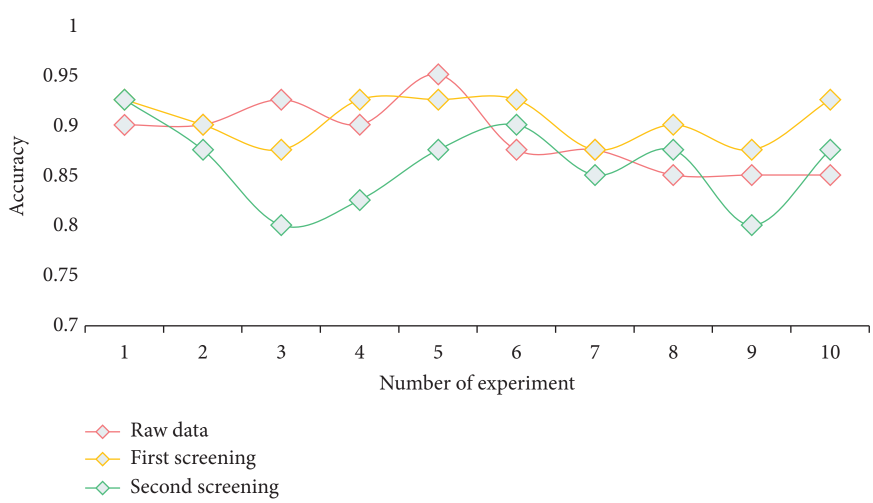


Figure 6: Prediction accuracy of PSO-SVM on different data.

mainly reflects the adaptability and fault tolerance of the neural network. In particular, the prediction accuracy of the BP combined prediction model is as high as 95%. The BP combined prediction model can compare the information of the subject sample. Classification integration improves the accuracy of prediction.

The accuracy of PSO-SVM for different data predictions is shown in Figure 6. It can be seen from the figure that the average accuracy of the model has reached 88%, 90.5%, and 86%, and the accuracy is within the interval of 0.8~0.95. The standard deviation shows that the prediction results produced by the model are The neatness is getting better and better with the continuous optimization of the index system. In the early warning of the three sets of sample data, the volatility of the data screened for the first time is relatively small, indicating that the PSO-SVM model established in this article has a relatively high degree of recognition of the data screened for the first time, and has reached a high degree of accuracy.

The performance comparison of early warning models is shown in Figure 7. The indicators of the two early warning models are above 80%, and both show good early warning performance. Comparing the indicators separately, it is found that the random forest model dominates the other

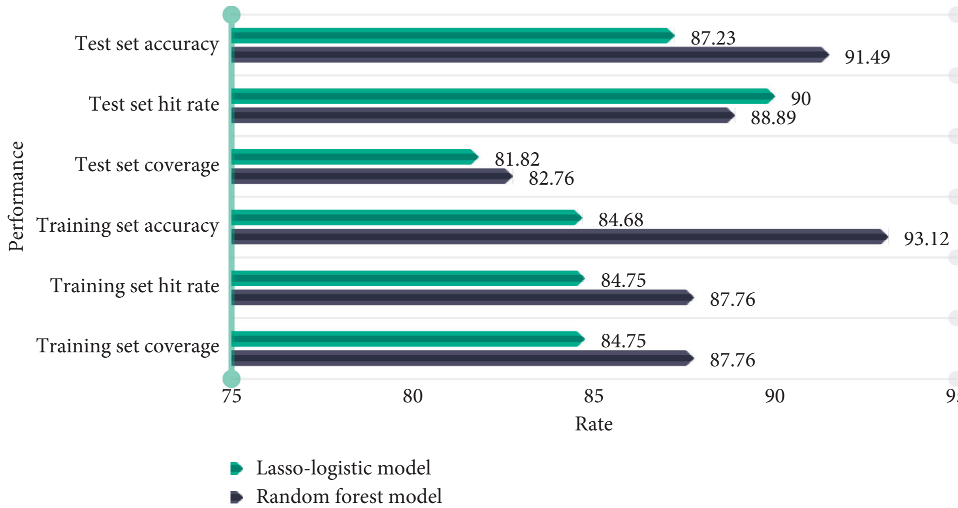


Figure 7: Performance comparison of early warning models.

Table 6: Comparison of differences in overall accuracy of each model.

Model	Training samples (%)	Prediction sample (%)	Difference in accuracy (%)
Logistic regression	90	83.3	6.7
Fisher discriminant	90	86.7	3.3
SWM model	90	76.7	13.3
Linear combination model	92	90	2

performance indicators except for the positive hit rate. This shows that although the Lasso-logistic early warning model can get a little more positive feedback information after the early warning signal is issued, there is still a certain gap in the accuracy of the ST early warning signal coverage and the overall prediction accuracy compared with the random forest early warning model.

Table 6 shows the comparison of the differences in the overall accuracy of each model. From the difference of the overall accuracy of each model, among the single models, the accuracy of the SVM model has the largest difference, reaching 13.3%, and the difference of the accuracy of the Fisher discriminant model is the smallest, which is 3.3%. The overall discriminant accuracy difference of the linear combination model is better than the above three single models, and the difference is further reduced to 2%. It can be seen that the robustness of the combined early warning model is better than that of a single early warning model, and the combination of models is beneficial to improve the robustness of the model.

5. Conclusions

With the increasingly fierce market competition, listed companies are being dealt with by ST due to financial failures, causing huge losses to investors and directly affecting the healthy development of the securities market. This paper constructs the Logistic regression model and the Fisher linear discriminant analysis model, which have good prediction accuracy in the three years before the dilemma. Comparing the two, whether it is the overall accuracy rate or the first type accuracy rate, the Logistic regression model is higher than the Fisher linear discriminant analysis model, and has a better prediction effect. Each GFC early warning model has its own advantages and disadvantages. In actual application, an early warning model suitable for each company should be selected according to the company's own conditions and the characteristics of the early warning model. And the company can consider combining various early warning models to achieve better early warning effects. For the company, the most important thing is how to integrate its own GFC early warning model, so as to avoid the company's GFC and achieve the effect of GFC early warning, so as to achieve a goal of better and smoother development of the enterprise.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] G. Konstantakopoulos, K. Pikouli, D. Ploumpidis et al., "The impact of unemployment on mental health examined in a community mental health unit during the recent financial crisis in Greece," *Psychiatriki*, vol. 30, no. 4, pp. 281–290, 2020.

[2] S Motsi, C Ntim, and O Ajuwon, "bank competition in sub-saharan african countries: has anything changed in the light of

2007-2008 global GFC?" *Kypriakai Spoudai: Deltion Tēs Hetaireias Kypriakōn Spoudōn*, vol. 68, no. 1, pp. 59–83, 2020.

[3] L. Debunov, "Modeling company's financial sustainability with the use of artificial neural networks," *Economy and Forecasting*, vol. 2019, no. 3, pp. 76–93, 2019.

[4] A. B Khan, M. F Basheer, J Iqbal, and M. Hatim, "Global GFC 2008-09, macro-economic variables and the performance OF ftse bursa Malaysia hijrah shariah index: a case OF MALAYSIAN stock market," *Hamdard Islamicus: Quarterly Journal of the Hamdard National Foundation, Pakistan*, vol. 43, no. 1, pp. 94–99, 2020.

[5] S. Callao, J. I. Jarne, and D. Wroblewski, "Do the burst of financial crisis and European Union membership impact Earnings Management. Evidence from emerging Eastern European countries," *Journal for East European Management Studies*, vol. 25, no. 4, pp. 608–647, 2020.

[6] N. Et.al, "Islamic and conventional banks stability during global financial crisis: evidence from Indonesia," *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, vol. 12, no. 3, pp. 2833–2840, 2021.

[7] F. Al Qaisi, "The role of corporate governance in reducing the global financial crisis implications in light of the Central Bank of Jordan," *Banks and Bank Systems*, vol. 15, no. 3, pp. 10–19, 2020.

[8] J. M. Na, "Knowledge of korea on sino-U.S. Relation after the global financial crisis : around analysis of research tendency and evaluation by meta theory," *Journal of International Relations*, vol. 23, no. 4, pp. 53–83, 2020.

[9] J. Kim, "A study on the prediction factors of housing market before and after the global financial crisis using panel VAR model," *Review of Institution and Economics*, vol. 14, no. 2, pp. 99–120, 2020.

[10] M. I Majid Imdad Khan, R. W Waheed Akhter, and M. U Muhammad Usman Bhutta, "Nexus between volatility of stocks and macroeconomic factors during global financial crisis: evidence from conventional & islamic stocks," *Journal of Accounting and Finance in Emerging Economies*, vol. 6, no. 2, pp. 465–473, 2020.

[11] O. F Sahin, P Sarajoti, and A Nasseh, "REIT spreads around dividend cuts and suspensions during the GFC," *Journal of Real Estate Portfolio Management*, vol. 26, no. 1, pp. 1–9, 2020.

[12] M. Babović, "Economic strategies of households during the period of recovery following the global financial crisis," *Südosteuropa*, vol. 68, no. 3, pp. 323–342, 2020.

[13] O. Kwon, S. H Han, S. H. Han, and D. H. Lee, "SME profitability of trade credit during and after a financial crisis: evidence from korea," *The Journal of Asian Finance, Economics and Business*, vol. 7, no. 7, pp. 35–47, 2020.

[14] A. E. F. Haines, F. Ferrari-Filho, and H. Neyra, "The consequences of the international financial crisis and the great recession in Argentina and Brazil," *Brazilian Journal of Political Economy*, vol. 40, no. 1, pp. 68–85, 2020.

[15] E Yaln and S. P Gürel, "The effectiveness of monetary transmission mechanism in Turkey after the global GFC," *Journal of Yasar University*, vol. 15, no. 59, pp. 444–460, 2020.

[16] A. Samout and E. A. Raddaoui, "The financial crisis: what impact on the economy and on the financial market?" *International Journal of Engineering Science Technologies*, vol. 4, no. 5, pp. 98–107, 2020.

[17] M. T Rodgers and J. E Payne, "Post-GFC changes in financial system structure: an examination of the J.P. Morgan & Co. Syndicates after the 1907 Panic," *Review of Financial Economics*, vol. 38, no. 4, pp. 226–241, 2020.

[18] P Ström, K Kartasalo, and H Olsson, "AI for diagnosis and grading of prostate cancer in biopsies: a population-based, diagnostic study," *The Lancet Oncology*, vol. 21, no. 2, pp. 222–232, 2020.

[19] T. van Nuenen, X. Ferrer, J. M. Such, and M. Cote, "Transparency for whom? Assessing discriminatory artificial intelligence," *Computer*, vol. 53, no. 11, pp. 36–44, 2020.

[20] K.-Y. Kim, J. H. Jung, Y. A. Yoon, and Y. S. Kim, "Designing a performance certification test for automatic detection equipment based on artificial intelligence technology," *Journal of Applied Reliability*, vol. 20, no. 1, pp. 43–51, 2020.

Hindawi
Scientific Programming
Volume 2022, Article ID 2536382, 8 pages
https://doi.org/10.1155/2022/2536382

Research Article

Integration of an AI-Based Platform and Flipped Classroom Instructional Model

Bing Li[1] and Miaomiao Peng[2]

[1]*School of Foreign Languages, Huzhou University, Huzhou 313000, Zhejiang, China*
[2]*School of Humanities, Huzhou College, Huzhou 313000, Zhejiang, China*

Correspondence should be addressed to Miaomiao Peng; 01989@zjhu.edu.cn

Received 11 December 2021; Revised 14 January 2022; Accepted 19 January 2022; Published 28 March 2022

Academic Editor: Ahmed Farouk

This article aims to evaluate a flipped class teaching model based on an AI (artificial intelligence) Language Learning Platform. The platform adopts mainstream collaborative filtering and BPMF (Bayesian Probabilistic Matrix Factorization) and big data management methods to provide students' detailed performance analysis reports and push recommendation exercises. The researcher reconciled the flipped teaching model with the AI-based language learning platforming in an experimental class and conventionally in a control class. At the end of the semester, the researcher compared students' performance as well as their attitudes toward the course between the two classes through a postexam paper and a questionnaire. Combining quantitative and qualitative methods, the survey shows that although the AI-based language learning mode failed to significantly increase students' English listening scores, compared with the students in the traditional class, those receiving the new mode held a more positive attitude toward their English listening experience, especially in regard to learning interest, study autonomy, and class involvement. The flipped class mode not only relieved students' partial cognitive processing workloads in class, but also boosted their confidence to engage in classroom discussion by reducing their nervousness through before-class preview. The AI-based language learning platform mainly performs monitoring and tutoring functions which facilitate the flipped class instruction. This study proposes a new flipped teaching model and proves it effective, indicating that for the flipped class learning mode to be successful, it is of importance to integrate face-to-face classroom instruction with the AI-technology-assisted online learning experience in a way that they can coherently support each other.

1. Introduction

In the conventional classroom where the instructor, as the knowledge conveyor, dominates the classroom, students passively receive information from the lecture by taking notes. Following the lecture, outside the classroom setting, students try to memorize, analyze, and understand the message and then apply the knowledge. The emergence of the flipped classroom teaching model provides great challenges to the traditional teacher-centred classroom mode. Since Baker coined the term "flip" in 2000 and Salman Khan first uploaded microclasses in 2004, flipped classroom has gradually gained popularity worldwide.

The flipped class, classified as blended or mixed learning mode, puts part of classroom content outside of the classroom that can be online learning or video learning or both. The flipped classroom requires students to complete knowledge assessments relevant to the course content, and the classroom becomes teacher-student interaction, students-student interaction, answering questions and solving problems, and practical applications. With the place, students take the initiative to learn, while the role of teachers changes from the authority of the class to the guidance of students learning [1].

The flipped classroom teaching model features a flexible learning environment, student-centred classroom culture, and thoughtfully selected classroom teaching content. Out-of-classroom content delivery can leave low-level learning processes such as memory and basic comprehension tasks before or after the class and free up the in-class time for high-level cognitive processing such as analysis, evaluation, application, and creation. Flipped classes simultaneously encourage students to independently work through course contents at their own pace, hence promoting their autonomy and learning efficiency.

Many studies have been conducted to examine the effects of flipped classroom on learning outcomes compared with the traditional classroom, and the flipped classroom has been proved to be more effective than traditional lecture-based instruction in improving students' learning experience and outcome due to the efficient use of class time [2], more active classroom engagement [3, 4], more student-teacher and student-student interactions [5, 6], addressing multiple learning styles [7], and reflective learning [8]. In spite of the obvious advantages, the flipped classrooms still encounter some issues and challenges. A recent meta-analysis of 198 flipped classroom teaching experimental studies published before 2018 found that flipped classrooms have a moderate effect on students' learning in general [9]. One prominent problem is that not all the students in the class are engaged in and even may disregard preclass activities, which will obviously influence the efficacy of the flipped class model. Even though most of the flipped classroom approaches include assessment for preclass activities to the course grading system as incentives, it still cannot guarantee students' devotion to preclass activities since students may merely complete the work but not necessarily with devotion or enthusiasm and the instructor may be unable to monitor the process of students' preparation. The rapid development in AI technology over the past few decades exhibits a totally new world of possibilities as to EFL teaching and learning which can solve the problem of the flipped classroom.

AI-based language learning platform has the function of tracing, monitoring, and recording users' behavior, which facilitates the accurate assessment of students' study, hence promoting their external motivation to complete preclass activities.

The purpose of this research is to develop an AI-based flipped classroom model for implementation in the course of English listening comprehension in the high education context and evaluate the efficacy of the model.

2. The AI-Based English Listening Learning Platform

2.1. Functions of the Platform. The English Listening Learning Platform is an online open course service platform developed by Beijing Xueyan Huizhi Network Technology Co., LTD. With MOOC characteristics of modularization, openness, and cloud services, and innovative hybrid teaching concepts, the platform adopts mainstream digital technologies along with big data analytic artificial intelligence.

The platform has six sections: online course, vocabulary, listening contest, teaching analysis, downloadable resources, and personal centre. The online course is divided into 4 gradients according to the topic difficulty coefficient, with 10 topics relevant to students' life under each gradient, covering campus life, friends making, etc. Under each topic, there are seven sections: warm-up, listening tasks, vocabulary and sentences, listening skills, news English training, English songs and videos, and other supplementary materials. The first four parts of listening training take into account the latest CET4 and CET6 listening comprehension training and the last two parts allow students to learn English using authentic materials for educational entertainment to improve their cross-cultural communication ability.

The system includes an intelligent diagnostic function and provides detailed learning progress reports for both students and teachers. The background system adopts big data management technology to synchronously track, record, and evaluate the students' listening and speaking training in real time, which is convenient for students to make full use of fragmented time. Besides their scores, students can also check the accuracy, learning duration, the highest score, and average score of the class. As long as students complete 80% of the exercise progress, the system will automatically provide a learning report, presenting a detailed analysis of students' mastery of the knowledge points, problem-solving skills, and question types. At the same time, the system will provide accuracy rate and diagnosis details. Diagnosis is detailed to the specific knowledge points, problem-solving skills, and exercise types. At the same time, the system will push targeted exercises to address their weaknesses according to the statistics of students' learning situation. The platform adopts the formula $\text{Final} = \text{score} + \text{means}/\text{times} + 1$ to encourage multiple practice attempts.

2.2. Evaluation Model. The system automatically pushes relevant extended exercises according to each student's learning situation, in order to consolidate his/her unfamiliar knowledge points.

The platform uses collaborative filtering and BPMF (Bayesian Probabilistic Matrix Factorization) methods to construct multidimensional sparse matrix based on three dimensions (knowledge points, skills, and question types) and weighs them accordingly. This multidimensional sparse matrix is decomposed into two low-dimensional matrices or factor matrices by matrix factorization, which, respectively, represent knowledge matrix and question matrix. Then the similarity between any two rows/columns in the question type matrix is calculated with cosine formula $\sin(I\_i, I\_j) = \cos(I(I), I(j))$ (I represents the factor and i and j represent the serial number of any two rows or columns) to calculate the extended questions to be recommended.

Collaborative filtering model contains the data of M (the number of questions) and N (the number of question types). M and N are not a one-to-one mapping relationship and only part of the sets M and N is connected, producing the score. Then, a machine-learning-based model can use partial data to predict the rest of the data with no relationship and recommends the most relevant topics to users.

The recommendation problem can be solved by a machine-learning-based model. Machine learning can establish an appropriate model by analyzing users' basic information and behavior habits. The model can be used to understand learners' learning patterns, predict their learning performance, and push personalized learning resources accordingly. Then the real-time data and the analysis during the learning process can in turn help to enact adjustments.

The scoring matrix can be decomposed into the product of two low-dimensional matrices, described as $R = UV$, where matrix U has D rows and N columns, describing the attributes of N questions, and matrix V has D rows and M columns, describing the attributes of M question types, with R as the observation value. According to the properties of matrix rank, the rank of R does not exceed U, and the minimum size of V is D.

In practice, such a perfect decomposition is impossible due to the presence of system noise, and R contains many unknown elements. The problem is hence transformed into the following: Decompose an approximate matrix $\hat{R} = UV$, requiring the approximate matrix $\hat{R}$ in the observed scoring part to be as similar as possible to the observation matrix R. In order to prevent overfitting, some form of constraint on U and V is required. In Bayesian terms, R is the observed value, and U and V describe the internal characteristics of the test.

The following procedure will mine the content based on the association rules. Learning results from a scoring matrix A according to the dimensions of the user's study time t, accuracy p, and the number of repeated questions c, the study effect constitutes a rating matrix A.

The system will evaluate users' knowledge mastery level f through the Apriori algorithm and FP growth algorithm. The system then looks for the same frequent data set as f, which is described with support level and reliability and the results are fed back to users as a reference and used as a basis to decide whether to recommend the relevant extension questions.

3. Methodology

3.1. Research Questions. The purpose of the present study is to answer two questions: (1) Do students demonstrate better performance from the class delivered using the AI-based flipped class in comparison with students who learn from a traditional lesson paradigm? (2) Do students who attend the class delivered using the English Listening Platform rate the quality of their instruction differently from those taught using a traditional paradigm?

3.2. Participants. This study was conducted in two classes with 61 freshmen who are aged between 17 and 19 and Chinese majors enrolled in a four-credit listening comprehension course as a requirement for their BA degree. None of the participants have international study experience. Of the total, two students failed to participate in the examination and therefore were not included in the data for pre- and posttests. Students were identified as less or more skilled English learners based on their performance on the listening pretest. Those scoring above the mean (80) were classified as higher-level listeners, and those scoring below the mean were classified as lower-level. The information of the participants is shown in Table 1. The same instructor taught both the experimental and the control groups, and although the teaching methodology for listening differed, both groups used the same textbook.

Table 1: Distribution of students—two classes.

Class	Number of participants	Gender	English background
Experimental	30	Male 5 Female 25	10 years
Control	31	Male 5 Female 26	10 years

3.3. Instruments

3.3.1. Pre- and Posttests. Students' listening competency was assessed using a listening comprehension test. The internal consistency of this test is high: $\alpha = .94$.

Subtests include (1) eighteen short conversations followed by a multiple choice question (36 points); (b) two long conversations followed by seven multiple choice questions (14 points); (c) three passages followed by ten questions (20 points); (d) spot dictation with ten blanks to fill in (20 points); and (e) video watching followed by five questions to answer (10 points). Listeners heard the stimuli in the first three subtests only once; the texts for the last two subtests were heard three times. The test required approximately 60 minutes to complete.

3.3.2. The Questionnaire. To investigate how students perceive the AI-based flipped classes, we administered a questionnaire to survey students' views toward the course. All the 61 students were invited to submit a questionnaire (Table 2). The questionnaire consists of 11 Likert Scale questions with five degrees from 1 (strongly disagree) to 5 (strongly agree). We conducted all quantitative data analysis in SPSS, version 19. Here, we present continuous data as mean ± standard deviation (SD). A two-factor ANCOVA test is used to compare students' responses between the experimental class and the control class and statistical significance was set at $\alpha = 0.05$.

The questionnaire was first provided to 15 students chosen from one class of the same university to check its clarity and determine its reliability. It was reliable at 0.751 Cronbach's Alpha, indicating that the satisfaction scale designed in this study has a high internal consistency. To evaluate the questionnaire content validity, the questionnaire was reviewed by three experts in English teaching who provided their suggestions for improving the content validity of the questionnaire.

3.4. Research Procedures. Prior to the experiment, all the participants were evaluated by an English listening pretest to assess their English listening comprehension level. Both classes received instructions from the same teacher for the

Table 2: Comparison of course evaluation between experimental class and control class.

Course evaluation questions	Mean ± SD for exp. class	Mean ± SD for control class	p-value
1. I am very interested in English listening and enjoy the current English listening learning process	3.37 ± 0.65	3.18 ± 0.55	>0.05
2. I do not feel nervous when answering questions in English listening class	3.95 ± 0.46	3.21 ± 0.37	<0.05
3. The teacher used appropriate and effective teaching methods in English listening class	3.85 ± 0.53	3.42 ± 0.39	<0.05
4. I have the habit of previewing before English listening class	4.12 ± 0.22	3.38 ± 0.45	<0.05
5. I have to prepare for class in order to follow up the English listening class	3.95 ± 0.43	3.62 ± 0.67	<0.05
6. The teacher encourages active participation in English listening class	3.87 ± 0.36	3.48 ± 0.45	<0.05
7. I participate and engage in discussions in English listening class	3.75 ± 0.56	3.21 ± 0.37	<0.05
8. In-class discussions with my peers enhanced my English listening level	3.55 ± 0.43	2.12 ± 0.27	<0.05
9. I think my autonomous study ability in English learning has been improved	4.07 ± 0.42	3.38 ± 0.55	<0.05
10. My listening skills have been improved	3.63 ± 0.66	3.45 ± 0.69	>0.05
11. What is your overall rating for this course?	3.66 ± 0.56	3.59 ± 0.51	>0.05

next sixteen weeks with different methods. At the end of the semester, both classes were asked to complete a posttest. In the interest of clarity, the pretest was intended to ensure that the two classes were equal in language competency and the two tests are not equal in difficulty, so that the researcher did not compare the difference between the pre- and posttests of each class to assess students' improvement in English competency.

At the beginning of the course, students of both classes acquired the learning materials from the teacher, including the course syllabus, course agenda, PPT slides, videos and course assessment system or standards, etc., and knew clearly the requirements of the course and the objectives of the course. At the same time, the teacher introduced the English Listening Learning Platform to the students of the experimental class and familiarized them with the platform's functions to integrate the platform with the course.

3.4.1. Preclass Activities—Listening as Comprehension. Preclass activities are task-based and have specific objectives. The purpose of this stage is for students to complete the comprehension questions in each unit on the platform required by the teacher. The students will be marked and get immediate feedback from the system, including the explanation of the wrong answers. They can repeat the practice and the system will record the highest score. At the same time, according to students' performance, the system will further push relevant extended exercises automatically in order to rectify students' weak points, but the students have the space to choose the content they are interested in among the materials on the platform while completing the compulsory tasks. The teacher can supervise students' learning process through the monitoring function of the platform as well as the statistics such as the score, study time, and accuracy.

3.4.2. In-Class Activities—Listening as Comprehension as well as Production. In class, the teacher carried out the targeted classroom teaching objectives based on the objectives of the unit as well as the practice problems reflected on the platform and the issues posed by students. Firstly, group discussions were used so that students can communicate with each other to explore the answers to some questions, during which process students were able to develop cooperation and critical thinking abilities while acquiring knowledge and training language skills. Following the discussion, the teacher would further explain issues for which students were unable to reach a consensus. Through this student-centred and interactive method, the enthusiasm and motivation of students can be thoroughly stimulated.

Afterward, the teacher played a different video or audio related to the topic of the present unit. At this stage, students listened to a passage three times. Before students listened to the audio for the first time, they were given the title of the passage and then brainstormed what information they would hear on the following on the basis of the topic. After they listened to the passage for the first time, they were asked to check their predictions and provide evidence about how they either confirmed or dismissed their predictions.

The second listening round can be noticing activities or restructuring activities. The purpose of noticing activities is to use the listening material as the basis for language awareness. Students were asked to complete certain exercises such as identifying differences between what they heard and a printed version of the passage, or filling in the blanks with certain missing key words. Restructuring activities can be oral or written tasks, involving productive use of selected items from the passage. Students read scripts in pairs, completed sentences using expressions and other language items in the text, and used some targeted words or expressions from the text to role play.

In class, the instructor also asked students to perform word recognition practice. One difficulty students often encounter with English listening is word recognition, because they are unable to parse the English speech stream and understand the spoken forms of words they know in written form [10]. Word recognition problems originate from the way English sounds are compressed closely together or stretched in speech [11], while EFL learners tend to segment based on their native language segmentation rules [12]. Consequently, Chinese EFL listeners appear to be under a rather unfavorable English language learning circumstance in this respect since Mandarin, as a syllable-timed language, has different rhythms and tones from English, which is a stress-timed language [13]. Thus, in this flipped class, word recognition activities were devised to help learners recognize lexical boundaries by sensitizing the students to some segmentation cues, such as weak forms, link-ups, and contractions. Two exercises were designed at this stage. The first exercise asked students to listen to sample sentences, pay attention to the weak forms, link-ups, and contractions, and then repeat the sentences. The second exercise lets the students listen to a dialogue and fill in the blanks with the targeted words. Then the teacher discussed with students how the targeted words are read in the dialogue.

3.4.3. Postclass Reflection and Assessment. At the end of each unit, students submitted their reflection on the unit, including their gains, difficulties, and confusions as well as their suggestions for the class. The teacher communicated with students through WeChat to give solutions or feedback to students. Through the autonomous analysis of the quizzes by the platform, the teacher can have comprehensive information of students' performance so as to position the weak links of students and be more effective as well as efficient in class.

4. Results

4.1. Comparison of the Experimental and the Control Classes in English Listening Performance. Our first and second hypotheses concerned the degree to which AI-based flipped class might result in variance in students' listening performance. We hypothesized that the class receiving experimental treatment would outperform the control class on the posttest of listening comprehension. In addition, we hypothesized that listeners who were less skilled at the outset of the experimental class would show a greater improvement in achievement than their more skilled counterparts.

In order to examine these two hypotheses, a two-factor ANCOVA was administered with SPSS. The independent variables consisted of the class (experimental and control) and the level of listening ability (high-level and low-level). In order to control any initial differences in the participants' listening ability, pretest scores were used as the covariate.

To meaningfully interpret the univariate F tests for the different groups, we determined whether any statistical assumptions underlying the use of ANCOVA were violated in the dataset. An examination of Levene's test of equality of error variance, which can be seen in Table 3, demonstrated that the data satisfied the condition of homogeneity of variance; therefore, postlistening error variance was equal across groups ($F = 2.373$; $p = 0.080$). Moreover, the results of the tests of between-subjects effects (i.e., the test of the interaction between the independent variable class and the covariate students' pretest scores) as shown in Table 4 demonstrated that the assumption of homogeneity of regression slopes was successfully met, $F = 10.87$, $p = 0.42$. The results of tests of the between-subjects effects were further examined for statistical significance of the main effects of the independent variables, class and listening competency.

Table 3: Levene's test of equality of error variance.

F	df_1	df_2	Sig.
2.373	3	55	0.080

Test the null hypothesis that the error variance of the dependent variable is equal across groups. a. Design: pretest + class (experiment/control) + group (high-level/low-level + class ∗ group).

Table 4: Descriptive statistics for posttest.

Source		Mean	SD	N
Experiment	High-level	83.41	3.063	17
	Low-level	73.64	7.724	11
	Total	79.57	7.162	28
Control	High-level	83.27	2.789	15
	Low-level	70.19	10.432	16
	Total	76.52	10.109	31
Total	High-level	83.34	2.892	32
	Low-level	71.59	9.419	27
	Total	77.97	8.894	59

Table 5 shows the mean and standard deviation of students' posttest scores for the experimental and the control group at each listening competency level (high-level and low-level). The estimated marginal mean on posttest listening score for the experimental class was 79.57, higher than that of the control class 77.97, but as evidenced in Table 5, these differences were not statistically significant ($F = 0.096$, $\eta_2 = 0.002$, $p = 0\ 758 > 0.05$), suggesting that AI-based instruction did not result in the significant variance in students' listening achievement between the two classes, with η_2 of 0.002, indicating a fairly weak effect.

For the high-level listeners in the experimental class, the mean ($M = 83.41$) was slightly higher than that of those in the control class ($M = 83.27$), but for the low-level listeners the difference is much wider with ($M = 73.64$) and ($M = 70.19$), respectively, for the experimental class and the control class. It seems that the teaching methodology influenced the lower-level listeners more compared with the high-level listeners, and the small sample does not allow a pair comparison of students' performance for both levels, so that the statistical significance cannot be ascertained.

In summary, the results of the analyses related to the first two hypotheses demonstrate that although the group receiving the AI-based flipped class outperformed the control group on the listening comprehension test, especially for the less skilled listeners in the experimental class when compared with their counterparts in the control class, the difference is not statistically significant.

4.2. Comparison of Students' Attitudes and Perceptions of the English Listening Classroom. This section evaluates students' perception of their English listening improvement and the effectiveness of the English listening class.

From Table 2, it can be generally observed that students from both classes are satisfied with their class since students evaluated most of the questions with a rating higher than 3,

Table 5: Tests of between-subjects effects.

Source	df	Mean square	F	Sig.	Partial eta squared
Corrected model	4	796.737	30.710	0.000	0.695
Classes (experiment/control)	1	2.479	0.096	0.758	0.002
Listening competency	1	231.399	8.919	0.004	0.142
Classes * competency	1	11.304	0.436	0.512	0.008
Prelistening	1	1087.051	41.900	0.000	0.437

R square = 0.695 (adjusted R square = 0.672) from SPSS result.

except for question 8 from students of control class. It demonstrates that students from the flipped class benefited from class discussion, while students from the traditional class did not obtain the same benefits probably due to the reduced opportunities for live discussions in the control group taught by traditional methods.

For the rest of the questions, even though students from both classes viewed their classes positively, students from the experimental class were more likely to react positively to their AI-based flipped classroom than students from the control class with their traditional classroom from class attraction, learning motivation, relaxing learning environment, student engagement, autonomous study ability cultivation, and learning effect. Students rated the experimental class significantly higher than the control class except for the first question related to students' interest in English listening and the last two questions related to their improvement in the course and their overall impression on the course. Even for these aspects, students in the experimental class still hold higher views toward the new approach compared with the traditional method, but the difference cannot reach statistical significance.

5. Discussions

5.1. Accounting for Students' Achievements of English Listening Class. The mean scores of the posttest for the flipped class were higher than the regular class and students' perception of their listening skills and overall rating of the course for the flipped approach was slightly more favourable than that of the regular approach, but the results showed no significant difference. This result seems to contradict with previous studies that the flipped classroom contributed to students' English academic performance in general [14], English writing [15], English grammar [16, 17], English speaking [18], and English listening [19].

But actually, several studies reported a lack of strong evidence for the effectiveness of flipped learning in various disciplines. The systematic review of the flipped classroom in higher nursing education yielded neutral or positive academic outcomes and mixed results for satisfaction [20]. Indeed, although extensively studied over the years, there is still debate about the effectiveness of flipped learning in improving learner outcome as compared to traditional learning. Half of the studies on flipped class showed no improvement in exam scores [21] and the flipped approach was not significantly better than the traditional approach for delivering this course in terms of their achievement and their perception of the course [22].

5.2. Accounting for the Feasibility of the AI-Based Flipped Class. Although the feasibility is not reflected in the listening test results, our results suggest that this AI-based flipped class fostered learning and provided positive learning experiences for students, because students of the experimental class reported feelings of relaxation in class when answering questions.

5.2.1. The Feasibility of the Flipped Class. More students in the flipped class than those in the traditional class can feel the improvement in English listening through the class discussion, which might be attributed to two causes. Compared with the traditional class, students of the experimental class are more motivated to prepare before the class. To better process the content in class, students better make preparations before class. According to cognitive load theory, the process of learning imposes a load on the working memory that has finite processing capacity [23]. In class, students need to associate the new information with what is already stored in the long term memory. If the load exceeds what students can digest, their learning capacity will be low [24]. Introducing material in advance can reduce cognitive load, hence enhancing learning efficacy. The instructor can take the best of invaluable face-to-face class time and prioritize higher-order cognitive tasks.

The second cause is due to the active participation in class due to the feature of the flipped class. The flipping class instruction model means more than shifting part of the content outside of the classroom. The underlying ideology is to transform teacher-centred classroom instruction into a students-centred classroom, which considers students as active learners instead of passive knowledge receivers. There is evidence that the participants in the flipped classes spent more time and effort learning on their own compared to students in the traditional classes, which indicated that they participated more in the learning process. Furthermore, the research on listening comprehension shows that nervousness ranked top 5 among ten major listening problems that Chinese university students encountered [25]. By reducing their nervousness and boosting their self-confidence as indicated in the questionnaire, the preclass preparation is especially beneficial for students' engagement in English listening class.

5.2.2. The Role of AI-Based Language Learning Platform in the Model. The significance of AI technology in teaching and learning has been acknowledged by flipped class teaching researchers, which is increasingly utilized to facilitate outside-the-classroom learning in a flipped class mode. There is evidence that if students in the traditional class extensively used similar resources with those in the flipped class such as videos and online resources, the differences between treatment and control groups might be blurred [26]. It has been proven that technology has a remarkable effect on students' English proficiency levels and attitudes toward learning English [27] as well as in speaking [28].

In this class design, AI-base language learning platform plays a significant monitoring and tutoring role. On one hand, the key to a successful flipped class is students' before-class preparation, but students' low engagement in the preclass activities is encountered by most of the flipped class designs. It is reported that around 70% of flipped classroom students did not prepare for a class [29] and even 39% of flipped classroom students skipped the preclass learning activities [30]. If students fail to complete the preclass learning activities, and the instructor follows the planned teaching procedure, the learning effect will be even worse than the traditional approach; but if the instructor reteaches the materials in class, this would render the entire flipped learning approach not different than a traditional class. In this experiment, the preclass activities can be measured and monitored through the AI learning platform by the instructor, which is considered as part of the course formative evaluation of the curriculum. In addition, students' learning motivation is also stimulated by the continuous improvement of scores. The instructor found that most of the students practiced the questions multiple times. Therefore, students are more motivated to form the habit of previewing and are able to achieve proficiency during repeated practice.

In addition, feedback information can help students to recognize the gap between their existing knowledge and their learning goals and clarify the direction of efforts. At the same time, teachers can supervise the students' study and help students to reflect on their own behavior. However, one disadvantage of the flipped class model is the lack of timely feedback available to students while watching instructional videos. Students are unable to ask questions and receive instantaneous feedback from teachers, as during in-class lectures [31]. In this experiment, the platform adopts mainstream digital technology and big data artificial intelligence analysis methods to analyze the weaknesses and strength of their study, diagnose their problems, and give students real-time feedback and material recommendation. In this way, students are encouraged to be more responsible for their own learning and do not rely solely on the teacher to provide information in the classroom as reflected in their evaluation of their autonomous study in the questionnaire. The system includes intelligent diagnostic functions and provides detailed learning progress reports for both students and teachers. Such timely feedback can also increase the opportunities for teachers to find problems in the teaching process, so as to improve the teaching method and continuously promote the improvement of teaching ability.

6. Conclusion

This research assesses a flipped English listening comprehension class teaching mode based on an AI Language Learning Platform. Combining quantitative and qualitative methods, the survey demonstrates that although the AI-based language learning mode failed to significantly increase students' English listening scores, compared with the students in the traditional class, those receiving the new mode of instruction held a more positive attitude toward their English listening class, especially in learning interest, study autonomy, and class involvement. Indeed, the flipped class mode requires students to prepare before the class, which can not only relieve partial cognitive processing workload in class, but also boost their confidence to engage in classroom discussion by reducing their nervousness through preclass activities. The AI-based language learning platform plays the facilitating role by monitoring students' before-class preview, analyzing their practice, and providing instant feedback. The contribution of this study is that it poses a new flipped class teaching mode and indicates the importance to integrate the face-to-face classroom instruction with the AI-technology-assisted online portion of the learning experience in a way that they can coherently support each other.

There are a few limitations in this study. First, this course only lasts one semester with sixteen weeks, but language improvement is a complicated process that needs time for learners to digest and reflect before the obvious improvement takes place. Second, the practice score graded by the platform allows repeated correction by users, which makes the data only influenced by practice frequency, without any correlation with students' English competency. Due to the limitations of the present study, further research is needed to have a more exhaustive study on the efficacy of both the improved blended teaching mode and the perfected language learning platform.

The future research should focus on longitudinal studies to observe the key factors affecting flipped classroom teaching effects and how to effectively develop the flipped classroom model according to different teaching situations with the improved language learning platform.

Data Availability

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

Conflicts of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Acknowledgments

This study was supported by the 2020 Industry-University Cooperative Education Program of Ministry of Education: Practice Course Construction Based on English Learning Platform (no. 202002070017), and 2020 Postgraduate Education Reform of Huzhou University: English Teaching Reform for Postgraduate Students Aiming at Establishing Knowledge System (YJGX20010).

References

[1] J. Jensen, T. Kummer, and P. Godoy, "Improvements from a flipped classroom may simply be the fruits of active learning," *Cell Biology Education*, vol. 14, no. 1, p. 1187, 2015.

[2] J. E. Cole and J. B. Kritzer, "Strategies for success: teaching an online course," *Rural Special Education Quarterly*, vol. 28, no. 4, pp. 36–40, 2009.

[3] J. Demski, "6 Expert tips for flipping the classroom," *Campus Technology*, vol. 26, no. 5, pp. 32–37, 2013.

[4] G. C. Gannod, J. E. Burge, and M. T. Helmick, "Using the inverted classroom to teach software engineering," in *Proceedings of the Acm/ieee International Conference on Software Engineering*, Leipzig Germany, May 2008.

[5] B. Danker, "Using the flipped classroom approach to stimulate deep learning in large classrooms," *IAFOR Journal of Education*, vol. 3, 2015.

[6] M. J. Lage, G. J. Platt, and M. Treglia, "Inverting the classroom: a gateway to creating an inclusive learning environment," *The Journal of Economic Education*, vol. 31, no. 1, pp. 30–43, 2000.

[7] K. Gallagher, "From guest lecturer to assignment consultant: exploring a new role for the teaching librarian," 2009, https://commons.emich.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1008&context=loexconf2007.

[8] Fu. Du and Y. Wang, "The flipped classroom: advantages and challenges," in *Proceedings of the International Conference on Economic, Management and Trade Cooperation, Trade Cooperation*, Xi`an, China, April 2014.

[9] P. Strelan, A. Osborn, and E. Palmer, "The flipped classroom: a meta-analysis of effects on student performance across disciplines and education levels," *Educational Research Review*, vol. 30, pp. 1–22, 2020.

[10] C. Goh, *Teaching Listening in the Language Classroom*, SEAMEORegional Language Centre, Singapore, 2002.

[11] G. Brown, "Dimensions of difficulty in listening comprehension," in *A Guide for the Teaching of Second Language Listening*, D. J. Mendelsohn and J. Rubin, Eds., pp. 59–73, Dominie Press, San Diego, CA, 1995.

[12] A. Cutler, "Listening to a second language through the ears of a first," *Interpreting*, vol. 5, pp. 1–23, 2001.

[13] J. Platt, H. Webber, and M. L. Ho, *The New Englishes*, Routledge & Kegan Paul, London, 1984.

[14] H.-T. Hung, "Flipping the classroom for English language learners to foster active learning," *Computer Assisted Language Learning*, vol. 28, no. 1, pp. 81–96, 2015.

[15] M. Farah, "The impact of using flipped classroom instruction on the writing performance of twelfth grade female Fmirati students in the applied technology high school (ATHs)," *Dissertations for Teaching English to Speakers of Other Languages*, pp. 1921–1933, The British University of Dubai, Dubai, UAE, 2014.

[16] M. Webb, E. Doman, and K. Pusey, "Flipping a Chinese university EFL course: what teachers and students think of the model," *Journal of Asia TEFL*, vol. 11, no. 4, pp. 53–87, 2014.

[17] Y. J. Han, "Successfully flipping the ESL classroom for learner autonomy," *NYS TESOL Journal*, vol. 2, no. 98, pp. 98–109, 2015.

[18] A. DewiSuryani, *The Use of "Flipping Classroom" for Teaching story-telling to the Tenth Graders*, Ejournal of Universitas, Negeri, Surabaya, 2014.

[19] N. Kang, "The comparison between regular and flipped classrooms for EFL Korean adult learners," *Multimedia-Assisted Language Learning*, vol. 18, no. 3, pp. 41–72, 2015.

[20] V. Betihavas, H. Bridgman, R. Kornhaber, and M. Cross, "The evidence for "flipping out:" a systematic review of the flipped classroom in nursing education," *Nurse Education Today*, vol. 38, pp. 15–21, 2016.

[21] M. K. Seery, "Flipped learning in higher education chemistry: emerging trends and potential directions," *Chemistry Education: Research and Practice*, vol. 16, 2015.

[22] R. S. Davies, D. L. Dean, and N. Ball, "Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course," *Educational Technology Research & Development*, vol. 61, no. 4, pp. 563–580, 2013.

[23] R. E. Mayer, "Cognitive theory of multimedia learning," in *Cambridge Handbook of Multimedia Learning*, R. E. Mayer, Ed., Cambridge University Press, Cambridge, 2005.

[24] A. H. Johnstone, R. J. Sleet, and J. F. Vianna, "An information processing model of learning: its application to an undergraduate laboratory course in chemistry," *Studies in Higher Education*, vol. 19, no. 1, pp. 77–87, 1994.

[25] Y. Zeng, *Metacognitive Instruction in Listening: A Study of Chinese Non-English Major Undergraduates*, Nanyang Technological University, Singapore, 2007.

[26] D. Yong, R. Levy, and N. Lape, "Why no difference? a controlled flipped classroom study for an introductory differential equations course," *Primus*, vol. 25, no. 9-10, pp. 907–921, 2015.

[27] F. Al-Kathiri, "Beyond the classroom walls: edmodo in Saudi secondary school EFL instruction, attitudes and challenges," *English Language Teaching*, vol. 8, no. 1, pp. 189–204, 2015.

[28] H. Obari and S. Lambacher, *Successful EFL Teaching Using mobile Technologies in a Flipped Classroom*, Research Publishing Net, 2015.

[29] K. Palmer, "Flipping a calculus class: one instructor's experience," *Primus*, vol. 25, no. 9-10, pp. 886–891, 2015.

[30] A. Sahin, B. Cavlazoglu, and Y. E. Zeytuncu, "Flipping a college calculus course: a case study," *Educational Technology & Society*, vol. 18, no. 3, pp. 142–152, 2015.

[31] N. B. Milman, "The flipped classroom strategy: what is it and how can it best be used?" *Distance Learning*, vol. 9, no. 3, pp. 85–87, 2012.

Hindawi
Scientific Programming
Volume 2022, Article ID 7835917, 13 pages
https://doi.org/10.1155/2022/7835917

Research Article

Animation Special Effects Production Method and Art Color Research Based on Visual Communication Design

Xiaoying Liu

School of Communication, Weinan Normal University, Weinan 714000, Shaanxi, China

Correspondence should be addressed to Xiaoying Liu; liuxiaoying@wnu.edu.cn

Received 26 December 2021; Revised 15 February 2022; Accepted 28 February 2022; Published 27 March 2022

Academic Editor: Ahmed Farouk

In the context of social informatization, the continuous progress of information technology has promoted the emergence and rapid development of new media. In recent years, the interaction between the design of visual communication and the increasingly popular virtual reality, special effects, and animation has constituted a new way of media communication. In the process of producing special effects of interactive animation, in order to improve the visibility of visual communication design works and achieve excellent information transmission effects, it is necessary to utilize many advanced science and technology methods such as visual communication design. This article, firstly, introduces the visual communication design technology, analyzes and introduces the animation special effects design technology, and then investigates and analyzes the application of visual communication design in real life. Experiments in this article show that animation special effects production based on visual communication design can not only save development companies at least 5% of development costs but also attract 15% of the younger age groups. The most important thing is to better promote the spread of animation film and television works.

1. Introduction

With the development of science and technology, people's production methods, living habits, and ways of thinking have undergone great changes. In particular, the invention and popularization of electronic computers have greatly changed people's lives. The birth of the internet has directly and strongly promoted new types of communication and media based on the internet. In the traditional sense, most of the visual communication design works are graphic works, which are mainly used to produce and promote the technical means of images. The technological innovation of using paper as the carrier of information transmission provides a broader development space for visual communication design. Today, with the rise of new media, visual communication design is not limited to the past logo design and poster design. Vision and other closely related professional design art fields have also begun to set foot in cross-development. The continuous update of media and various developments, communication media, and materials has created an unprecedented multidimensional world in the field of visual communication and has provided more attention to people. In this context, visual communication design has enriched its reasonable development. The designer's design concept can not only be well communicated to the audience, but also meet the audience's new needs and aesthetic psychology.

With the rapid development of the national economy, people's consumption and entertainment levels continue to improve, and the current new media animation market mainly has some common problems, which are reflected in creativity and design. The special effects and colors of animation are important symbolic language in information transmission, and each has a different communication effect. In today's era, for artistic performance, combining multiple visual languages has become the current trend. In the future development, the number of mixed images and graphics will also increase. In the current field of visual communication design, with the emergence and rapid development of new media in recent years, the phenomenon of image special effects and graphic color mixing is becoming more common, and its scope of application is expanding and becoming more extensive. In the previous graphics, simple colors and geometric forms were mixed in the animation, however, this method is relatively monotonous and widely known. Hence, it is difficult to generate new visual feelings. However, the upgrade of images and graphics that appear today is a fusion of the two and complements each other. At this time, we have a lot of new visual feelings. The mixing and matching of special effects and colors of visual communication design and animation is not only a new revolution in the field of art but also in the field of production. It also brings a new revolution in the development of new technologies. The mixed design of visual communication and the special effects of animation also have a great influence. In order to improve people's artistic aesthetics, the fusion of visual communication design and special effects of animation has become a feature of modern fashion. At the same time, the special effects of visual requirements and result communication design and animation effects will continue the new media, constantly updating, changing, and improving people's various emotions about beautiful things.

Since the emergence of visual communication design technology, it is often seen in people's daily life. In the classroom teaching, Zhu analyzed the problems existing in the teaching of decorative painting for the visual communication design specialty based on the characteristics of decorative painting and proposed corresponding strategies to adjust teaching content, change teaching mode, update teaching thinking, and promote multimedia. The process of technical teaching has improved teaching efficiency [1]. In the corporate logo construction culture, Zomay proposed that the company's corporate image and colors used in logo design have a great impact on shaping the target audience and customer perception. For a business to make its corporate image effective and reach the target audience directly, the logo design should include colors that can attract people's attention and satisfy their requirements. Zomay studied the favorite colors of many students studying visual design by the use of visual communication design technology, and then using various studies showed that the success of the company is related to the colors used in the logo and packaging choices [2]. In people's daily recreational activities, graffiti culture is becoming more popular. In his research on graffiti culture, Wu stated that to further promote the creation of graffiti workers, promote the development of graffiti culture, and strengthen the vitality and expressiveness of graffiti art, he combined cloud computing and the Internet of Things to obtain more visual communication design elements to provide more visual communication design elements with graffiti workers [3]. Zhang pointed out in a survey of computer software development that interface design has become an important part of software development. He proposed to use visual communication design technology to analyze people's perception of the physical and psychological characteristics of colors, graphics, images, text, and animation and use virtual art to focus on creating a natural and beautiful human-computer interaction interface, which is more conducive to the user's interaction interface and the degree of favorite of the software [4]. Visual communication design technology can not only enhance the communication power of works but also improve the expressive power of works using diversified artistic colors. Mahoney said in an event that to show that different colors have important historical significance in art and archaeology, he provided students with a 4-day short course, which involved the chemical synthesis of pigments used in art. His students synthesized four pigments in the chemistry laboratory: Egyptian blue, madder lake (red), cobalt green, and cobalt yellow. It not only shows the charm of chemistry for students but also increases students' understanding of color art [5]. Of course, art color is not just for people to watch. In medicine, art color doctors are an important basis for diagnosing patients' disease. Especially under the influence of the virus epidemic, Yang established a case and rule knowledge representation method, case retrieval technology, and rule conflict resolution strategy. The color case database has been established so that doctors can judge people's health in a timely and accurate manner and strengthen the prevention of virus epidemics [6]. However, in today's society, visual communication technology and art color are more applied to the performance of multimedia, especially in the production of animation. Cheung pointed out in his research on website pages that websites usually use animation to capture the attention resources of online consumers, and the number of individual attention resources may vary under different conditions. To demonstrate this view, he conducted a large number of experiments and concluded that product projects using animation will increase visual attention to all projects on the web page. Animation effects how individuals allocate their attention resources, thus increasing their visual attention [7]. Although most of the current videos, images, pictures, etc., use many visual communication design techniques, it takes a lot of time and capital costs in the production process and production costs, which still need to be improved.

The innovation of this paper is to analyze and study the production methods of animation special effects using visual communication design technology. It can not only express the content that the author wants to express through visual media but also convey to the audience more the combination of art, culture, and technology, which is both practical and beautiful. Moreover, by the use of visual communication design technology, we can accumulate visual language expression forms from the fields of drama, oil painting, calligraphy, folk art, and music and enrich the artistic expression technology of visual communication design, enrich the appeal of visual communication design works, and make the production effect of motion picture special effects more realistic and the colors more diversified. It will be loved by the majority of customer groups.

2. Animation Special Effects Production Method Based on Visual Communication Design Technology

2.1. Visual Communication Design Technology. Visual communication design is an activity that spreads specific things using visual forms. Most or part of it depends on vision, using two-dimensional images, such as logo,

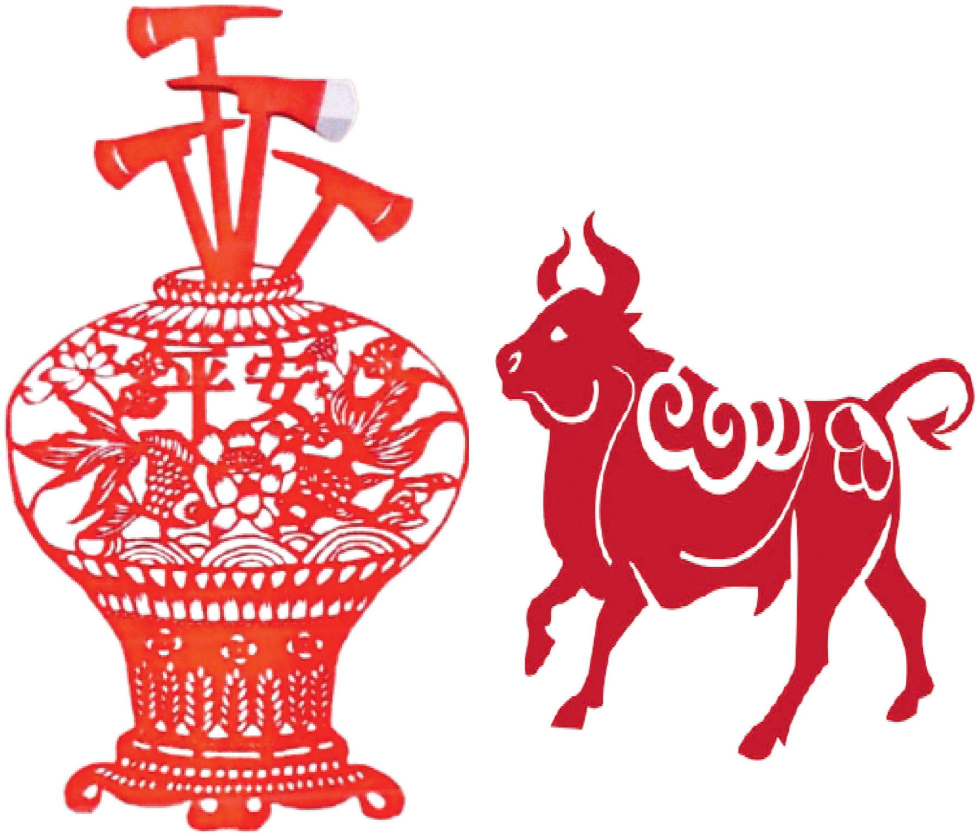


Figure 1: An illustration based on visual communication design.

typography, painting, graphic design, illustration, color, and electronic equipment to express [8]. The phenomenon was discovered during the visual communication design process. The images of communicating, educating, and persuading the audience will have a greater impact on language. It is the process of guiding according to a specific purpose, conveying specific information to the object conveyed in the form of visual art, and having an impact on the conveyed object [9]. In the visual communication design, we must grasp the use of color. First of all, on the basis of following the principles of the inherent customary color attributes, overall collocation, and regional characteristics of the design object, we should skillfully use different colors in a wide range of visual design fields. To achieve a good publicity effect. Science and technology, such as computer design, bring changes to designers, however, they also bring uniformity. For example, a column can divide the text into two vertical rows, thus, to a certain extent, the creativity and conception of designers are less obliterated.

First of all, visual communication design, which is guided by a certain purpose, conveys a series of specific information to and affects the conveyed object in a form that can be conveyed by the naked eye. Visual communication design is mainly to convey all kinds of information to people through vision. We can see symbols that can express certain properties of things, such as photography, film, television, buildings, plastic arts, and various design products. As you can see, they are all in the category of artistic symbols [8]. The so-called "transmission" is actually the process by which the sender of information uses symbols to spread the information to the recipient. The basic elements of visual communication design can be summarized as follows: graphics, text, and color. color, such as designing posters, industrial products, and signs. Visual communication design includes logo design, illustration design, layout design, font design, display design, packaging design, advertising design, etc. Among them, it is most widely used in animation special effects design, illustration design, advertising design, and display design, and it has achieved satisfactory comprehensive effects. At the same time, it is also one of the most economical, most convenient, and fastest communication methods used in the field of animation special effects production. It has the characteristics of good publicity effect, no time limit, and wide audience. It is not only of practical value for communication but also has a high art collection value and appreciation value [10]. As shown in Figure 1, it is an illustration designed and produced using visual communication design.

It can be seen from Figure 1 that it is a natural phenomenon for people to watch illustrations on computers or books at this stage. In the process of observing illustrations, people can also obtain basic economic and cultural characteristics at a certain time and stage through illustrations. Otherwise, it is the ideology that the writer wants to express in the writing process. An example diagram of artistic color is shown in Figure 2.

Figure 2: Example of artistic color.

At the same time, the use of illustrations can make the expression of words more modern, and it can also allow people to accept and recognize the content of the words. In fact, illustrations are not only a visual form of expression but also a major carrier of information dissemination. Therefore, in the process of the development of science and technology, with the continuous maturity of network technology, modern illustration art also follows its own characteristics and shows many styles on the basis of traditional illustrations. Hence, it can be seen that the technological development of advances in illustration design has a very important impact.

2.2. Animation Special Effects Production Technology. Whether it is an animated movie or an actual movie, adding animation and special effects will give the movie a more significant visual effect. To let the audience feel the story and experience driving, animation and special effects are very important for the movie. Animation and special effects can not only make animated movies but also complete movies and TV shots that cannot be solved with actual shots, and they are not affected by factors, such as weather and seasons [11]. In addition, high-level changes can be made, and this product can be controlled more simply to bring unprecedented audiovisual effects.

2.2.1. Animated Image and Video Keying Technology. In the 1990s, the alpha-based matting technology was proposed, and the alpha channel was introduced to generate complex digital images by synthesizing multiple images. The description of the most general combination operation summarizes it as a combination equation, and the formula is as follows:

$$A = \alpha B = (1 - \alpha)C. \quad (1)$$

A represents the composite image, B represents the foreground image, C represents the three-dimensional vector of the background image, and α represents the opacity of the color, and its value is between (0-1). The keying process is actually the inverse process of the combination process, and its goal is to reconstruct the alpha channel, B foreground image, and C background image from the original image A. The production process of extraction and synthesis are shown in Figure 3.

Environmental keying is also a kind of keying technology, however, its alpha image is mainly used to highlight the optical interaction of reflection, refraction between the object and the surrounding environment, and semitransparent or transparent objects [12]. It introduces the ambient light C, and the formula is as follows:

$$F = \alpha B + (1 - \alpha)C + C. \quad (2)$$

2.2.2. Video Keying and Synthesis Technology. Because of the large size of images processed every day, most of the existing algorithms cannot achieve a proper compromise between calculation speed and accuracy. Based on previous work, a fast image keying algorithm is designed—Bayesian keying based on binary segmentation [13]. Firstly, use the GraphCuts algorithm to roughly divide the image, and then use the Bayesian keying algorithm to calculate the opacity. Figure 4 shows the first frame of video segmentation process.

When the video segmentation is completed, it is convenient to use Bayesian keying algorithm and other techniques for video synthesis, as shown in Figure 5.

As can be seen from Figure 5, our basic idea of video keying is based on the Bayesian keying method of binary segmentation. Firstly, we use the background subtraction method based on background modeling to automatically divide the foreground and background regions of the first frame of the input video, i.e., the binary segmentation result trimap is obtained. The second frame calculates the color likelihood probability of each pixel according to the trimap of the first frame, sets the threshold to divide the image into three parts, namely foreground, background, and unknown area, and optimizes each pixel in the unknown area by Graphcut. It is finally determined that it belongs to the foreground or background so that each frame after the trimap of the second frame is obtained by binary segmentation according to the trimap of the previous one.

2.2.3. Introduction to Video Keying and Synthesis. To be able to key the video sequence more accurately and conveniently,

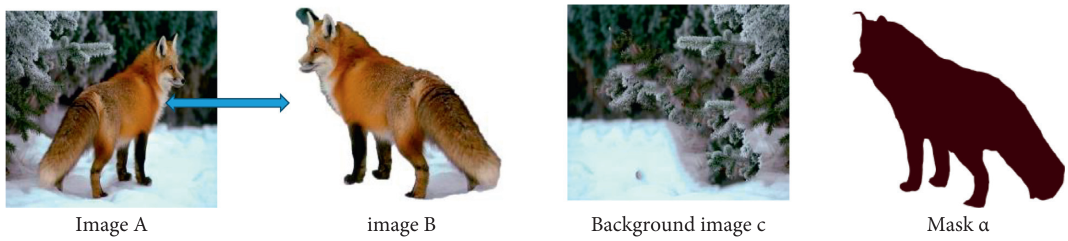


FIGURE 3: Image keying and synthesis.

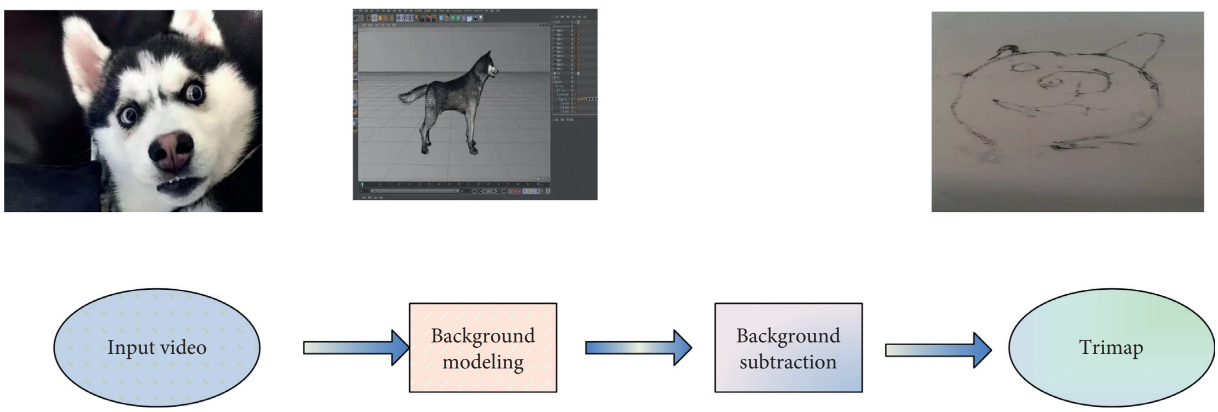


FIGURE 4: The first frame of video segmentation process.

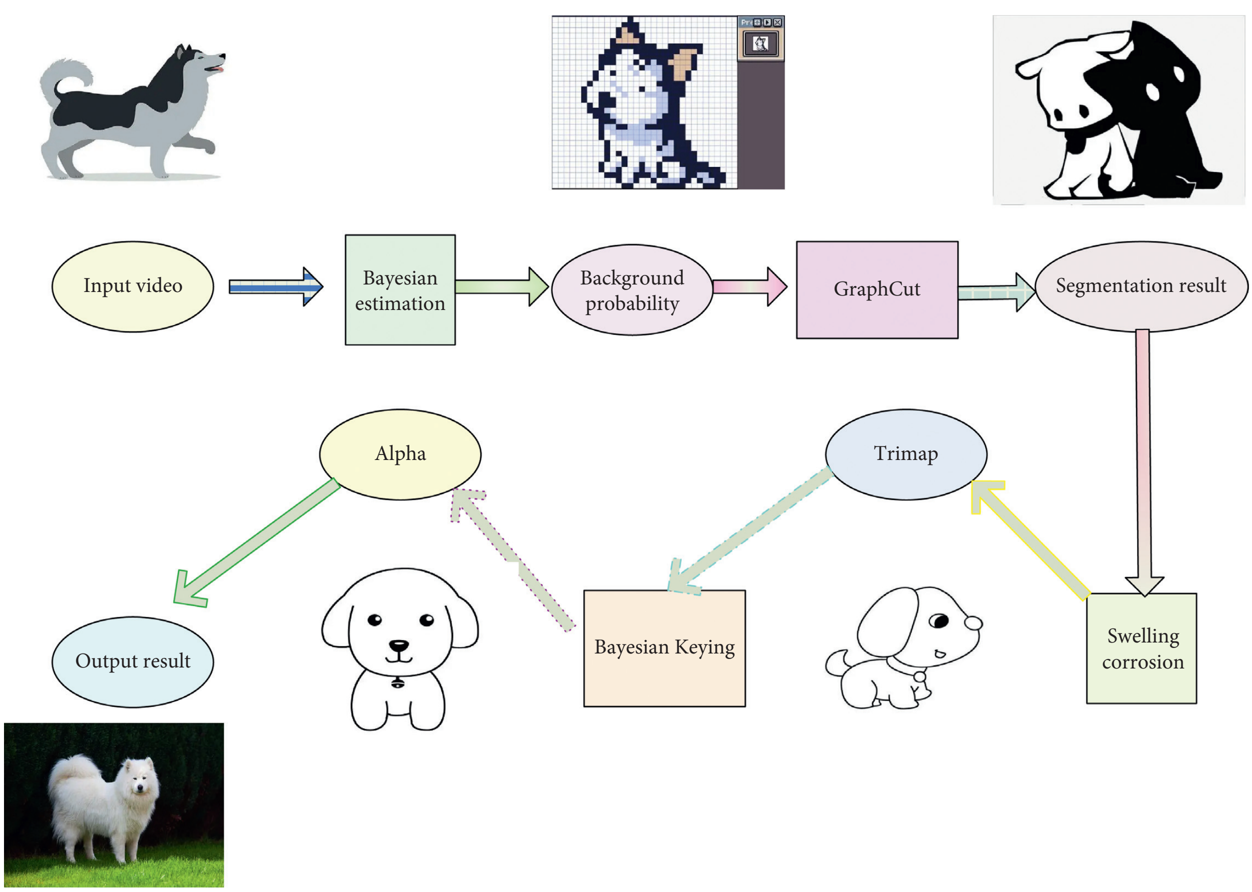


FIGURE 5: Keying and synthesis flow chart.

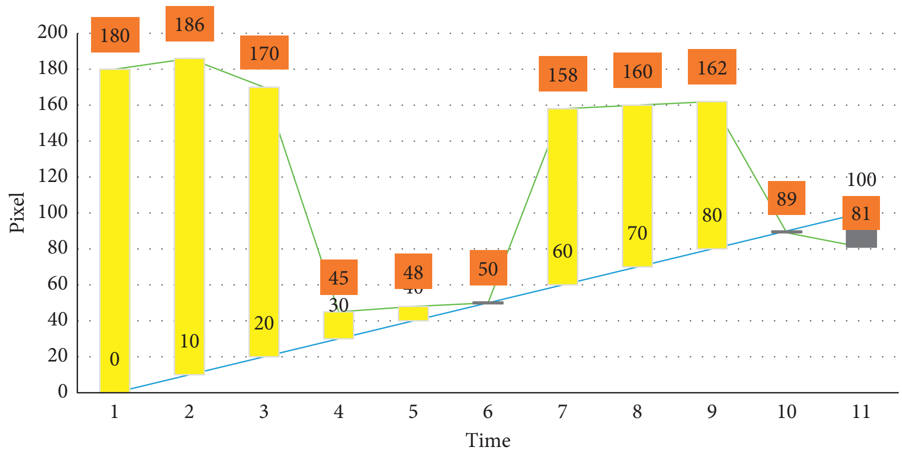


Figure 6: Schematic diagram of the R value of a pixel in an image sequence changing with time.

we need to know the foreground and background segmentation results of the first frame. A completely automatic method is used here. Generally, automatic image segmentation has two methods: interactive segmentation and background subtraction according to the target video type [14]. If the background of the real-time video is fixed before shooting, the first frame can be segmented using background subtraction. Hence, the entire segmentation process does not require user operation.

The principle of the static background subtraction algorithm in this paper is to perform histogram statistics on the three channel values during modeling, and the highest frequency value obtained is used as the background model pixel value [15]. With reference to the gray-scale statistical classification method, the pixel values are statistically classified and the background model is established. The value with the highest current frequency is used as the average value of the background pixels, as shown in Figure 6.

As shown in Figure 6, frames 1 to 20 belong to one category, frames 21 to 53 belong to other categories, frames 54 to 83 belong to a new category, and frames 84 to 100 belong to a new category. Find the category with the highest probability of occurrence, and take the average value to obtain the pixel value. It can be seen from the figure that the probability of the first category is the highest, the average value is about 168, and the value component of the pixel is 168. By traversing the values of all pixels in this way, a complete color background model image can be obtained.

2.2.4. Introduction to Background Subtraction Algorithm. In video synthesis technology, the most common is background subtraction. According to the comparison between the background model and the current video image, it is found that different pixels are classified as foreground targets, and pixels without distinction are classified as background. It is a common background subtraction [2].

Use DW $(x, y) = (G, F, Q)$ to represent the GFQ value of the (x, y) pixel in the current video image and FB $(x, y) = (G, F, Q)$ to represent the background of the corresponding position number of pixels.

$$\begin{aligned} s_1(x, y) &= |G - G_1|, \text{Interpolation of the red component}, \\ s_2(x, y) &= |F - F_2|, \text{Interpolation of the green component}, \\ s_3(x, y) &= |Q - Q_1|, \text{Interpolation of the blue component}. \end{aligned} \tag{3}$$

If none of $s_1(x, y)$, $s_2(x, y)$, $s_3(x, y)$ is greater than the specified value set in the image sequence, then (x, y) is judged as the background. Otherwise, it is judged that (x, y) is the prospect target.

Of course, the distance between two corresponding pixels in the GFQ spatial distribution point can also be calculated, and whether the pixel has changed can be judged by the distance between the two points.

The formula for calculating the spatial distance between DW $(x, y) = \{G, F, Q\}$ and FB $(x, y) = \{G, F, Q\}$ is as follows:

$$K = \sqrt{(G - G_1)^2 + (F - F_1)^2 + (Q - Q_1)^2}. \tag{4}$$

If K is greater than the specified value, the pixel is the foreground target, otherwise, it is the background.

In this article, the process of inferring the pixel foreground of a video frame is a Bayesian classification process. We know the classification result of the previous frame, i.e., because we know the conditional probability density and the prior probability, we assume that the conditional probability density and the preprobability of two adjacent frames are almost the same [16]. The basic principles of Bayesian classification are introduced below.

Proving the category posterior probability $H(b|y)$ is a place where the Bayesian algorithm is widely used. Its formula is as follows:

$$\begin{aligned} H(b \mid y_i) &= \frac{H(b \mid y_i) H(y_i)}{H(b)} \\ &= \frac{H(b \mid y_i) H(y_i)}{\sum_{i=n}^{n} H(b \mid y_i) H(y_i)}, \quad i = 1, 2, \ldots, n. \end{aligned} \tag{5}$$

In the case of using the 0–1 loss function, to minimize the classification error, the category y of b is determined as follows:

$$y = \arg\max_{1<i<n}\{H(b \mid y_i)\}. \tag{6}$$

However, $H(y) = \sum_{i=n}^{n} H(b \mid y_i)H(y)$ can be regarded as a constant, using formula (5), we can get the following:

$$\text{y} = \arg\max_{1<i<n}\{H(b \mid y_i)H(y_i)\}. \tag{7}$$

We apply Bayesian classification to the foreground estimation and calculate the probability $I_{\text{prob}}(H)$ that each pixel H belongs to the foreground. Calculate the conditional probability using the Bayesian formula.

$$I_{\text{prob}}(H) = H(A \mid B_p) = \frac{H(B_p \mid A)H(A)}{H(B_p \mid A)H(A) + H(B_p \mid C)H(C)}. \tag{8}$$

B_p is the pixel point, $I(x, y) = aF(x, y) + (1 - a)B(x, y)$ color vector, F and B are recorded as foreground and background, $P(^*)$ represents * probability, and probability $H(B_p \mid A)$ and $H(B_p \mid C)$ are estimated from foreground and background color histograms. The foreground probability $H(A)$ is estimated from the segmentation results of the previous burst using spatiotemporal consistency.

2.2.5. Trimap Introduction. Trimap roughly divides the image into the foreground area, the background area, and the unknown area to be obtained by drawing the boundary. As Trimap has a more obvious guiding effect, it is easy for people to know how to classify a better Trimap to get a better keying result. Common keying synthesis equations are as follows:

$$G = \partial F + (1 - \partial)A. \tag{9}$$

It can be concluded from figure (9) that the keying problem has a lot of incompatibility. Therefore, we construct the corresponding Trimap according to the relevant rules, which contain three values. The corresponding relationship formula is as follows:

$$\begin{aligned} f\left(I_{\text{peob}}(H) < \varepsilon\right)&: Tr(H) = A, \\ f\left(I_{\text{peob}}(H) > 1 - \varepsilon\right)&: Tr(H) = B, \\ \text{otherwise}&: Tr(H) = V. \end{aligned} \tag{10}$$

Among them is a small real number.

2.2.6. Graphcut Algorithm. Unlike the Trimap algorithm, the Graphcut algorithm is mostly used to solve the problem of interactive foreground segmentation [17]. This method is fast and effective. In recent years, it has become an important algorithm in foreground segmentation.

To better solve the optimal segmentation, they defined the energy function of the segmentation as follows:

$$M = N\text{cut}(A, B) = \frac{\text{cut}(A, B)}{\text{assoc}(A, S)} + \frac{\text{cut}(A, B)}{\text{assoc}(A, W)}. \tag{11}$$

We have

$$\text{assoc}(A, S) = \sum_{n \in A, i \in S} M(n, i). \tag{12}$$

It is the sum of the energy weights of the edges between the connected nodes in A and S. Under this definition, the segmentation of isolated small areas is no longer the optimal segmentation. As ASSOC (A, S) will be small at this time, its proportion will be relatively large. The Graphcut algorithm establishes a connection between the energy function optimization and the maximum flow minimum cut algorithm in the graph theory. In many cases, it can be used to find a more reasonable local optimal solution. In some cases, the global optimal solution can be obtained [18]. Figure 7 is a schematic diagram of Graphcut's algorithm structure.

Firstly, the user interactively sets some front scenic spots and background points on the image. Then, add two imaginary nodes a and b to the graph defined in the above figure, which visually represent the foreground and background colors, respectively. These two nodes are connected to each node in the graph with an edge, and the weight of the edge indicates the similarity of the pixel point corresponding to the node with the foreground and background [19]. The segmentation result divides the graph into two parts, namely h and y, and a belongs to h, whereas b belongs to y. The segmented pixels are the front scenic spot, and the pixel point it belongs to is the background point. The split energy is defined as follows:

$$N = \sum_m N_g + \lambda \sum_n E_v. \tag{13}$$

Here,

$$N_g = \begin{cases} -\log\text{MA}(I_N \mid O)I_N \in O \\ -\log\text{MA}(I_N \mid B)I_N \in B \end{cases}. \tag{14}$$

The above formula reflects the similarity between the pixel and the foreground or background, MA (.) represents the probability that the point belongs to the foreground, which can be obtained from the statistical information of the foreground and background. When the point is the front scenic spot or background point specified by the user, the value is infinitely small at this time, which is mainly used to ensure that it still belongs to the foreground or background specified by the user after segmentation:

$$Ca = \exp\left(-\frac{(I_i - I_n)^2}{2\sigma^2}\right) * \frac{1}{\text{dist}(i, n)}. \tag{15}$$

As the number of people using the Graphcut algorithm increases, the Graphcut algorithm is continuously optimized by people. We use the optimized Graphcut algorithm to perform image segmentation on an unknown area. Let sc be an image segmentation, where sc (n) selects M for each pixel. Define the energy function.

$$W(\text{sc}) = \text{Data}(\text{sc}) + \lambda\text{sm}(\text{sc}). \tag{16}$$

The data item Data (sc) evaluates the cost function of a single pixel, and the smoothing item sm (sc) evaluates the cost function between pixels. It is the weighting factor. This function can be optimized by the min-cut algorithm, and

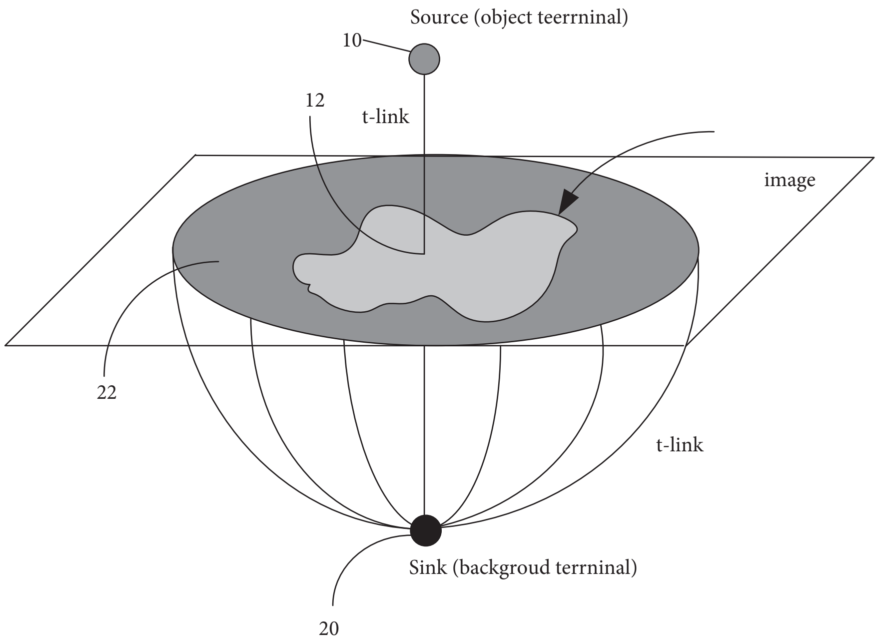


Figure 7: Schematic diagram of Graphcut algorithm structure.

this optimized solution can get a better segmentation result. Definition of Data (sc) and sm (sc) is as follows:

$$\mathrm{Data}\,(\mathrm{sc}) = \sum_{z\in n} -\log\left(p\left(c_2 \mid \mathrm{sc}\,(z)\right)\right) + \mu \sum_{z\in n} -\log\left(I_{\mathrm{prob}}\,(z)\right),$$
$$\mathrm{sm}\,(\mathrm{sc}) = \sum_{(z,m)\in n} [\mathrm{sc}\,(z) \neq \mathrm{sc}\,(m)] \frac{e^{\left\|C_X - C_y\right\|^2} / \left(2a^2\right)}{\|\mathrm{dist}\,(z,m)\|}. \quad (17)$$

where sc(z) represents the set of adjacent pixel pairs, and dist ($p.q$) represents the Euclidean distance between pixels p and q.

2.3. Art Color. Color is the most sensitive shape element and can evoke our common aesthetic joy. Because of its nature, color directly affects people's feelings. Hence, it is one of the most expressive elements. The rich and varied colors can be divided into two categories: neutral color and color. Color has three basic characteristics: hue, purity (also called chroma, chroma), and brightness [20].

Color estimation is a very important process in the color design process. First of all, we have to define a reasonable Bayesian framework and establish a color estimation model and a calculation model for m-values. Use the maximum posterior probability (MAP) to optimize the solution. In MAP estimation, for a given unknown area pixel A, look for the most likely estimated values of V, F, and m. This problem is described as an optimization problem on the probability distribution T (A, F, m | N), namely,

$$\arg\max_{A,F,m} T\,(A,F,m \mid N) = \arg\max_{A,F,m} \frac{T\,(N \mid A,F,m) T\,(A) T\,(F) T\,(m)}{T\,(N)}. \quad (18)$$

After the samples are clustered, the points in each cluster obey the Gaussian distribution in the RGB color space, and the weighted mean Σf and covariance matrix f are as follows:

$$f = \frac{1}{A}\sum_{N\in M} \omega_N F_N, \sum f = \frac{1}{A}\sum_{N\in M} \omega_N \left(F_N - f\right)\left(F_N - f\right)^t, \quad (19)$$

in $\omega_N = m * m * g_i$, and m is not a transparency value.

3. Experimental Process and Result Analysis

3.1. Preliminary Research on Traditional Animation Special Effects Production. Animation is characterized by dynamic art, and the exquisite paintings of each plane cannot be said to be animation. What the animation needs is the time dynamics accumulated by the plane painting to gradually form a complete action presentation. The character conveys the storyline information to the audience through physical activity. An animation production company has previously produced five two-dimensional animations, A, B, C, D, and E, and three three-dimensional special effects animations, Q, W, and R, respectively, for preschoolers, lower grades of elementary school, upper grades of elementary school, junior high school, and Bao Da Bao Mom. Animation developers conduct a survey on the degree of affection and obtain the average value (the higher the score of 1–10, the higher the degree of affection). The survey results are shown in Table 1.

3.2. Preliminary Research and Analysis of Traditional Animation Special Effects Production. By the analysis and data comparison of Table 1, obtain the distribution of the degree

Table 1: Results of the survey on the degree of favorite animation.

	A	B	C	D	E	Q	W	R
Preschooler	8	5	9	8	7	2	1	3
Lower grades of elementary school	9	5	7	5	8	3	2	2
Upper grades of elementary school	7	4	8	9	8	5	3	5
Junior high school student	5	5	2	4	8	7	6	9
Bao Mom and Dad	3	1	4	2	6	8	8	9
Animation developer	1	2	6	4	5	6	8	9

of preference for animation special effects between high and low age groups (Figure 8).

After analyzing and judging Figure 8, we can get a trend graph of different age groups' preference for different types of animation special effects, as shown in Figure 9.

3.3. Analysis of Animation Special Effects Production Methods Based on Visual Communication Design. Through the above experiments, it can be concluded that the animations produced based on traditional animation production technology, whether in two-dimensional or three-dimensional animations, have more serious imbalances in different age groups. In two-dimensional animation, the proportion of people in the lower age group is as high as 72%, and in three-dimensional animation, the proportion of people in the senior group is as high as 60%. The survey data is shown in Table 2.

By the analysis of the data, it can be concluded that there are big differences between different groups of people based on traditional animation production technology. To further confirm that the animation special effects production method based on visual communication design technology is more conducive to people's love, a company also investigated the animation produced based on visual communication design technology (A_1, B_1, C_1, D_1, and E_1 are two-dimensional animation, Q_1, W_1, and R_1 are three-dimensional animations). The data results obtained are shown in Table 3.

By comparing with the previous data and some other data, the percentage change before and after the improved technology can be obtained (Figure 10).

From the figure, we can find that in the animation special effects designed based on visual communication technology, both high and low age groups and animators have a high degree of preference for them. From data analysis, whether it is two-dimensional or three-dimensional animation, the degree of affection of different groups of people has increased by at least 5%.

From Figure 11, it can be concluded that animation production based on modern visual communication technology has a decline in the proportion of technical production costs. It not only reflects the progress of technology but also implies the application of visual communication design technology. The scope is getting wider.

3.4. Art Color Research Based on Visual Communication Design Technology. The so-called color composition, i.e., the interaction of colors, is based on people's perception and psychological effects of color. It uses scientific analysis methods to restore complex color phenomena to basic elements, and it uses color in space, quantity, and quality. Variability is the process of combining the interrelationships between components according to certain rules and then creating new color effects. Color composition is one of the basic theories of art design. It has an inseparable relationship with plane composition and three-dimensional composition. Color cannot exist independently of shape, space, position, area, texture, etc.

Color is one of the most basic needs of human beings and an indispensable element in life. Because of colors, we can feel the beauty of the world and the splendor of life. Hence, colors play a very important role in our lives. An organization conducted a survey on people's love of color in daily life, the survey results are shown in Table 4.

The higher the number, the higher the priority. On the contrary, the opposite is true.

After comparing the data, the results shown in Table 5 are obtained by making a short film with several common colors as the main color.

By the analysis of the data in Table 5, although most people do not like dark colors and other colors, once they are incorporated into the film, they will also increase people's liking for these colors.

4. Discussion

This article is dedicated to the study of animation special effects production methods based on visual communication design, and it is committed to applying its production technology to more animation special effects production. We not only researched the technology of visual communication design but also have a detailed understanding of the production technology of animation special effects. This paper analyzes and investigates some of the film and television works designed and produced by the early animation special effect technology and modern visual communication design technology. This article, firstly, analyzes the investigation of animations designed and manufactured by different groups of people in the early stage of technology and then organizes and summarizes the relevant data. Then, the animation special effect videos designed based on modern visual communication design technology are surveyed on the popularity of the crowd. By investigation, comparison, analysis, and sorting of one after the other, it is concluded that the production of animation special effects based on modern visual communication design technology is good. A good way of expression is also more conducive to the acceptance and love of different groups of people.

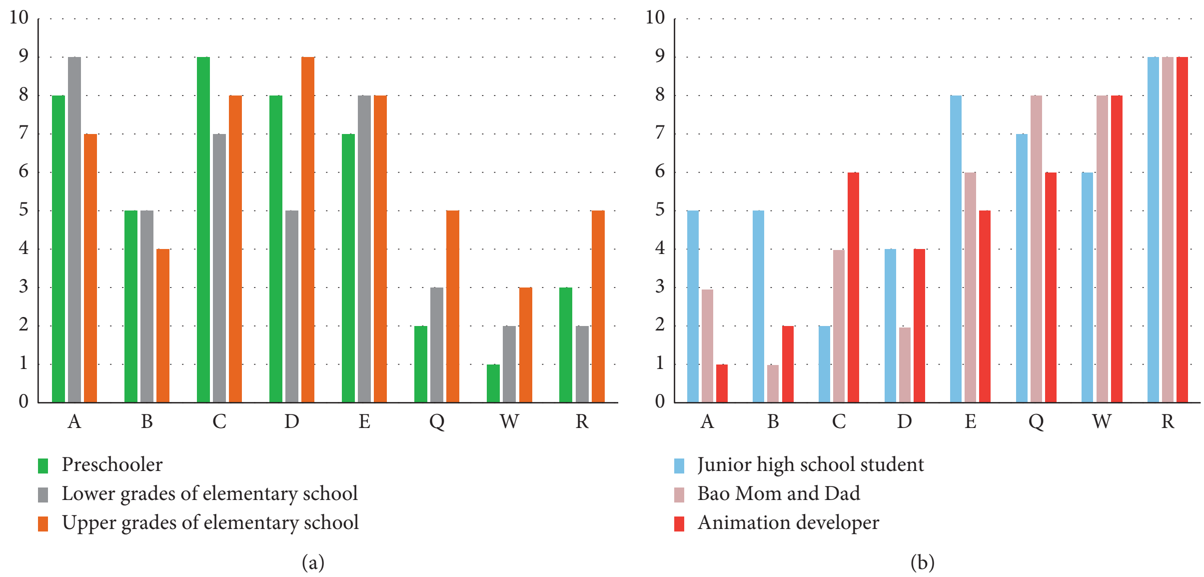


Figure 8: The distribution of the degree of affection in different age groups. (a) Distribution of the lower age group. (b) Distribution map of senior age group.

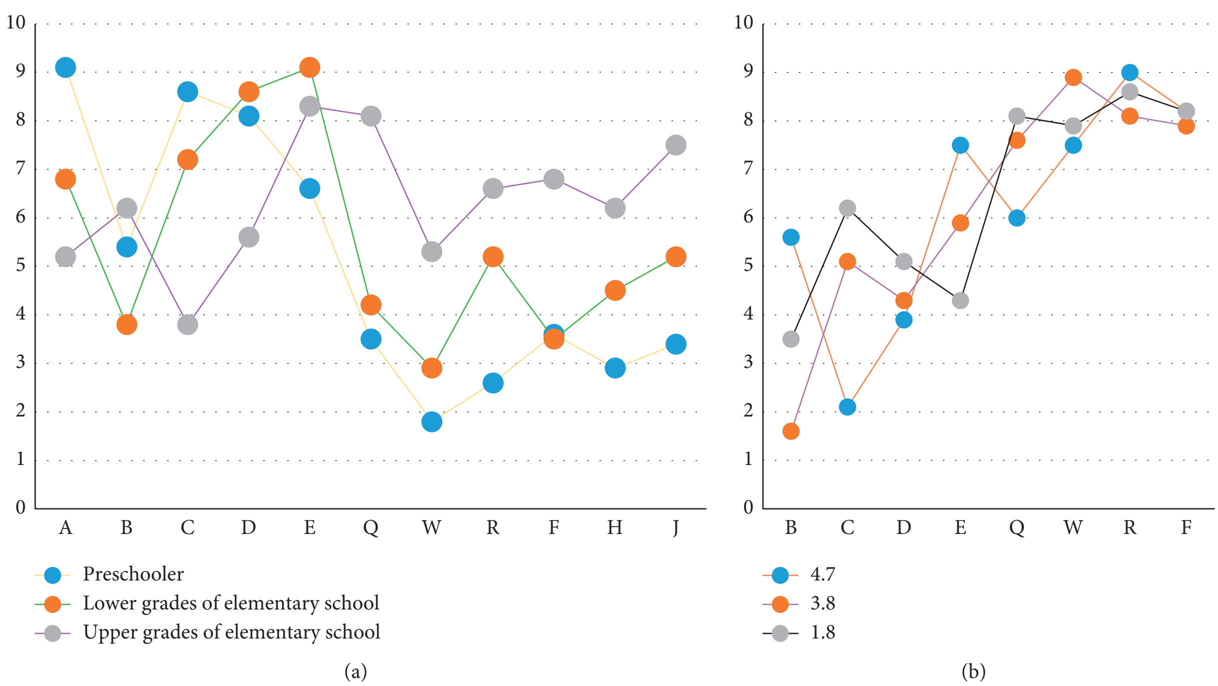


Figure 9: Trends of love levels of different age groups. (a) Trend chart of the younger age group. (b) Trend chart of the senior age group.

By the analysis of the article case, it is concluded that the reasonable use of visual communication design plays a significant role in the production of animation special effects. Continuing to do a good job in the visual communication design of animation special effects is a major event with long-term significance and related to social development and civilization progress for the work in the field of animation production. It also proves the value of visual communication design in the production of animation special effects. The use of visual communication design technology can not only improve the authenticity and visibility of animation special effects but also provide people with more vivid film and television characters. Although it can be seen in domestic animated special effects movies, our digital production technology is still very poor. Compared with the special effects of developed countries, the advancement of China's film and television technology is more than 10 years behind. However, with the

Table 2: Proportion table of the degree of preference for traditional animation among high and low age groups.

	Younger age group	High age group	Animation developer
Two-dimensional animation	72.8	65.4	40.8
3D animation	27.2	34.6	59.2

Table 3: The percentages of different groups of people's preference for the improved animation types.

	A_1	B_1	C_1	D_1	E_1	Q_1	W_1	R_1
Younger age group	8	8.6	9	7	8.9	5.6	6.2	7.8
High age group	5.5	6.9	7.2	6.8	8.1	7.9	8.8	8.9
Animation developer	5.9	7.3	7.6	6.8	8.2	7.1	6.9	8.5

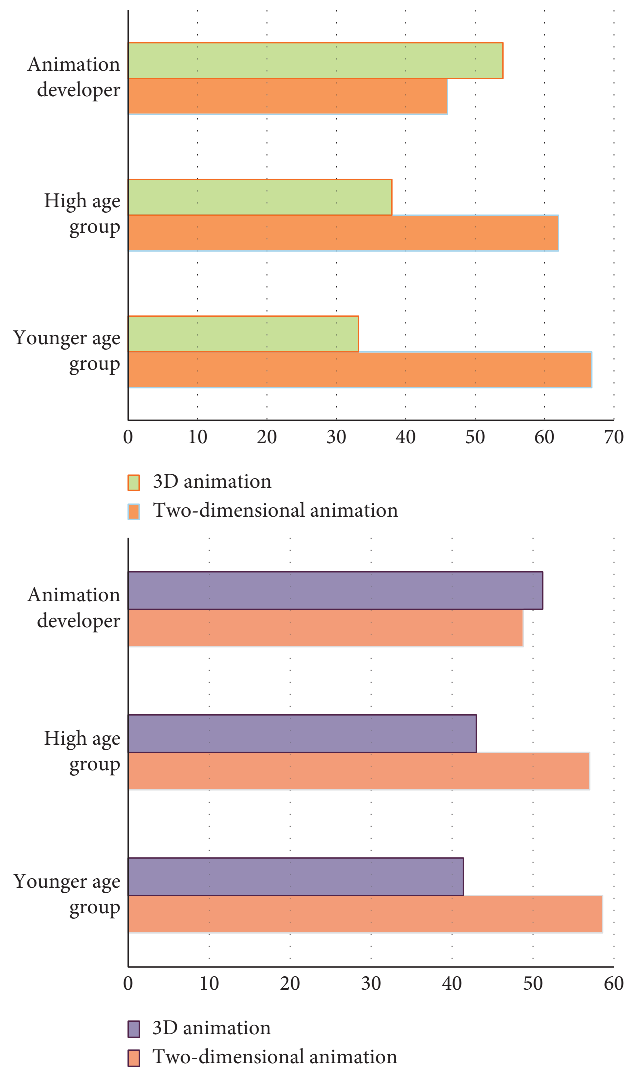


Figure 10: The proportion of people's love of animation after improving technology.

development of the times, filmmakers in our country have gradually realized the nature and functions of digital special effects. At the same time, China has a strong and actively developing computer technology industry. The film industry has given full play to our relative advantages in computer technology, taking digital special effects as the highlight of Chinese films and creating influential domestic hits.

This article analyzes the popularity of animation special effects of a certain company among different groups of people. Firstly, it analyzes the preference of different groups of people for different film and television works. The degree

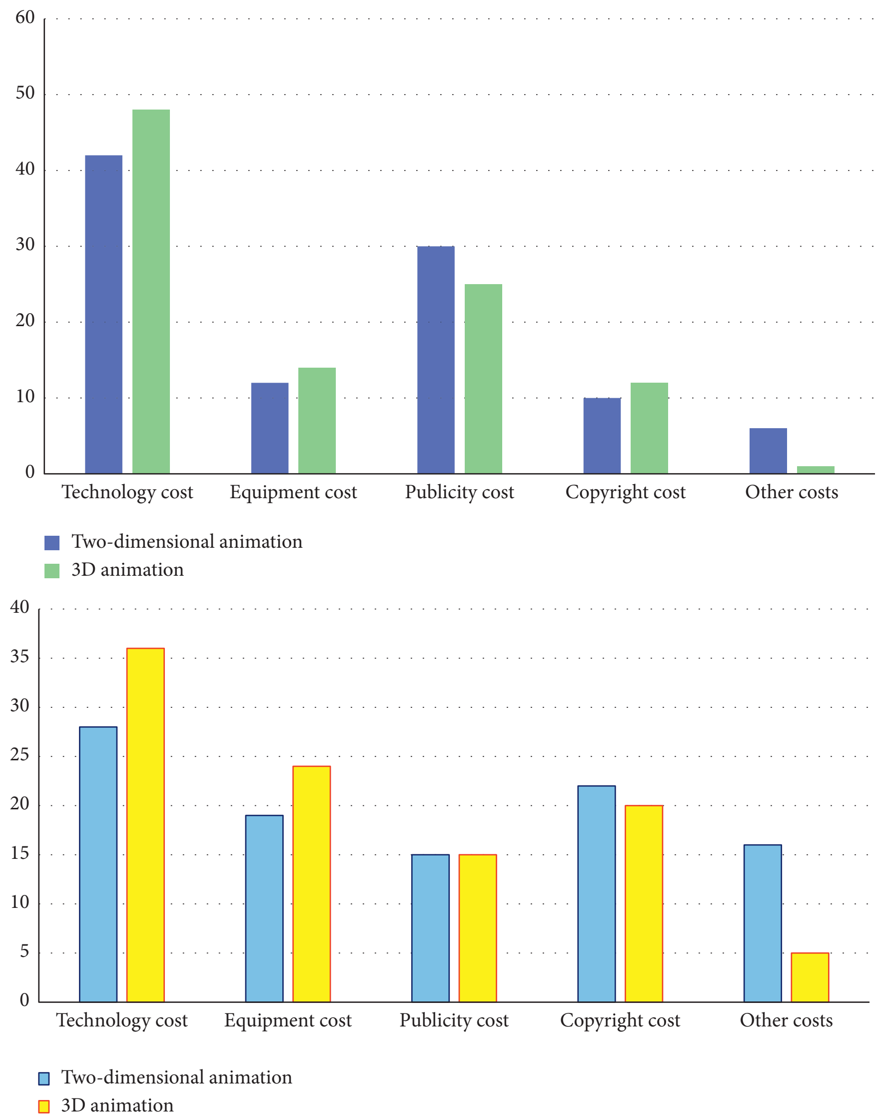


Figure 11: Animation production cost analysis chart. (a) Early animation production costs. (b) Modern animation production costs.

Table 4: The degree of preference for some colors of different age groups.

	White	Red	Black	Purple	Blue	Color	Green	Orange	Yellow
Child	5	9	3	7	8	9	6	5	8
Teenager	3	6	4	8	6	6	5	8	6
Adult	8	5	7	6	5	3	6	7	7
Elder	3	8	5	5	6	8	6	6	5

Table 5: The degree of preference for different colors in different age groups.

	Five colors	Six colors	Seven colors	Eight colors	Nine colors	Ten colors	Eleven colors
Child	6	5	8	9	8	8	7
Teenager	7	8	9	7	8	9	9
Adult	9	8	7	8	8	7	8
Elder	5	6	7	8	6	7	6

of fondness for film and television works is, to a certain extent, restricted by the integration of film and television production technology and colors, rather than unilateral likes or dislikes.

5. Conclusions

This article starts with the influence of visual communication design in the field of animation special effects production on people's love, and it elaborates and discusses the far-reaching influence of visual communication design in animation special effects design and production. From the viewpoints in the article, it can be known that the animation special effects production based on modern communication design technology can not only make the animation effect more expressive but also improve the appeal of its film and television works. However, in some modern film and television environments, the design language expressed by a single graphic design graphic form tends to appear single and lacks expressiveness. Only by continuously strengthening the theoretical and innovative research of animation special effect production in visual communication design can we better promote the deepening and progress of visual communication technology. The understanding of the field of animation special effects production can be used as a basis to give full play to the role of modern communication design technology in the field of animation production. In addition, in visual communication design, we should also focus on exploring and thinking about the problems of animation special effects production, explore the open problems in visual communication design, and give new meaning to animation special effects production through the special media force of visual communication design.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this article.

References

[1] H. Zhu, "On the teaching of decorative painting for the major of visual communication design," *Journal of Landscape Research*, vol. 10, no. 4, pp. 166–168, 2018.

[2] Z. Özomay, B. Keskin, and C. Şahin, "Görsel İletişim Tasarım Bölümü Öğrencilerinin Sektörel Logolardaki Renk Tercihleri," *OPUS Uluslararası Toplum Araştırmaları Dergisi*, vol. 17, no. 37, pp. 4181–4198, 2021.

[3] H. Wu and G. Li, "Visual communication design elements of internet of things based on cloud computing applied in graffiti art schema," *Soft Computing*, vol. 24, no. 11, pp. 8077–8086, 2020.

[4] C. Zhang, "Research on interface visual communication design based on virtual reality technology in paper manufacturing," *Paper Asia*, vol. 2, no. 1, pp. 146–150, 2019.

[5] C. R. Vyhnal, E. H. R. Mahoney, Y. Lin, R. Radpour, and H. Wadsworth, "Pigment synthesis and analysis of color in art: An example of applied science for high school and college chemistry students," *Journal of Chemical Education*, vol. 97, no. 5, pp. 1272–1282, 2020.

[6] S. Yang, "Application of fuzzy intelligent reasoning method in art color measurement," *Journal of Intelligent and Fuzzy Systems*, vol. 39, no. 6, pp. 8887–8895, 2020.

[7] M. Cheung, W Hong, W. Hong, and J. Thong, "Effects of animation on attentional resources of online consumers," *Journal of the Association for Information Systems*, vol. 18, no. 8, pp. 605–632, 2017.

[8] H. Turgut and G. K. Özgür, "The effect of an animation video and music on anxiety and pain scores before TRUS-guided biopsy," *The Bulletin of Urooncology*, vol. 20, no. 1, pp. 7–10, 2021.

[9] M. Rusli and I. Negara, "The effect of animation in multimedia computer-based learning and learning style to the learning results," *The Turkish Online Journal of Distance Education*, vol. 18, no. 4, pp. 177–190, 2017.

[10] A. Waszkiewicz-Raviv, "Recenzja książki Giorgii Aiello i Katy Parry "Visual communication. Understanding images in media culture", Londyn 2020," *Studia Medioznawcze*, vol. 22, no. 1, pp. 904–907, 2021.

[11] C. Rigutto, "The landscape of online visual communication of science," *Journal of Science Communication*, vol. 16, no. 2, pp. 1–9, 2017.

[12] R. Piazza and L. Haarman, "A pragmatic cognitive model for the interpretation of verbal-visual communication in television news programmes," *Visual Communication*, vol. 15, no. 4, pp. 461–486, 2016.

[13] P.-E. Gabert, F. Bodin, N. Aljudaibi, V. Duquennoy-Martinot, and P. Guerreschi, "The Transverse musculocutaneous gracilis free flap," *Plastic and Reconstructive Surgery*, vol. 137, no. 5, pp. 1384–1387, 2016.

[14] G.-C. Liu and C.-H. Ko, "Photoshop and illustrator use in instructional design: a case study of college visual communication course design," *The International Journal of Design Education*, vol. 15, no. 1, pp. 119–130, 2021.

[15] Y. Wada, "On the occasion of publication of the special issue on "now and future of technology of microwave chemical processes"," *Journal of the Japan Petroleum Institute*, vol. 61, no. 2, p. 87, 2018.

[16] S. B. Oğuzkan and A. S. Bozkurt, "A study on the effect of prolactin gene variants on milk production Traits of holstein Cattle," *Russian Journal of Genetics*, vol. 55, no. 4, pp. 480–486, 2019.

[17] D. Abewoy, "Review on effects of genotypes and harvesting age on herbage and oil production of sweet basil (*Ocimum basilicum* L.)," *International Journal of Novel Research in Engineering & Pharmaceutical Sciences*, vol. 8, no. 1, pp. 1–6, 2021.

[18] G. Sawadwuthikul, T. Tothong, T. Lodkaew et al., "Visual goal human-Robot communication framework with few-shot learning: a case study in Robot Waiter System," *IEEE Transactions on Industrial Informatics*, vol. 18, no. 3, pp. 1883–1891, 2022.

[19] J. Lin, "Research on the performance of impressionist painting color visual communication based on wireless communication and machine vision," *Security and Communication Networks*, vol. 2021, no. 1, 6 pages, Article ID 5511252, 2021.

[20] G. Dadalan, E. Ta, and E. Kaya, "The effects of virtual reality and animation supported science education on students' some learning products," *Journal of Computer and Education Research*, vol. 9, no. 17, pp. 62–79, 2021.

Hindawi
Scientific Programming
Volume 2022, Article ID 1875774, 6 pages
https://doi.org/10.1155/2022/1875774

Research Article

A Corpus-Driven Study on the Revolutionary Image Construction of Sun Yat-sen in English Literature from the Perspective of Attitudinal System in Appraisal Theory

Yuxiao Luo

Zhongshan Institute, University of Electronic Science and Technology of China, Zhongshan 528402, Guangdong, China

Correspondence should be addressed to Yuxiao Luo; luoyuxiao@zsc.edu.cn

Received 8 January 2022; Revised 18 February 2022; Accepted 28 February 2022; Published 26 March 2022

Academic Editor: Ahmed Farouk

Under the background of developing the Guangdong-Hong Kong-Macau Greater Bay Area and with the purpose of responding to initiatives named "co-building humanities in bay area" and "supporting Zhongshan to promote Sun Yat-sen's culture," this research applies AntConc software to establish the English literature corpus related to Sun Yat-sen's revolutionary deeds and analyzes the affect system, judgement system, and appreciation system in the English literature with the theoretical framework of the attitudinal system in appraisal theory. The following are discovered. (1) The proportion of the affect system in the corpus is the largest, while the proportion of the appreciation system is the smallest. Three systems differ greatly in quantity. (2) Focuses described by three systems are consistent. Through specific language representations, it is believed that Sun Yat-sen has the determination to dedicate and sacrifice for the revolution. He is undoubtedly the leader and pioneer of Chinese revolution. (3) Among 1854 language representations, positive attitudinal resources account for as much as 70%, which has important enlightenment in translating Sun Yat-sen's revolutionary deeds to foreigners. Translators should reduce the usage of negative category of the attitudinal system as much as possible and adapt to the internal and ingrained cognitive model of western readers by increasing the usage of positive category of the attitudinal system. In this way, barriers from language representations and conflicts related to the deep culture will be eliminated, and ultimately Sun Yat-sen's revolutionary culture will be exchanged and promoted at home and abroad.

1. Introduction

On the basis of Outline Development Plan for the Guangdong-Hong Kong-Macau Greater Bay Area issued by State Council of the PRC in 2019, initiatives named "co-building humanities in bay area" and "supporting Zhongshan to promote Sun Yat-sen's culture" are demonstratively emphasized. From 2019 to 2021, the tendency for investigating Sun Yat-sen's culture has continued to rise, which implies that much more attention has been paid to the study of Sun Yat-sen. As the great pioneer of the national democratic revolution in China, Sun Yat-sen has not only exhausted all his life and made indelible contributions for China's independence, democracy, and prosperity but also always been a research highlight in the academic field for studying the history of China in the past century. Qiushan pointed out that Sun Yat-sen was both a great forerunner of the democratic revolution in China and a great man in the whole world [1]. Since he spent most of his time abroad, a lot of studies about Sun Yat-sen have been kept overseas. Harold Z. Schiffrin is an outstanding representative scholar to study Sun Yat-sen's revolutionary culture. His famous book named Sun Yat-Sen and the Origins of the Chinese Revolution cited abundant foreign language materials and elaborated Sun Yat-sen's political activities deeply. How did Harold Z. Schiffrin construct the revolutionary image of Sun Yat-sen through specific language representations? In order to explore this issue, this article attempts to break the previous research paradigm, takes the attitudinal system in appraisal theory as the theoretical framework, makes use of the AntConc corpus software to build the English literature corpus related to Sun Yat-sen's revolutionary deeds, analyzes specific language representations, and ultimately explores international scholars' cognition for the revolutionary image construction of Sun Yat-sen.

2. Theoretical Framework

In 2000, James Martin published a paper called Beyond Exchange: Appraisal Systems in English, heralding the advent of appraisal theory. Shizhu claimed that appraisal is a kind of conscious activity with the subjective consciousness and moreover it is a conceptual activity of meaning and value related to human beings [2]. Martin and White believe that appraisal theory, as an interpersonal system, is a process of interaction among three subsystems including the affect system, judgement system, and appreciation system because it focuses on coordinating language resources and attitudinal expressions in social relations [3]. Compared with the judgement and appreciation systems in appraisal theory, Ying demonstrated that the attitudinal system is the core system of appraisal theory, emphasizing the author's or speaker's evaluation of specific values of human behaviors and physical objects [4]. The attitudinal system mainly involves the description of personal emotions in language, which is culturally oriented to a large extent and is closely connected with people's cognitive positioning.

The attitudinal system consists of three subsystems: affect system, judgement system, and appreciation system. Xinyue maintains that the affect system is related to interpreting emotional responses, as it is defined as the emotional response and emotional tendency of the author or speaker to the occurrence or state of certain behaviors, discourses, processes, or phenomena [5]. The affect system with the positive category and negative category can be realized through a variety of grammatical structures, such as grammatical metaphors, modal adjuncts, and other language forms. The affect system includes three subsets: happiness/unhappiness, security/insecurity, and satisfaction/dissatisfaction. The judgement system based on the common and normative culture is applied to judge what kind of behavior people should behave as members in the society. The judgement system can be achieved through many grammatical means, such as adjectives including "dishonest," "warm-hearted," and so on, adverbs including "unskillfully," "wisely," and so on, nouns including "a genius," "an official," and so on, and verbs including "to success," "to win," and so on. The judgement system is generally divided into two subsets which are social esteem and social sanction. Both subsets have the positive category and negative category. The appreciation system, as an aesthetic category, refers to people's evaluation of certain discourses, processes, and phenomena. The appreciation system includes reaction, composition, and valuation, which can be divided into the positive category and negative category.

At present, there are countless books and literature related to the attitudinal system in appraisal theory at home and abroad. Wahyu analyzed the attitudinal system in the presidents' inauguration speeches from the perspective of appraisal theory in order to discover differences in effects of the affect system, judgement system, and appreciation system on the communication between speakers and audiences [6]. Munday employed appraisal theory to analyze Trump's inaugural speech in 2017 and identify the mediating effect of the translator by interpreting the affect system, judgement system, and appreciation system in the translation process [7]. Jalilifar et al. explored the appraisal language model in the brief introduction and found that people who write brief introductions tend to use the appreciation system to promote their works and products [8]. Jie applied the attitudinal system in appraisal theory to systematically interpret the construction of China's national image in The Chinese Are Coming [9]. Xingrui used the attitudinal system in appraisal theory to compare and analyze news discourses of the Belt and Road Initiative [10]. It is found that China has been portrayed as a hypocritical, unreliable, irresponsible, and unstable nation by The Times [10].

On the basis of the literature review, it is discovered that there are few studies on English discourses related to Sun Yat-sen from the perspective of the attitudinal system in appraisal theory. Furthermore, with the help of search engines at home and abroad, it is found that there is almost null literature on the revolutionary image construction of Sun Yat-sen under the theoretical framework of the attitudinal system in appraisal theory. This article attempts to explore the revolutionary image of Sun Yat-sen in English literature, which will help Chinese scholars to understand the great revolutionary pioneer more clearly. In addition, specific language representations and deep cognitive adaptation models will be provided for Sun Yat-sen's revolutionary cultural translation and publicity.

3. Research Design

3.1. Research Framework. This research explores the revolutionary image construction of Sun Yat-sen in English literature on the basis of the attitudinal system in appraisal theory. The schematic diagram of three subsystems and seven subsets of the attitudinal system is shown in Figure 1.

In Figure 1, A, B, and C are applied to reduce the repetition of three subsystems; meanwhile, A1 to C3 are employed to avoid the repetition of seven subsets. A1+/A1− mainly covers emotions related to the mood, such as "misery," "jubilant," "whimper," and so on; A2+/A2− mainly covers emotions related to happiness, such as "anxious," "jolted," "staggered," and so on; A3+/A3−mainly covers emotions related to feelings of pursuing the goal, such as "castigate," "engrossed," "chuffed," and so on. B1+ refers to things that people will admire, such as "powerful," "mature," and so on, whileB1- refers to things that people should criticize, such as "weak," "insane," and so on. According to Ngo and Unsworth, criticism of B1- is not conducted from the juridical perspective. B2+ means things that people should praise, such as "just," "fair," and so on, while B2− means things that people should condemn, such as "evil," "corrupt," and so on [11]. Condemnation of B2− is conducted from the juridical perspective. C1+/C1− in appreciation system involves influence and quality. Influence refers to how things are attractive, such as "remarkable," "tedious," and so on, and quality means if the evaluator likes the evaluated object, such as "enchanting," "nasty," and so on. C2+/C2−in the appreciation system includes balance

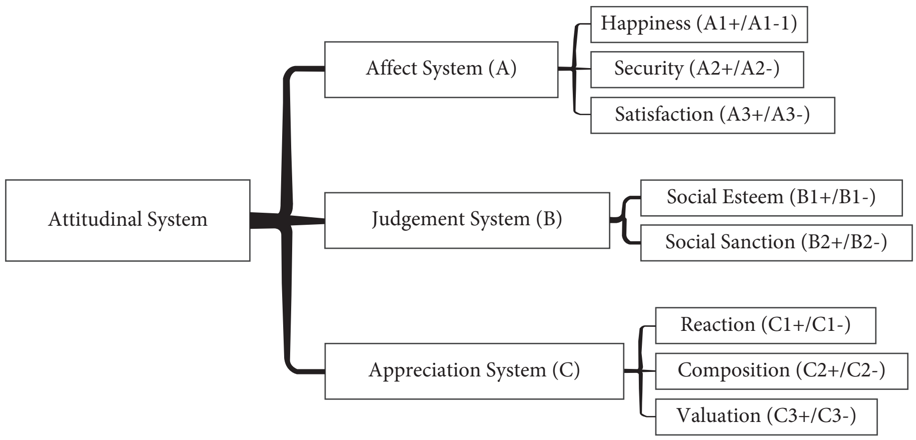


Figure 1: Three subsystems and seven subsets of the attitudinal system.

and complexity. Balance refers to whether the composition of things is proportional or not, such as "harmonious," "distorted," and so on, while complexity means whether the structure of things is concise and understandable or not, such as "precise," "unclear," and so on. C3+/C3− in the appreciation system consists of the importance, value, and meaning of things. C3+/C3− is not the subjective judgement from individuals, but the collective view from a group of people, such as "valuable," "worthless," and so on.

3.2. Research Instruments. This article makes use of AntConc software to transform the book named Sun Yat-Sen and the Origins of the Chinese Revolution into the corpus. As the representative work, this treatise including 12 chapters, nearly 100,000 words, and more than 600,000 characters is written from Sun Yat-sen's early revolutionary activities. As the book involves a large amount of precious historical materials and analyzes the trajectory of Sun Yat-sen's revolutionary deeds, it is praised by scholars at home and abroad as the "most detailed and authoritative" masterpiece about Sun Yat-sen. With the help of concordance, word list, file view, collocates, and other functions in the software, the author regards "Sun Yat-Sen" and "he/his/him" as search terms, and then relevant contexts describing Sun Yat-sen's revolutionary deeds will be retrieved. Since "Sun Yat-Sen" and "he/his/him" are direct terms to describe the great revolutionary, specific sentences are retrieved to depict the image of Sun Yat-sen. On the basis of the "Hit" column on the left side of the software, contexts related to Sun Yat-sen's descriptions are analyzed, four parts of speech including nouns, verbs, adjectives, and adverbs in KWIC are dissected, and language representations of A, B, and C in Figure 1 are ultimately marked.

3.3. Research Procedures. Procedures of data collections consist of four steps.

(1) The first step is to mark three systems of A, B, and C and divide them into seven subsets of A1, A2, A3, B1, B2, C1, C2, and C3.

(2) The second step is to analyze specific language representations in three systems and seven subsets for capturing Sun Yat-sen's revolutionary image with the help of concordance, word list, file view, collocates, and other functions in the AntConc software.

(3) The third step is to compare the number of three systems distributed in 12 chapters and seven target subsets in order to explore whether Sun Yat-sen's revolutionary images are discrepant in different periods or not.

(4) The last step is to explore the internal cognition for the revolutionary image construction of Sun Yat-sen by comparing language representations, summarize strategies for translating Sun Yat-sen's revolutionary deeds in line with foreign readers, and finally promote the exchange of Sun Yat-sen's revolutionary culture at home and abroad.

4. Data Analysis and Discussion

4.1. Revolutionary Image Construction of Sun Yat-sen in the Affect System. 861 language representations of the affect system related to the revolutionary image construction of Sun Yat-sen are marked, such as "famous," "confident," "success," "dispatched," and "commitment," which express the emotional response and emotional tendency of the author to the occurrence or state of certain behaviors, discourses, processes, or phenomena.

In Table 1, language representations of A2 take up the largest number of the affect system, while language representations of A1 have the least number of the affect system. The usage of positive category of the affect system in the corpus which accounts for 75.21% is far more than the usage of negative category of the affect system in the corpus which merely accounts for 24.79%. Language representations including "in favor of," "be fond of," "embraced," and "affection" directly express a person's sense of happiness. All of those descriptions revolve around Sun Yat-sen, and their triggers are scenarios and themes related to the revolutionary deeds.

Table 1: Distribution of language presentations in the affect system.

Affect system	A	A1 (A1/A)	A2 (A2/A)	A3 (A3/A)
Chapter1	29	7 (24.1%)	13 (44.8%)	9 (31.1%)
Chapter 2	45	12 (26.7%)	15 (33.3%)	18 (40%)
Chapter 3	23	7 (30.4%)	8 (34.8%)	8 (34.8%)
Chapter 4	126	45 (35.7%)	47 (37.3%)	34 (27%)
Chapter 5	149	42 (28.2%)	58 (38.9%)	49 (32.9%)
Chapter 6	92	31 (33.7%)	39 (42.4%)	22 (23.9%)
Chapter 7	116	20 (17.2%)	63 (54.3%)	33 (28.5%)
Chapter 8	115	15 (13%)	43 (37.4%)	57 (49.6%)
Chapter 9	16	4 (25%)	7 (43.8%)	5 (31.2%)
Chapter 10	34	7 (20.6%)	11 (32.4%)	16 (47%)
Chapter 11	73	19 (26%)	31 (42.5%)	23 (31.5%)
Chapter 12	38	12 (31.6%)	16 (42.1%)	10 (26.3%)
Chapter 1–12	861	221 (25.7%)	351 (40.8%)	289 (33.5%)

Table 2: Distribution of language presentations in the judgement system.

Judgement system	B	B1 (B1/B)	B2 (B2/B)
Chapter 1	22	16 (72.7%)	6 (27.3%)
Chapter 2	45	17 (37.8%)	28 (62.2%)
Chapter 3	16	7 (43.8%)	9 (56.2%)
Chapter 4	85	57 (67.1%)	28 (32.9%)
Chapter 5	74	60 (81.1%)	14 (18.9%)
Chapter 6	60	32 (53.3%)	28 (46.7%)
Chapter 7	58	25 (43.1%)	33 (56.9%)
Chapter 8	55	26 (47.2%)	29 (52.8%)
Chapter 9	16	5 (31.3%)	11 (68.7%)
Chapter 10	28	17 (60.7%)	11 (39.3%)
Chapter 11	63	40 (63.5%)	23 (36.5%)
Chapter 12	33	18 (55.5%)	15 (44.5%)
Chapter 1–12	555	320 (57.7%)	235 (42.3%)

Eg1. The evidence further suggests that before making a decision in favor of revolution, Sun made a final attempt to ally himself with the gentry reformists (Chapter II: Sun Yat-sen's Early Influences).

"In favor of" followed by "revolution" in example 1 is used to show Sun Yat-sen's enthusiasm and support for the revolution. This direct expression of happiness leaves readers with the impression of Sun Yat-sen's enterprising spirit in revolutionary deeds. When Sun Yat-sen was still only a low-ranking medical student, his early attempts for the revolution did not receive any response, but his awakened interest in the revolution for the whole China has not diminished at all. Furthermore, he believed that China definitely needed to conduct the revolution.

Eg2. The Chinese people, Sun believed, were bound to rise sooner or later, but he was trying to pacify them and provide leadership (Chapter VII: Li Hung-chang, Sir Henry Blake, and Ho Kai).

"Assert," "declare," "trustworthy," and "believe" are typical language representations of A2 in the affect system. In example 2, Schiffrin applies A2 to enable overseas readers to understand Sun Yat-sen's willingness to seek like-minded people for conducting the revolution with a positive attitude and his efforts to awaken the faith of Chinese people for continuing revolutionary activities.

4.2. Revolutionary Image Construction of Sun Yat-sen in the Judgement System. 555 language representations of the judgement system related to the revolutionary image construction of Sun Yat-sen are marked, such as "powerful," "predictable," "normal," "blunt," and "ethical," which indicate the judgement of human behaviors according to the common and normative culture.

In Table 2, language representations of B1 take up the largest number of the judgement system, while language representations of B2 have the least number of the judgement system. The usage of positive category of the judgement system in the corpus which accounts for 78.56% is far more than the usage of negative category of the judgement system in the corpus which only accounts for 21.44%.

Eg3. Actually, Sun's political personality had matured considerably since 1896 (Chapter I: Introduction).

"Loyalty," "loyal," "mature," "heroic," and "reliable" are typical representations of B1 in the judgement system. In example 3, Schiffrin makes use of "mature" to convey that in terms of the political vision and commitment, Sun Yat-sen exceeded other supporters for the revolution in the same period. He has been seeking opportunities for the revolution and firmly believed that the establishment of a powerful China will benefit the whole world. Language representations including "loyalty," "mature," and "heroic" are all positive social esteem. These descriptions demonstrate the maturity of Sun Yat-sen's revolutionary mindset, the loyalty of Sun Yat-sen's revolutionary followers, and the heroic image of Sun Yat-sen's revolutionary leader.

Eg4. It seems hardly credible that any Chinese nationalist movement, not to mention one connected with the name of Sun Yat-sen, could invite even greater foreign interference, as for example, in the proposition concerning the Maritime Customs (Chapter IV: The Canton Plot of 1895).

"Fair," "ethical," "moral," "truthful," and "credible" are typical language representations of B2 in the judgement system. In example 4, Schiffrin employs "hardly credible" to express his positive affirmation and recognition for the nationalist revolution led by Sun Yat-sen. Sun Yat-sen started his revolutionary career because of the Canton Plot of 1895. Not only that, Qing government intended to hunt Sun Yat-sen down at all costs, which exactly placed Sun Yat-sen to a prominent position as a national revolutionary.

4.3. Revolutionary Image Construction of Sun Yat-sen in the Appreciation System. 438 language representations of the appreciation system related to the revolutionary image construction of Sun Yat-sen are marked, such as "lively," "enchanting," "clear," "valuable," and "worthless," which explain people's evaluation of certain discourses, processes, and phenomena.

In Table 3, language representations of C1 take up the largest number of the appreciation system, while language representations of C2 have the least number of the appreciation system. The usage of positive category of the appreciation system in the corpus which accounts for 75% is far more than the usage of negative category of the appreciation system in the corpus which merely accounts for 25%.

Eg5. Sun Yat-sen is not unlikely to become a prominent character in history, for it may be safely said that he is a remarkable man, with most enlightened views on the undoubtedly miserable state of China's millions (Chapter V: Kidnapped in London).

"Remarkable" and "enchanting" are typical language representations of C1 in the appreciation system. In example 5, Schiffrin makes use of "remarkable" to describe Sun Yat-sen as an extraordinary person, who has the great wisdom to reconcile various parties and powers. Because of his full understanding of the revolutionary situations and his desperate courage, Sun Yat-sen's enterprising spirit for the revolution will inevitably have a huge impact in China. More and more Chinese people are inspired by Sun Yat-sen to conduct the revolution for the whole country without fear of sacrifice.

Eg6. Yet the picture becomes distorted by overemphasis of his backroom enthusiasm for radical anti-dynasticism (Chapter II: Sun Yat-sen's Early Influences).

"Clear," "unclear," and "distorted" are typical language representations of C2 in the appreciation system. Although Sun Yat-sen has repeatedly emphasized his opposition to the governance of Qing Dynasty, he is by no means a ghostly rebel. Therefore, in example 6, Schiffrin uses "distorted" to express his negative attitude towards the rebel identity of Sun Yat-sen and his positive attitude towards the revolutionary identity of Sun Yat-sen. The usage of the negative category of attitudinal system "distorted" in example 6 is the double negative language phenomenon which has the effect of more affirmation.

4.4. Comparison in Revolutionary Image Construction of Sun Yat-sen. On the basis of the corpus, four parts of speech of KWIC in the corpus are analyzed, and language representations of the three systems and seven subsets in the attitudinal system are marked. In the corpus of nearly 100,000 words, the author has retrieved a total of 5,631 KWIC, in which 1854 language representations are labeled. Among them, the number of language representations associated with the affect system is the largest, the number of language representations associated with the judgement system is the second, and the number of language representations associated with the appreciation system is the least. Their proportions are 46.4%, 29.9%, and 23.7%, respectively.

With the aid of language representations related to the affect system, the emotional response and emotional tendency to happy/unhappiness, security/insecurity, and satisfaction/dissatisfaction are depicted when Schiffrin described Sun Yat-sen's revolutionary behaviors, processes, and deeds. The positive category of the affect system in 861 language representations accounts for 75.21%. With the aid of language representations related to the judgement system,

Table 3: Distribution of language presentations in the appreciation system.

Appreciation system	C	C1 (C1/C)	C2 (C2/C)	C3 (C3/C)
Chapter 1	29	7 (24.1%)	13 (44.8%)	9 (31.1%)
Chapter 2	45	12 (26.7%)	15 (33.3%)	18 (40%)
Chapter 3	23	7 (30.4%)	8 (34.8%)	8 (34.8%)
Chapter 4	126	45 (35.7%)	47 (37.3%)	34 (27%)
Chapter 5	149	42 (28.2%)	58 (38.9%)	49 (32.9%)
Chapter 6	92	31 (33.7%)	39 (42.4%)	22 (23.9%)
Chapter 7	116	20 (17.2%)	63 (54.3%)	33 (28.5%)
Chapter 8	115	15 (13%)	43 (37.4%)	57 (49.6%)
Chapter 9	16	4 (25%)	7 (43.8%)	5 (31.2%)
Chapter 10	34	7 (20.6%)	11 (32.4%)	16 (47%)
Chapter 11	73	19 (26%)	31 (42.5%)	23 (31.5%)
Chapter 12	38	12 (31.6%)	16 (42.1%)	10 (26.3%)
Chapter 1–12	861	221 (25.7%)	351 (40.8%)	289 (33.5%)

Sun Yat-sen's attempts, efforts, struggles, dedication, and sacrifices for the revolution are judged by Schiffrin and readers based on the common and normative culture. The positive category of the judgement system in 555 language representations takes up 78.56%. With the aid of language representations related to the appreciation system, Schiffrin successfully examines the reaction, composition, and valuation of Sun Yat-sen's revolutionary process. The positive category of the appreciation system in 438 language representations occupies 75%.

According to Tables 1–3, three systems differ greatly in quantity. These specific forms of language representation describe Sun Yat-sen's urgent desire to awaken the whole nation, his sincere and persistent attitude towards the revolution, and his self-confidence and determination to the revolution.

5. Conclusions

Due to limited time and energy, mere attitudinal system in appraisal theory is included in the research. Based on the analysis of three systems and seven subsets in the attitudinal system, it is discovered that although there are abundant language representations related to the affect system, judgement system, and appreciation system in this book, they are unevenly distributed. The largest proportion is the number of language representations related to the affect system and the smallest proportion is the number of language representations related to the appreciation system. Among language representations of A, A2 with a total number of 351 takes up the largest proportion; among language representations of B, B1 with a total number of 320 accounts for the largest proportion; among language representations of C, C1 with a total number of 178 occupies the largest proportion. Three major systems used by Schiffrin differ greatly in quantity, but the focus and core of those language representations are consistent. Readers are convinced of Sun Yat-sen's determination to dedicate and sacrifice for the revolution because he is undoubtedly the leader and the pioneer of the whole nation.

Schiffrin makes use of the affect system from Sun Yat-sen himself, judgement system from others, and appreciation system from Sun Yat-sen and others to outline Sun Yat-sen's revolutionary activities and revolutionary undertakings in multiple dimensions. Language representations related to the affect system such as "in favor of," "embraced," "trustworthy," "asserted," "claim," and "anxious" directly present Sun Yat-sen's enthusiasm and support for the revolution. Language representations related to the judgement system such as "loyalty," "mature," "heroic," "fair," "truthful," and "credible" indirectly demonstrate the maturity of Sun Yat-sen's revolutionary mindset and Sun Yat-sen's urgent desire to awaken the nation. Language representations related to the appreciation system such as "remarkable," "enchanting," "clear," "distorted," "genuine," and "worthy" regard Sun Yat-sen as an extraordinary person because of his full understanding of the revolutionary situation and his desperate courage.

The description of 100,000 words, the retrieval of 5631 KWIC, the language representations of 1854, and more than 70% of positive category in three systems enable readers to realize the lofty and profound image of Sun Yat-sen as the revolutionary leader and pioneer. The usage of positive category in three systems provides an implication for contemporary scholars when they translate Sun Yat-sen's revolutionary deeds into English. It is better for translators to conform to demands of western readers for the positive category in the attitudinal system. In other words, translators can choose four parts of speech including nouns, verbs, adjectives, and adverbs which are embedded with the positive energy. Through minimizing the usage of negative category in the attitudinal system, the deep cognitive model of western readers will be adapted to. In this way, barriers from language representations and conflicts related to the deep culture will be eliminated, and ultimately Sun Yat-sen's revolutionary culture will be exchanged and promoted at home and abroad.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

This study was supported by projects named First-Class Online and Offline Blended IT English Course in Guangdong Province (published in 2020, No. 16) and First-Class Online and Offline Blended IT English Course (YLKC202102).

References

[1] M. E. N. G. Qiushan, *Research on the History Teaching Strategies of Junior Middle School with "Characters" as the Master Line*, Nanning Normal University, Nanning, China, 2021.

[2] S. Liu, "The development of appraisal theory in China," *Foreign Languages and Their Teaching*, vol. 8, no. 5, pp. 33–37, 2010.

[3] J. R. Martin and P. R. R. White, *The Language of Evaluation: Appraisal in English*, Foreign Language Teaching and Research Press, Beijing, China, 2008.

[4] L. I. Ying, *A Study on the Protagonist's Personality in Tender Is the Night from the Perspective of Attitude in Appraisal Theory*Xinjiang University, 2020.

[5] X. Sun, *A Comparative Study of Two English Versions of Du Fu's Poems from the Perspective of Attitude in Appraisal Theory*, Beijing Foreign Studies University, Beijing, China, 2020.

[6] P. Wahyu, "Image construction in politics: political advertisement in 2009 Indonesian election," *Journal of Social Issues in Southeast Asia. SOJOURN*, vol. 27, no. 2, pp. 310–327, 2012.

[7] J. Munday, "A model of appraisal: Spanish interpretations of President Trump's inaugural address 2017," *Perspectives*, vol. 26, no. 2, pp. 180–195, 2018.

[8] A. Jalilifar, R. Banari, and Z. G. Shooshtari, "Exploring the Patterns of Evaluative Language in Physics Blurbs: The Appraisal System Strategies in Focus," *International Journal of Society, Culture & Language*, vol. 7, no. 1, pp. 1–15, 2019.

[9] X. U. Jie, *A Research on the Construction of China's National Image in the Chinese Are Coming from the Perspective of Appraisal Theory*, Yangzhou University, Yangzhou, China, 2014.

[10] H. E. Xingrui, *What National Images of China Are Constructed in News Discourses on the Belt and Road Initiative: A Comparative Analysis Based on Appraisal Theory*, Guangdong University of Foreign Studies, Guangzhou, China, 2016.

[11] T. Ngo and L. Unsworth, "Reworking and Appraisal Framework in ESL Research: Refining Attitude Resources," *Ngo and Unsworth Functional Linguistics*, vol. 2, pp. 1–24, 2015.

Hindawi
Scientific Programming
Volume 2022, Article ID 6369074, 6 pages
https://doi.org/10.1155/2022/6369074

Research Article

Application of Clustering and Recommendation Algorithm in Sports Competition Pressure Source

Lipeng Zhang [1] and Lingling Guo [2]

[1]Physical Education Institute, Nanchang Institute of Science & Technology, Nanchang 330000, Jiangxi, China
[2]School of Media Design, Nanchang Institute of Science & Technology, Nanchang 330000, Jiangxi, China

Correspondence should be addressed to Lipeng Zhang; lipeng6668882021@163.com

Received 12 January 2022; Revised 3 February 2022; Accepted 14 February 2022; Published 25 March 2022

Academic Editor: Ahmed Farouk

With the vigorous development of China's sports industry, the rules and number of events are increasing, and the competition pressure on the playground is also increasing. The increase of competition pressure will bring many negative effects to athletes. In order to relieve the pressure of athletes in sports competition and eliminate the negative significance of pressure to athletes, this paper mainly introduces the clustering algorithm of sports source and competition. The clustering algorithm uses the similarity of attributes between data objects to calculate the clustering structure of fractional clustering. In this paper, the original data of sports competition pressure are obtained through the questionnaire survey, using clustering and recommendation algorithms to calculate and analyze the original data, the data utilization rate is as high as 98%, and the analysis efficiency is as high as 97%. Dividing athletes into three categories, the magnitude and source of stress are analyzed, respectively, and application methods are recommended according to their respective stress distributions, so as to assist psychologists in the diagnosis, and the corresponding height is 80%; this enables athletes to receive good counseling advice and remain mentally healthy.

1. Introduction

1.1. Research Background and Significance. The competition in today's sports arena is quite fierce. Due to the development of sports science, sports technology is more advanced than before. It is not enough to have good technology alone. In the face of numerous internal and external pressures, what is tested is a player's ability to withstand pressure and psychological control. It is very important for an excellent athlete to be able to show the results of hard training in normal times on the field, to remain calm at critical moments, to stably exert one's skills, and to show a better competitive state and psychological quality.

With the vigorous development of sports in China, the rules and quantity of events are increasing, and the pressure on the sports field is increasing. Competition pressure comes from various aspects, among which the most lethal pressure is also psychological pressure. To play normally or abnormally on the field, psychological stress had to be surmounted. As a result, there has been an increasing focus on game stress by many psychologists and athletic coaches. In order to make athletes play normally and play for a long time in the competition, of course, the psychiatrists will give psychological guidance and conduct psychological diagnosis regularly. However, the psychological state of athletes is uncertain and fuzzy, and it is not possible to effectively understand and solve the pressure of athletes. Therefore, this paper proposes to apply clustering and recommendation algorithm to stress psychoanalysis and recommendation and give corresponding suggestions after cluster analysis, which can relieve the pressure of athletes and also provide athletes' data for psychological expert diagnosis. At the same time, it provides psychological treatment assistance information for psychologists and relieves stress for athletes.

1.2. Relevant Contents. In sports events, the sources of pressure on athletes are diverse. Liu et al. proposed a set of cognitive neuroscience evaluation systems for athletes' stressors to protect athletes in sports competitions. According to the stress of athletes, they designed questionnaires for many experts at home and abroad who study the stress of athletes and conducted in-depth and detailed investigations on the life process of athletes who often participate in sports events. At the same time, a cognitive neuroscience evaluation system in sports competitions is constructed by using the clustering algorithm and recommendation algorithm [1]. Their proposal is only aimed at the evaluation of cognitive nerves, and the stressors may also be reflected in the psychological and physical aspects, so they have a certain one sidedness [2]. Wang et al. proposed a clustering algorithm for fast searching and finding density peaks, which is a clustering algorithm for fast finding clustering centers. A method is suggested to automatically pull the baseline values through automatic threshold extraction using the potential entropy of the data fields in the original dataset. The accuracy of this method relies too much on the threshold value and there is no valid way to choose the proper value. The value is estimated empirically. For any dataset to be aggregated, the threshold value can be objectively calculated from the dataset rather than empirically estimated. Experimental results show that the algorithm clusters better compared to the empirical thresholds [3]. However, this algorithm has some prediction error with some bias. Hotta et al. proposed a new self-adaptive rate of change function integrating an index function with a linear function and applied this method to the SVD++ referral algorithm [4]. As a recommendation algorithm related to singular value decomposition (SVD), this algorithm is widely used and has good prediction performance. However, with the rapid growth of intelligent social data, the bad performance of the SVD++ referral algorithm becomes a salient drawback because of the long optimization time of the objective function in building the prediction model [5, 6]. Therefore, the study rate function is an important factor for prediction models based on SVD++ algorithm for recommendation. It directly affects the convergence rate and performance of the forecasting computer model [7]. However, the relative error of this algorithm will increase while improving the efficiency [8, 9].

1.3. Main Innovations. The innovations of this paper are as follows: (1) using clustering and recommendation algorithms to analyze the survey data of sports competition stressors; (2) using scientific calculation methods to calculate and analyze the data obtained from the survey; and (3) the research results are objective and reasonable. It uses the knowledge of computer theory and the pressure of sports competition. It also provides psychotherapy aids for future psychologists and stress relief for athletes.

2. Concept and Research Method

2.1. Concept of Pressure and Pressure Source. Pressure is a feeling caused by various aspects of oppression, which can be reflected in individual life continuously. Multiple stressors can cause the same stress response, and one stressor can cause multiple stress responses. The stress source is all the subjective and external stimuli that can cause people's stress response. By nature, stressors are divided into three categories: biological stressors, mental stressors, and socio-environmental stressors [10, 11]. Among them, biological stressors are a set of events that directly hinder and destroy the survival of the individual and the continuity of the race, including physical illness trauma or illness, hunger, sexual deprivation, sleep deprivation, noise, temperature changes, etc. Psychological stressors are a set of internal and external events that directly hinder and destroy the normal spiritual needs of an individual including wrong cognitive structure, bad personal experience, moral conflict and bad personality, and psychological characteristics caused by long-term life experience. Social environmental stressors are a set of events that directly hinder and disrupt an individual's social needs [12]. They are divided into two aspects: purely social, such as major social changes, the breakdown of important relationships, long-term family conflicts, war, incarceration, etc. The second category is interpersonal adaptation problems caused by their own conditions, such as personal mental disorders, infectious diseases, and anthropophobia. The pressure source of the sports competition studied in this paper is also described and studied from these three aspects. At the same time, stressors are divided into acute stressors and chronic stressors according to the degree of impact on life.

2.2. Clustering Algorithm and Recommendation Algorithm. With the development of human science and technology, the requirements for classification are getting higher and higher, so that sometimes it is difficult to classify accurately only by experience and professional knowledge. So, people gradually introduced mathematical tools to taxonomy, forming numerical taxonomy, and then introduced multivariate analysis technology to numerical taxonomy to form cluster analysis. This paper studies the hierarchical clustering method; its implementation principle is to use the similarity of attributes between data objects to calculate the clustering structure of fractional clustering. Cluster analysis, also known as group analysis, is a statistical analysis method for studying (sample or index) classification problems and is also an important algorithm for data mining [13, 14]. The process of clustering method is the process of merging and decomposing each layer structure [15–17]. Algorithms of cluster analysis can be divided into partition method, hierarchical method, density-based method, grid-based method, and model-based method. This paper divides athletes into three types by cluster calculation and analyzes each type. According to the calculation content and the athlete's pressure data, a model is established on the basis of analyzing the similarity, and then the prediction result of the pressure is calculated by the recommendation algorithm. The advantages of recommendation algorithms are that the recommendation results are intuitive, easy to interpret, and do not require domain-wide knowledge [18, 19]. However, there are sparse problems and new user problems, and complex attributes are difficult to deal with. There must be enough data to construct a classifier.

2.3. Questionnaire Survey. In order to understand the sources of sports competition pressure, the pressure sources of athletes are subdivided, and the pressure source questionnaire is used. In this paper, 100 athletes of different grades and ages are randomly selected from sports colleges and universities to fill in the questionnaire, and the recovery rate is 100%, which provides the original data for clustering algorithm and recommendation algorithm.

3. Clustering Evaluation and Recommendation Algorithm Flow

3.1. Clustering Evaluation Algorithm. In using clustering algorithms to process data, it is more critical to determine how good the clusters are, which is called cluster identification [20]. Generally speaking, the evaluation criteria of clustering algorithms are divided into the following categories: First, identify whether there is nonrandom structure or noisy data in the data; second, determine the number of cluster sets; third, pay attention to the quality of cluster analysis results, the degree of close separation, etc. fourth, compare the cluster results with known results [21, 22]. The first three are non-supervised evaluation, and the last is supervision evaluation. Generally, cluster sets are evaluated by the measurement standard of classification model. The common ones are pitch, accuracy, recall rate, F value, and so on [2, 23, 24]. The following describes several clustering evaluation criteria.

3.1.1. Contour Formula. Contour coefficient is a method to explain and verify the clustering results. It can display the advantages and disadvantages for a simple picture of any object present in the collection of data [25]. Assume that the data can be clustered into K clusters. To impose any object I of the data, $a(I)$ denotes the mean variance of object I from other objects in the same cluster. That is, it represents how favorably or unfavorably object I is allocated to the current cluster. The more similar I is to the other objects in the cluster, the more suitable I is to be allocated to the current cluster. $a(I)$ is specified below.

$$a(i) = \frac{\sum_{o' \in c_{i, o \neq o'}} \operatorname{dis}(o, o')}{|c_i| - 1}, \tag{1}$$

where $B(I)$ denotes the least distance, on average, between subject I and every other available cluster (not the one to which I is assigned), i.e., the object I's distance from its next best adjacent cluster. If object I is not effectively assigned, then the best cluster it should be assigned to should be the nearest available neutral neighborhood to that of the presently assigned cluster. B is given by the following formula:

$$b(i) = \min_{c_j : 1 \leq j \leq k, j \neq i} \left\{ \frac{\sum_{i' \in c_j} (o, o')}{|C_j|} \right\}. \tag{2}$$

So, the contour factor might be specified as follows:

$$s(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}}, \tag{3}$$

or it can be written as follows:

$$s(i) = \begin{cases} 1 - \dfrac{a(i)}{b(i)}, & a(i) < b(i), \\ 0, & a(i) = b(i), \\ \dfrac{b(i)}{a(i)} - 1, & a(i) > b(i). \end{cases} \tag{4}$$

From the formula, $s(I)$ is taken as [−1,1]. As $a(I) < B(I)$, the smaller $a(I)$ is, the higher the distribution of I is, for $a(I)$ denotes the closeness of I to the targets within the cluster. The larger $B(I)$, the lower the distribution of I in the neighboring clusters. In this case, $s(I)$ near 1 indicates a better overall distribution level in the dataset; $s(I)$ near 0 indicates that object I is at the boundary of two clusters; $s(I)$ near −1 indicates that subject I is different from the objects in this cluster and object 1 is poorly assigned to a cluster. $s(I)$ means value in the set of data is used to rate the cluster results' quality. Therefore, the contour coefficient can serve as a useful reference point to choose the desired amount of clusters in the dataset. For example, if one chooses the k-means algorithm for clustering, the value of $s(I)$ can vary significantly if the value of k chosen is too large or too small.

3.2. Flow and Similarity Calculation in Recommendation Algorithm. The main principle of recommendation algorithm is to infer the most likely similar information of current customers according to the historical evaluation or opinion of existing customers. According to similar information to calculate the corresponding conclusion, the process is as follows.

As can be seen from Figure 1, the recommendation algorithm starts from obtaining user data, then establishes user information evaluation model to calculate the similarity, and then predicts the result by using similar user set according to the similarity.

At present, there are three common similarity calculation methods.

3.2.1. Cosine Similarity. The goal of the cosine similarity calculation method is to compute the value of the cosine of the degree of similarity among users or items based on the cosine value of the angle between the attribute vectors of the users or items. The larger the cosine value, the higher the similarity between them. The cosine similarity calculation formula is as follows (the similarity calculation formula of users and items is similar, and the subsequent formulas take the user similarity calculation as an example):

$$\operatorname{sim}(u_i, u_j) = \frac{\sum_{k=1}^{m} P_{ik} * P_{jk}}{\sqrt{\sum_{k=1}^{m} P_{ik}^2} * \sqrt{\sum_{k=1}^{m} P_{jk}^2}}, \tag{5}$$

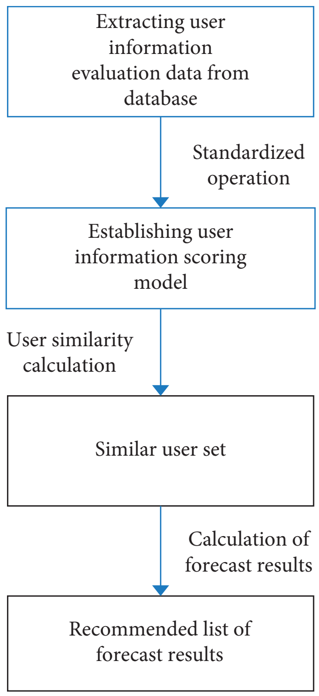


Figure 1: Flowchart of similarity calculation of recommendation algorithm.

where P_{ik} is the user I's score of item K. Formula (5) selects the customer's score information of all items in the database, including the data with a score of 0 and no score.

3.2.2. Adjusted Cosine Similarity. Cosine similarity calculation will have prediction error to a certain extent, especially when the amount of data is large, so some professionals put forward the adjusted cosine similarity formula.

$$\mathrm{sim}(i,j) = \frac{\sum_{k\in I_{ij}}\left(P_{ik}-\overline{P_i}\right) * \left(P_{jk}-\overline{P_j}\right)}{\sqrt{\sum_{k\in I_{ij}}\left(P_{ik}-\overline{P_i}\right)^2} * \sqrt{\sum_{k\in I_{ij}}\left(P_{ij}-\overline{P_j}\right)^2}}. \tag{6}$$

In this calculation method, the item set is used as the item set in which both users I and j have participated in scoring. P represents the average value of user I's rating of all over rated items, which can reflect the user's standard to a certain extent. The greater the similarity value is, the more similar they are.

3.2.3. Pearson Correlation Coefficient. Pearson correlation coefficient is set as the average score of the food set that users evaluate jointly. The formula is as follows:

$$\mathrm{sim}(i,j) = \frac{\sum_{k\in I_{ij}}\left(P_{ij}-\overline{P_{iI_{ij}}}\right) * \left(P_{ik}-\overline{P_{jI_{jk}}}\right)}{\sqrt{\sum_{k\in I_{ij}}\left(P_{ij}-\overline{P_i}\right)^2} * \sqrt{\sum_{k\in I_{ij}}\left(P_{jk}-\overline{P_j}\right)^2}}. \tag{7}$$

The greater the similarity value is, the more similar they are. The last step in the process is the calculation of the prediction results. The quality of the recommendation system lies in the accuracy of the final prediction results. The following formula is used to predict the score of user I on over rated thing K.

$$P_{ik} = \overline{P_i} + \frac{\sum_{j\in S_i}\mathrm{sim}(i,j) * \left(P_{ik}-\overline{P_{ik}}\right)}{\sum_{j\in s_i}\mathrm{sim}(i,j)}. \tag{8}$$

According to formula (8), we can get the target user's prediction score of the things that have not been rated too much, then sort the things according to the score value, and select the item with the highest score to form the user's recommended things.

4. Specific Analysis of the Prediction Results of Clustering and Recommendation Algorithm

4.1. Analysis of Clustering Algorithms in the Stressors of Physical Competitions. For the data analysis of the competition stress or questionnaire, the data are first clustered, and the questionnaire is divided into several parts, which are described in detail from the aspects of reduced sense of achievement, emotional support, social support, and negative sports evaluation. Thus, we can obtain a full range of data for analysis and obtain information on clustering. After calculation, the following final cluster centers can be obtained.

As can be seen from Table 1, 75 people belong to category 1, followed by category 2, with 25 people. The least number is category 3, with only 5 people. In Figure 2, the data of the first type are relatively stable, and the change is stable between 2 and 3. The range of the second type is also large, between 1 and 6. The change range of the third type is the largest, between 3 and 10. On the whole, we can draw the following conclusions:

(1) The third-type athletes have the largest change range, and there is a significant gap with the first category. This indicates that the athletes in the third category have a poorer mental level and a higher total score, suggesting a higher level of stress.

(2) The small range of variation in the first category suggests a relatively good mindset of the athletes. A low total rating indicates inconsistency with the stressor, indicating low stress. It indicates that mindfulness affects stress and that the athletes in the first group have a high level of self-happiness.

(3) Comparing the second type with the first category, the overall score is moderate, indicating that the pressure is moderate, but in terms of the mentality, it is not as good as the first type of athletes, so they will feel greater pressure.

In summary, the first type of athletes is worth training, and the overall mentality is good; for the second category, we should focus on the construction of mentality and relieving pressure. The third type of athletes is under great pressure, which is not conducive to the competition and is easy to get tired of the competition. Psychological and physical methods should be adopted to relieve the pressure.

Table 1: Final cluster center.

Serial number	The ultimate cluster center	Total data
1	(0.734 0.121 0.908 0.108)	75
2	(0.599 0.513 0.421 0.235)	20
3	(0.483 0.776 0.973 0.465)	5

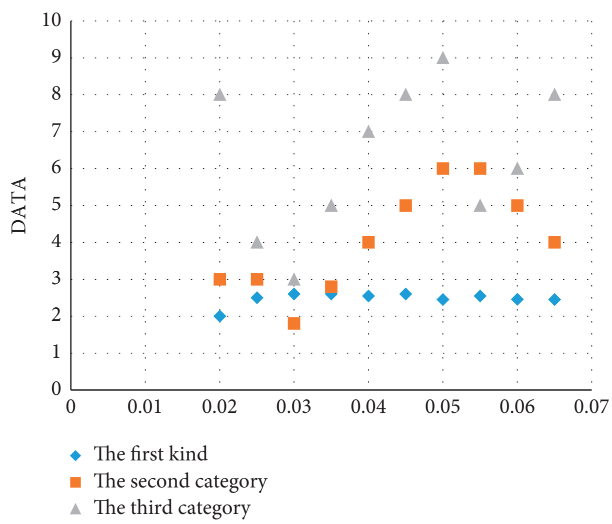


Figure 2: Variation of aggregation algorithm in pressure data of sports games.

4.2. Application of Recommendation Algorithm in Sports Competition. In the paper, we concentrate on analyzing the terms of stressor analysis in the questionnaire and calculate them by the recommended algorithm to obtain the following prediction results. Because the first type of pressure source is relatively small, this part of the pressure source analysis is only for the second and third types to predict the results.

From Table 2, it can be seen that the physical and mental fatigue of the second type athletes is high, and the athletes' burnout, goals, and development and social support are medium. This suggests that category 2 athletes are more likely to be physically and psychologically fatigued and have relatively inadequate social support. The athletes have not paid much attention to their own goals and development, and the stress and emotion are not enough, so they have been in such a state continuously, and the pressure and emotion are not enough. Therefore, the second type of athletes should pay attention to their own development, obtain higher social support, and relieve the current pressure with honor and social support.

It can be seen from Table 3 that the qualification selection, physical and mental fatigue, athlete burnout, and social support of the third kind of athletes are high. It shows that the ability of the third kind of athletes is excellent, and they have the highest degree of recognition and support in the society, but they are also faced with the greatest pressure, such as physical pressure, psychological pressure, and social pressure. Therefore, the third type of athlete should calm down and keep a relaxed and happy attitude to deal with the competition.

Table 2: Sources of the second type of athletes' stressors.

Similarity	Text theme	Grade
0.09	Athlete burnout	Secondary
0.07	Goals and development	Secondary
0.06	Social support	Secondary
0.05	Tired both physically and mentally	Higher

Table 3: Sources of the third type of athletes' stressors.

Similarity	Text theme	Grade
0.12	Qualification selection	Higher
0.05	Tired both physically and mentally	Higher
0.04	Athlete burnout	Higher
0.03	Social support	Higher

5. Discussion

Due to the rules, the contestants must deal with various situations in the competition alone on the field. Neither coaches nor other personnel may give any assistance or guidance to an athlete unless the athlete is in danger or forced to withdraw from the competition. This requires each player to have independent decision-making ability and the ability to solve problems on the spot. From another point of view, the pressure that individual sports athletes need to bear is much greater than that of team sports. Athletes suffer from serious disorders of their physical and psychological functions due to excessive competition pressure. The inability to effectively relieve pressure leads to the failure of the competition, athletes getting frustrated, and athletes doubting their own ability, which eventually leads to the athlete's injury or early retirement. Therefore, understanding and effectively judging the source of athlete's stress and taking effective coping strategies in a scientific and timely manner are crucial for the normal performance of windsurfers' competitive level. In this paper, a certain amount of sports competition pressure data are obtained through questionnaire survey, and then clustering and recommendation algorithm calculation and analysis are carried out according to the data. First, it is divided into three categories by clustering, and the corresponding results are obtained. Then, the similarity of the recommendation algorithm is calculated by combining different pressure sources, and the pressure sources of different types of athletes are obtained, and they are analyzed and corresponding recommendations were made. It can provide some auxiliary information for the relief of athletes' pressure and professional psychologists and promote the development of sports psychology in the future. Due to the limitations of technology and time, the research in this paper does not deeply explore the generation of stressors in sports competitions, and we will explore them in the future.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] H. Liu, P. Yi, W. Lu et al., "A novel DC-driven atmospheric-pressure cold microplasma source for biomedical application," *IEEE Transactions on Radiation and Plasma Medical Sciences*, vol. 1, no. 5, pp. 460–467, 2017.

[2] Y. Zhou and F. Zhou, "Cognitive neural mechanism of sports competition pressure source," *Translational Neuroscience*, vol. 10, no. 1, pp. 147–151, 2019.

[3] S. Wang, D. Wang, C. Li, Y. Li, and G. Ding, "Clustering by fast search and find of density peaks with data field," *Chinese Journal of Electronics*, vol. 25, no. 3, pp. 397–402, 2016.

[4] K. Hotta, M. Iguchi, T. Ohkura, and K. Yamamoto, "Multiple-pressure-source model for ground inflation during the period of high explosivity at Sakurajima volcano, Japan-c," *Journal of Volcanology and Geothermal Research*, vol. 310, no. 15, pp. 12–25, 2016.

[5] Y. V. Bodyanskiy, O. K. Tyshchenko, and D. S. Kopaliani, "A multidimensional cascade neuro-fuzzy system with neuron pool optimization in each cascade," *International Journal of Information Technology and Computer Science*, vol. 6, no. 8, pp. 11–17, 2016.

[6] R. Mitra, A. K. Goswami, and P. K. Tiwari, "Voltage sag assessment using type-2 fuzzy system considering uncertainties in distribution system," *IET Generation, Transmission & Distribution*, vol. 11, no. 6, pp. 1409–1419, 2017.

[7] X.-W. Chen, J.-G. Zhang, and Y.-J. Liu, "Research on the intelligent control and simulation of automobile cruise system based on fuzzy system," *Mathematical Problems in Engineering*, vol. 2016, no. 6, pp. 1–12, 2016.

[8] C. Li, M. Tang, G. Zhang, R. Wang, and C. Tian, "A hybrid short-term building electrical load forecasting model combining the periodic pattern, fuzzy system, and wavelet transform," *International Journal of Fuzzy Systems*, vol. 22, no. 1, pp. 156–171, 2020.

[9] L. Scrucca, M. Fop, and T. B. Murphy, "Mclust 5: clustering, classification and density estimation using Gaussian finite mixture models," *The R Journal*, vol. 8, no. 1, pp. 205–233, 2016.

[10] S. Gama-Castro, H. Salgado, A. Santos-Zavaleta et al., "RegulonDB version 9.0: high-level integration of gene regulation, coexpression, motif clustering and beyond," *Nucleic Acids Research*, vol. 44, no. 1, pp. D133–D143, 2016.

[11] G. O. Aragon and V. Nanda, "Strategic delays and clustering in hedge fund reported returns," *Journal of Financial and Quantitative Analysis*, vol. 52, no. 1, pp. 1–35, 2017.

[12] W. Wu, S. An, C. H. Wu, S. B. Tsai, and K. Yang, "An empirical study on green environmental system certification affects financing cost of high energy consumption enterprises-taking metallurgical enterprises as an example," *Journal of Cleaner Production*, vol. 244, Article ID 118848, 2020.

[13] U. Srilakshmi, N. Veeraiah, Y. Alotaibi, S. Alghamdi, O. I. Khalaf, and B. V. Subbayamma, "An improved hybrid secure multipath routing protocol for MANET," *IEEE Access*, vol. 9, pp. 163043–163053, 2021.

[14] R. Rout, P. Parida, Y. Alotaibi, S. Alghamdi, and O. I. Khalaf, "Skin lesion extraction using multiscale morphological local variance reconstruction based watershed transform and fast fuzzy C-means clustering," *Symmetry*, vol. 13, no. 11, Article ID 2085, 2021.

[15] G. Peters and R. Weber, "DCC: a framework for dynamic granular clustering," *Granular Computing*, vol. 1, no. 1, pp. 1–11, 2016.

[16] H. Okajima, S. Hashitsume, R. Oishi, and T. Miyahara, "Reconstruction of sports competition video using fixed camera based on receding horizon strategy," *Transactions of the Society of Instrument and Control Engineers*, vol. 55, no. 2, pp. 135–143, 2019.

[17] L. Cui, W. Huang, Y. Qiao, F. R. Yu, Z. Wen, and N. Lu, "A novel context-aware recommendation algorithm with two-level SVD in social networks," *Future Generation Computer Systems*, vol. 86, pp. 1459–1470, 2017.

[18] Y. Zeng, G. Chen, K. Li, Y. Zhou, X. Zhou, and K. Li, "M-skyline: taking sunk cost and alternative recommendation in consideration for skyline query on uncertain data," *Knowledge-Based Systems*, vol. 163, no. 1, pp. 204–213, 2019.

[19] S. W. Park, L. Mesicek, J. Shin, K. Bae, K. An, and H. Ko, "Customizing intelligent recommendation study with multiple advisors based on hierarchy structured fuzzy-analytic hierarchy process," *Concurrency and Computation: Practice and Experience*, vol. 33, Article ID e5930, 2021.

[20] L. Wu, Q. Zhang, C.-H. Chen, K. Guo, and D. Wang, "Deep learning techniques for community detection in social networks," *IEEE Access*, vol. 8, pp. 96016–96026, 2020.

[21] W.-J. Cho, J.-Y. Jang, J.-Y. Shin, and S.-H. Jeong, "The effect of sports competition anxiety on performance strategy and perceived performance of badminton members," *Korean Journal of Sports Science*, vol. 27, no. 1, pp. 267–278, 2018.

[22] C. F. Olson, "Parallel algorithms for hierarchical clustering," *Pattern Analysis & Machine Intelligence IEEE Transactions on*, vol. 12, no. 11, pp. 1088–1092, 2016.

[23] G. Zheng, H. Yu, and W. Xu, "Collaborative filtering recommendation algorithm with item label features," *International Core Journal of Engineering*, vol. 6, no. 1, pp. 160–170, 2020.

[24] G. Liu, K. Meng, J. Ding, J. P. Nees, G. Hongyi, and Z. Xuewen, "An entity-association-based matrix factorization recommendation algorithm," *Computers, Materials & Continua*, vol. 58, no. 1, pp. 101–120, 2019.

[25] I. Comeig, A. Grau-Grau, A. Jaramillo-Gutiérrez, and F. Ramírez, "Gender, self-confidence, sports, and preferences for competition," *Journal of Business Research*, vol. 69, no. 4, pp. 1418–1422, 2016.

Hindawi
Scientific Programming
Volume 2022, Article ID 2520087, 13 pages
https://doi.org/10.1155/2022/2520087

Research Article

Research on the Application of Multimedia Entropy Method in Data Mining of Retail Business

Ting Li[1] and Can Zhang[2]

[1]School of Logistics Management, Yunnan University of Finance and Economics, Kunming 650000, Yunnan, China
[2]School of Business Management, Yunnan University of Finance and Economics, Kunming 650000, Yunnan, China

Correspondence should be addressed to Can Zhang; zz1379@ynufe.edu.cn

Received 28 December 2021; Revised 23 January 2022; Accepted 3 February 2022; Published 23 March 2022

Academic Editor: Ahmed Farouk

In recent years, database technology has developed rapidly and is changing with each passing day. With the support of network technology, its application scale, scope, and depth are constantly expanding. With the explosive growth of data, we are also faced with such a challenge: First, as a basic information storage and management method, database technology can only perform simple data processing, such as query, statistics, reports, etc.; lack of decision-making; analysis; prediction; and other advanced functions. Secondly, in the face of these massive data, people pay more attention to how to dig out the important information hidden in these data, rather than the data itself. Therefore, data mining technology, which integrates statistics, artificial intelligence, pattern recognition, and optimization, emerges as the times require. Data mining technology is application-oriented from the very beginning, and its great success in various industries has fully demonstrated its strong vitality, especially in the retail industry. If the data mining technology can be perfectly combined with the retail industry, it can not only bring great convenience to customers but also inject new vitality into enterprises, making them invincible in the fierce competition. This paper proposes a filtering of high-quality customer system framework based on maximum entropy, which expresses customer data as a feature vector for feature selection and feature smoothing. The filtering performance of different feature sets is compared by combining different characteristics of customer data. Experiment and conduct multimedia presentations. Experiments show that the filtration performance of this system is better than the general filtration system.

1. Introduction

Retail trade is an activity that involves selling goods or services directly to the final consumers. The target of this industry is more consumers than wholesalers or manufacturers [1]. This also determines that retail owners have the following characteristics: (1) As far as customers are concerned, they come to consume, and the relationship with retailers is intermittent. (2) As far as commodities are concerned, retailers adopt marketing, consignment, joint marketing, and so on. The number of suppliers connected with retailers is also very large. (3) In terms of profit, the gross margin of the retailer is lower than that of the manufacturer. (4) There is also an important characteristic that retailing is a kind of sales behavior, which is not only affected by seasons, holidays, and other external factors but also caused by its own promotion, price reduction, and so on. The so-called data mining, in business applications, is a way to analyze the huge amount of data stored in enterprises through mathematical models, to find out different customers or market segments, and to analyze consumers' preferences and behavior. The tasks of data mining include association analysis [2], clustering analysis, classification, prediction, temporal pattern, and deviation analysis: (1) The purpose of association analysis is to find out the association between data. Generally, two thresholds of support and credibility are used to measure the relevance of association rules. (2) Clustering is to classify data into several categories according to similarity. Data in the same category are similar to each other, and data in different categories are quite different from each other [3–6]. (3) Classification is to find a conceptual description of a category, which represents the overall information of such data, that is, the connotation description of the class, and use this description to construct a model. Generally, rule or decision tree pattern is used to represent [7]. (4) Prediction is to use historical data to find out the law of change, establish a model, and then predict the types and characteristics of future data. (5) Time series pattern refers to the pattern with high repetition probability which is searched by time series. (6) There are many abnormal data in the database. It is very important to find the abnormal data in the database. It may correspond to the abnormal phenomenon in business [8–10].

There are many kinds of data mining methods. The main data mining methods used in customer relationship management of retail industry are prediction analysis, correlation analysis, and clustering analysis. Predictive analysis is generally based on the operation of the predictive analysis model designed to achieve. Predictive analysis models usually assume that some phenomena (dependent variables) arise from the appearance of other phenomena (independent variables), or change with the change of other phenomena. There is a stable quantitative relationship between dependent variables and independent variables. In this way, the possible situation can be predicted by known data [11–13]. In data mining, the construction of the prediction analysis model is usually to detect the customer's response to a particular marketing activity and the degree of reflection. Data mining technologies that can predict and analyze include logistic regression, decision tree, and so on. Logical regression is used to construct the quantitative relationship between the target variable (dependent variable) and more than one predictive variable (independent variable) [14–16]. Formally, logistic regression is very similar to linear regression. The main difference is that the dependent variables in logistic regression are not continuous variables, but discrete or categorical variables [17]. Generally, logistic regression can be used to predict two or more levels of results. But in retail business, two levels of results are commonly used, such as customer response or nonresponse to a promotional activity [18–21]. Decision tree is also used to construct the quantitative relationship between target variables (dependent variables) and more than one predictive variable (independent variables), so as to detect the attributes of target objects (such as customers or products) in a dependent variable. The method of decision tree is to divide the data of the target object according to the order of independent variables, and divide all the target objects into different groups. There is a great heterogeneity among the groups, and there is a great homogeneity within the groups [22]. Then, we find out the relationship between each factor and the target event, and use it to predict the customer's behavior [23–25]. For example, in order to reasonably classify customers, the membership level of customers is determined according to their annual consumption points. On this basis, the decision tree method in data mining technology is used to find the judgment rules to measure the valuable members. The rules can be used as the basis for judging the value of new customers and potential customers, and lay the foundation for enterprises to make targeted marketing to customers, so as to achieve win-win situation between enterprises and customers on the basis of improving customer satisfaction [26–28].

But the process of data mining is actually the process of analyzing the certainty of a data. Uncertainty analysis methods include fuzzy set theory, rough set theory, statistical entropy, and so on. In this paper, the maximum entropy model is used to verify the advantages of the maximum entropy model, which can be used to express various features conveniently, and there is no need to assume independence between features [29, 30]. The multimedia display function is very rich. The main purpose of the multimedia display is to disseminate information and promote some product content. The content to be promoted is displayed in a multimedia presentation mode, so that people can receive the information in time. This article will show the data mining on the multimedia platform and achieve good results.

2. Proposed Method

2.1. Maximum Entropy Model. In the nineteenth century, scientists proposed the laws of thermodynamics in order to study the efficiency of steam engines, and in the process of continuous in-depth research, they proposed the concept of entropy. In physics, entropy is the ratio of heat energy to temperature, indicating the degree to which heat is converted into work. In thermodynamics, entropy can represent the state of matter and the degree of chaos in the system. The greater the entropy, the greater the degree of chaos. "Information entropy" was first proposed by Shannon to realize the quantitative measurement of information. When people learn more about a random event, the uncertainty about that random event decreases. In probability theory, information entropy is actually the expectation of the amount of information. The greater the entropy, the greater the uncertainty of the event, and the entropy value of the event is determined to be 0.

Information entropy is a measure of uncertainty of random variables. The greater the uncertainty of random variables, the greater the information entropy; if the random variables degenerate to a fixed value, the information entropy is 0. For a random variable with N possible outcomes, from an information perspective, the more the information obtained, the more the uncertainty eliminated.

Entropy can be divided into individual entropy, joint entropy, and conditional entropy. In single entropy, as the name implies, the size of the event entropy is determined by a random variable. The entropy value of joint entropy is jointly determined by two random variables X and Y. Conditional entropy is the calculation of the entropy value when some information Y is known.

It can be known from the concept of entropy that the greater the entropy, the more chaotic the system and the more uniform its probability distribution. Therefore, according to the principle of maximum entropy, in the probability distribution set that meets the known conditions, we choose the optimal probability distribution as the final prediction result with the maximum entropy as the criterion.

In 1957, based on information entropy, Jaynes proposed the maximum entropy principle for the first time. He believed that a feasible solution with the largest degree of confusion (i.e. maximum entropy) should be selected from all feasible solutions. That is to say, in the process of processing information, only objective and completely definite information is added, and no artificial assumptions are added, so that the maximum entropy of the results can be obtained and all possible situations can be included. Maximum entropy principle is the criterion for choosing the statistical characteristics of random variables which are most suitable for objective conditions. Albert Einstein once said that the theory of entropy is the first law of the whole science. In nature, different random phenomena may follow the same probability distribution, and any random phenomena often follow the common probability distribution in probability theory. These common probability distributions should follow the maximum entropy principle, so the maximum entropy principle can be used as a criterion to determine the probability distribution of random variables. That is to say, using the maximum entropy formula as the objective function and combining with different constraints, we can deduce the common probability distribution in probability theory.

The establishment of maximum entropy model first needs to determine all kinds of uncertainties that may occur in the system. Then, a mathematical model with maximum entropy as the objective function and probability of occurrence of various states as independent variables is deduced to obtain the probability of occurrence of each kind of uncertainties under the condition of maximum entropy. For retail business filtering, the condition of resource allocation is to satisfy the business needs, so first we must determine the probability of high-quality customers, and then establish a mathematical model with maximum entropy as the objective function by introducing the gravity model. After the establishment of the model and the determination of the relevant parameters, the conclusions can be checked according to the examples, so as to determine that the conclusions obtained in this paper have universal applicability.

The purpose of system modeling is to construct a stochastic model to ultimately predict the stochastic process. So, the establishment of the model needs to solve two key problems. The first problem is feature selection. The selected statistics can correspond to the stochastic process of the target. The second problem is how to construct a precise model after specifying the statistics. Maximum entropy model provides a unified method to solve these two problems. Given the training data set, our goal is to select the best classification model based on the maximum entropy principle, that is, for any given input $x \in$ Input, we can output $y \in$ Output with probability $P(y|x)$. Figure 1 is a general form of the maximum entropy model framework.

In the training process of the model, we first select the features according to the data of the target training set, output the training sample set of the part, and then use the model selection algorithm to train the model. During the execution of the model, the system chooses the features of the data to be processed to get the sample, then calculates the final probability $p(y \mid x')$ through the model, and finally carries on the next operation.

Entropy and maximum entropy models have very rich applications in practice:

(1) Application in real life. Information entropy has important guiding significance in hydrological sequence analysis, station network layout evaluation, hydrological forecasting, water quality evaluation, water resource evaluation, and so on. In addition to the application of information entropy in the natural environment, it can also improve the quality of teaching. In order to improve the quality of teaching and guide teachers to improve their teaching level, it is necessary to evaluate the teaching quality of teachers. However, it is difficult to measure the quality of teaching. Using information entropy can comprehensively and reasonably analyze the quality of teaching evaluation, which has a very important guiding significance.

(2) Financial economy. Security risk is generally measured by the variance of security returns, but the computational complexity of variance is high; there is a problem of overestimating risk, and there is a limitation of assuming that the return distribution is normal. In order to reduce the investment risk, three investment portfolio models are established based on the information entropy, which improves the risk control in the investment process. In a complex investment environment, the concept of entropy plays a very important role in the application of different investment models, risk estimation, and rational decision-making.

2.2. Feature Selection Algorithm. Feature selection technology is an important method of data dimensionality reduction. Its essence is to select a set of optimal feature subsets that meet certain evaluation criteria from the original feature set of the original data, so as to perform classification or regression. When performing tasks, better models can be obtained and more accurate analysis results can be obtained.

Like variables, attributes, etc., features are also an aspect of data, which can be discrete data, continuous data, or Boolean data. In common classification problems, features can be divided into three categories: relevant features, which affect the classification results to a large extent and cannot be replaced; irrelevant features, which have strong random values and have no effect on the classification results; redundant features do not affect classification results or features that are associated with other features. The task of feature selection is to remove useless or redundant features from the input data, and obtain the optimal feature subset composed of related features that are most valuable for classification.

Feature Selection is also called Feature Subset Selection (FSS), or Attribute Selection. It refers to the process of

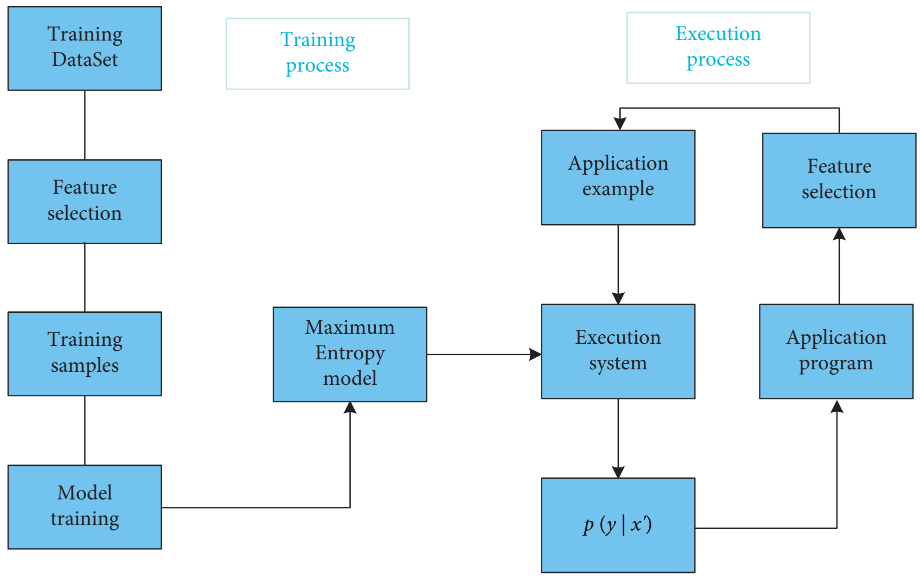


Figure 1: General form of maximum entropy model framework.

selecting N features from the existing M features to optimize the specific indicators of the system. It is a process of selecting some of the most effective features from the original features to reduce the dimensionality of data sets. It is an important means to improve the performance of learning algorithms, and also a key data preprocessing step in pattern recognition. For a learning algorithm, a good learning sample is the key to the training model. In addition, feature selection and feature extraction need to be distinguished. Feature extraction refers to the calculation of a more abstract feature set by using existing features, and also refers to the algorithm of calculating a feature.

According to the feature selection framework, the general feature selection algorithm includes four steps: subset generation, subset evaluation, stopping condition, and subset verification. Subset generation is a continuous search process. Based on the original feature set, a starting feature set is selected, and a specific search strategy is used to generate a feature subset for the next evaluation according to a certain search direction. The subset evaluation is to evaluate the feature subset generated during the subset generation process through some evaluation criteria to determine whether it is the optimal feature subset, and if so, replace the current optimal feature subset. The stop condition is set to prevent the search process from entering an infinite loop, which is generally a threshold for the number of searches or the number of features. Subset verification is the last step of the feature selection algorithm. Usually, a classifier is used to train and test the original feature set and the selected optimal feature subset to compare the pros and cons of the selected optimal feature subset.

The feature selection process generally includes four parts: generation process, evaluation function, stop criterion, and verification process. Generally speaking, feature selection can be regarded as a search optimization problem. For feature sets of size n, the search space is composed of $2n-1$ possible states. Davies et al. proved that the search for the minimum feature subset is a NP problem, that is, besides an exhaustive search, it cannot guarantee to find the optimal solution. However, in practical applications, when the number of features is large, an exhaustive search cannot be applied because of too much computation, so people are committed to using heuristic search algorithm to find suboptimal solutions. General feature selection algorithms must determine the following four elements: (1) search starting point and direction; (2) search strategy; (3) feature evaluation function; and (4) stop criteria. The search starting point is the state point where the algorithm starts to search, and the search direction refers to the order in which the feature subset of the evaluation is generated. The starting point and direction of the search are related, and they decide the search strategy together. Generally, according to different search starting points and directions, there are four situations as follows: (1) The forward search starting point is an empty set S. According to a certain evaluation criterion, as the search progresses, the best feature is selected from the feature set not included in S to continuously join S. (2) The backward search starting point is the complete set S, and the least important features are continuously removed from the S according to certain evaluation criteria until a certain stopping criterion is reached. (3) The two-way search starts from both directions. When the middle of the feature subset space is generally searched, the subset that needs to be evaluated will increase dramatically. When using one-way search, if the search passes through the middle of the subset space, it will consume a lot of search time, so two-way search is a more common search method. (4) Random search starts from any starting point, and it has certain randomness to add and delete features [31].

Assuming that the original feature set has n features (also known as input variables), there is a possible subset of $2n-1$ nonempty features. The search strategy is meant to find the optimal feature subset from the search space containing $2n-1$ candidate solutions. Search strategies can be roughly divided into the following three categories: (1) Exhaustive search can search each feature subset. The disadvantage is that it will bring huge computational overhead, especially when the number of features is large, and the computational time is very long. Branch and Bound (BB) shortens the search time by pruning. (2) Sequence search avoids simple exhaustive search, and adds or eliminates features to the current feature subset according to a certain order in the search process, so as to obtain the optimized feature subset. Typical sequence search algorithms are forward and backward search, floating search, bidirectional search, sequence forward, and sequence backward search, etc. Sequential search algorithm is easy to implement, and its computational complexity is relatively small, but it is easy to fall into local optimum. (3) Random search begins with a random subset of candidate features, and approximates the global optimal solution step-by-step according to certain heuristic information and rules. For example, genetic algorithm, simulated annealing algorithm, particle swarm optimization algorithm, and immune algorithm.

In feature selection, a subset of feature sets that can express the statistical characteristics of the stochastic process is selected. Commonly used classification feature selection methods include document frequency, information gain, mutual information, expected cross-entropy, and so on. Feature selection filters out some features. A possible problem with this approach is that some useful information is ignored. Due to the small number of keywords and to avoid filtering out any useful information during feature selection, this paper adopts the solution provided by the maximum entropy model.

This paper mainly uses two incremental feature selection (IFS) algorithms, namely, basic algorithm and approximation algorithm, which are based on incremental feature selection and conditional maximum entropy method proposed by Berger et al. Each step of the iteration process is represented by the change of activity characteristic S. The current activity feature S determines the maximum entropy model P_s and model space $C\ (S)$:

$$\begin{aligned} C(S) &= \left\{p \in P | E_p(f) = E_p(f), f \in S\right\}, \\ P_s &\equiv \underset{p \in C(S)}{\arg\max}\, H(p). \end{aligned} \tag{1}$$

After adding a new feature $\hat{f}$ to S, new activity feature $\hat{f} \cup S$ and model $P_{\hat{f} \cup S}$ are obtained.

$$\begin{aligned} \mathrm{C}(S \cup \hat{f}) &= \left\{p = E_p(f), f \in S \cup \hat{f}\right\}, \\ \mathrm{P}_{S \cup \hat{f}} &\equiv \underset{p \in C(s \cup \hat{f})}{\arg\max}\, H(p). \end{aligned} \tag{2}$$

With the addition of $\hat{f}$, the model $(P_{S \cup \hat{f}})$ can better represent the characteristics of the training set and generate logarithmic likelihood gain $\Delta L(S, \hat{f})$ of training set data.

$$\Delta L(S, \hat{f}) \equiv L\left(P_{s \cup \hat{f}}\right) - L(P_s). \tag{3}$$

Each iteration process selects the feature $\hat{f}$ which maximizes the $\Delta L(S, \hat{f})$ value in the candidate feature space and adds it to the current active feature.

(1) The basic incremental feature selection algorithm estimates the model under the new feature set with iteration algorithm at each step, and calculates the maximum likelihood gain. The basic process is described as follows (Algorithm 1):

The key problem of the algorithm is that the computational complexity is too large. Each feature needs to call IIS algorithm for all candidate features, and the logarithmic likelihood of training set data is calculated. Obviously, this algorithm is not feasible.

(2) The approximate incremental feature selection algorithm is based on the basic algorithm to reduce the amount of computation. Assuming a new feature is added, only this new feature parameter is changed in the whole model, while other existing feature parameters remain unchanged, or the model after adding a new feature only depends on the original model and parameter α, that is:

$$P_{s,f}^{\alpha} = \frac{1}{Z_{\alpha}(x)} P_s(y \mid x) e^{\alpha f(x,y)} \text{ where } Z_{\alpha}(x) = \sum_{y} Ps(y \mid x) e^{\alpha f(x,y)}. \tag{4}$$

The formula for calculating the approximate gain is as follows:

$$\begin{aligned} G_{s,f}(\alpha) &\equiv L\left(p_{s,f}^{\alpha}\right) - L(P_s) = -\sum \tilde{p}(x) \log Z_{\alpha}(x) + \alpha E_{\tilde{p}}(f), \\ \sim \triangle L(s,f) &\equiv \max_{\alpha} G_{s,f}(\alpha), \\ \sim P_{s \cup f} &\equiv \underset{p^{\alpha}_{P_{s \cup f}}}{\arg\max}\, G_{s,f}(\alpha). \end{aligned} \tag{5}$$

This approximation simplifies the calculation of logarithmic likelihood gain caused by introducing new features into a one-dimensional optimization problem and greatly reduces the computational complexity. But, at the same time, it may lead to a problem: it is possible to choose the characteristic f with the maximum approximate gain $\sim\triangle L(s, f)$, while ignoring the characteristic $\hat{f}$ with the maximum gain $\sim\triangle L(s, \hat{f})$. The approximation algorithm is a feasible one, but it is time-consuming. On this basis, the IFS is improved, and a selective gain calculation algorithm is proposed. Each step only calculates the gain of some features which gain more in the last feature selection process, and calculates the gain of the current feature selection step.

At present, the feature selection technology is widely used in the fields of Web document processing, image processing, network security, and medical diagnosis and analysis. The research on feature selection algorithms is also more in-depth, and a large number of new algorithms are emerging. The selection of algorithms has become a very important issue. The problem. Generally speaking, in addition to considering the specific scenarios of the application, the selection of the

(1) Initialize $S = \varnothing$;
(2) For each candidate feature f, the following steps are performed:
(a) $P_{S \cup f}$ is calculated by IIS algorithm;
(b) Calculate the gain $\Delta L(S, f)$ when adding f;
(3) Check the algorithm end condition, and if the condition is true, it ends;
(4) The characteristic f with maximum gain $\Delta L(S, f)$ is selected and added to S.
(5) The P_s is calculated by IIS algorithm and go to step 2;

ALGORITHM 1: Basic incremental feature selection algorithm.

feature selection algorithm also needs to pay attention to the following factors: First, the scale of the data. For small-scale data sets, you can use the Filter method or Wrapper method that is close to full search, such as the BB algorithm; and when the scale of the data set is large, you should use a more efficient Filter method, such as Relief or ReliefF algorithm, etc. Second, the type of data to be processed. Different feature selection algorithms can handle different types of data. For example, the BB algorithm cannot handle discrete data. The Relief and ReliefF algorithms can handle both discrete and continuous data. MIFS and MRMR algorithms are processing for continuous data; it needs to be discretized first. Third, the category of data to be processed. For data samples whose classes are unknown, unsupervised methods should be used. Fourth, the requirements for classifier performance. If the requirements for the output accuracy of the classifier are very high, the Wrapper method based on heuristic search or genetic algorithm can be selected.

2.3. Customer Feature Smoothing. Smoothing assigns a small number of probabilities to events that do not occur. When there are enough training data, smoothing has less effect. The feature vectors transformed from customer information are sparse. For the maximum entropy of the maximum likelihood model, which is essentially an exponential form, when the feature vectors are sparse, the model will become worse. Therefore, smoothing optimization is needed to reduce or overcome the influence of over-adaptation in the training process. For those features that do not appear in the training set, it is not appropriate to simply think that the probability is zero. Generally, it is necessary to smooth them. There are relatively many studies on N-gram smoothing technology, including absolute discount, linear discount, Good-Turing method, Katz regression, linear interpolation, and so on. The research usually introduces the smoothing technology of N-gram into the smoothing of maximum entropy model. Martin's absolute discount method based on Cut-Offs and absolute discount method has better smoothing effect. Stanley compares the smoothing algorithm of the maximum entropy method with the traditional N-gram smoothing algorithm, and the performance of the Gaussian prior distribution is better among the alternative smoothing methods.

The smoothing method is a forecasting method that weighs the continuously obtained actual data and the original forecast data to make the forecast result closer to the actual situation, also known as the smoothing method or the recursive correction method. The smoothing method is a specific method in the trend method or time series method.

For the situation where the actual data is close to stationary, a smoothing method can be applied to eliminate the influence of accidental factors. Expanding the above iterative formula in time, it is directly represented by the sampling value and the estimated value 1, which means that the estimated value at time $t + 1$ is the weighted smoothing of the actual sampling value in the past, and the relationship between its weighting coefficient and time. It conforms to the exponential law, so that the situation at the earlier time has less influence on the forecast. Therefore, this smoothing method is also called exponential smoothing. The value of the smoothing parameter a should be selected according to practical application experience. The larger the a, the greater the influence of the recent actual sampling value. Sometimes, in order to obtain a better correction effect, the value of a can be adjusted at any time to make it time-varying.

Absolute discount smoothing technology refers to discounting the observed events in the model, subtracting a fixed value d, and then apportioning the probability of discount to all the events that do not occur. That is, if the number of occurrences of event w is r, the probability of using absolute discount w is:

$$p(w) = \begin{cases} \dfrac{r - d}{N}, & r > 0, \\[2ex] \dfrac{(B - N_0)d}{N_0 N}, & r \leq 0. \end{cases} \tag{6}$$

Among them, N is the number of all events, B is the number of different events, and N_0 is the number of no events. Because customer information is used as the value of feature function in this paper, the problem of keeping probability 1 is not involved when discounting the number of feature occurrences.

3. Experiments

JOLAP (Java Online Analytical Processing) is used in the selected technology architecture. Java Community Process JSR 69 plans to create a simplified and comprehensive unified API for OLAP services and applications. The purpose of the JOLAP specification is to deploy or interact with the Java enterprise platform. It makes full use of the Common Warehouse Metamodel (CWM), an OMG standard that defines logical OLAP structures in a vendor-independent manner. It also leverages the Meta Object Facility, XML Metadata Interchange, and the Java Metadata Interface. The JOLAP model is a UML model consisting of some related submodels. The package consists of logical groupings of models. From this perspective, JOLAP is divided into six groups: core metadata is adapted from CWM metadata definitions, which define OLAP metadata in a vendor-independent manner. Resource models define connection and connection factories, which are based on the principles of Java Connector Architecture Common Client Interface. The resource model is different from the standard JCA implementation because it includes OLAP-style interactions. The query model defines the concepts of dimension selection, boundary, cube view, and aggregation and manipulation of dimension data. The model also contains asymmetric and transactional features. The cursor model defines how to view the dimension result set returned by the query. The source model and the server-side metadata model are defined as optional packages. The source model provides support for primitive query operations; the server-side metadata model defines other metadata for deployment-oriented classes.

System software deployment includes data warehouse products: DB2 8.1; OLAP server DB2 OLAP Server 8.1; FTL tools: DataStage; middleware: IBM WebSphere; and data presentation tools: FEnet BI. Office.

4. Discussion

The retail industry provides consumers with needed goods and related services. It is the link between production and consumption, and the final channel of the circulation link. It can be said that whoever masters the retail link will master the market. The retail industry is one of the largest and most important industries in my country's national economy with a large number of employees, a huge number of enterprises, and a large proportion of sales in GDP.

For market competition, monopoly will lead to the loss of social welfare, but the existence of excessive competition will also make the basic function of competition in rational allocation of social resources and improvement of social and economic efficiency not fully exerted. The so-called effective market concentration is to make the market concentration reach such a level that the economic efficiency of the society reaches a stable and sustained high level, which is an interval concept rather than a point concept.

Data mining can be defined in terms of technology and business. From a technical point of view, data mining is the application of a series of technologies to extract interesting information and knowledge from data in large databases or data warehouses. The extracted knowledge is expressed in the form of concepts, rules, laws, and patterns; from a business point of view, data mining is a new type of business analysis and processing technology. It is a new technology for discovering and extracting information hidden in large databases or data warehouses, helping decision-makers to find potential correlations between data and discover overlooked factors. These information and factors are critical for predicting trends and decision-making behavior.

The functions of data mining include: characterizing and distinguishing data, data characterization, and data differentiation.

The commonly used algorithms of data mining technology include: set theory method of data mining, decision tree method of data mining, genetic algorithm, and neural network method of data mining. Set theory methods mainly include methods based on rough set theory, methods based on concept trees, and learning methods that cover positive examples and exclude negative examples.

The customer data set collected in this paper includes 4658 customers, of which 2322 are high-quality customers and 2336 are general customers. 2927 (80%) of them were randomly selected as the training set and 731 (20%) as the test set. All the experiments in this paper were carried out in this data set. Recall, Precision, F1 value, and Error are selected as the evaluation indexes of filtering performance. In order to facilitate comparison, a commonly used statistical filtering method, Bayes method, is introduced.

In the whole Bayes test process, although the independence between features is not true in many cases, in application, due to its simple calculation advantages, it also has a certain better filtering performance. So this method is often used as a basis for performance comparisons with other filtering methods.

Evaluation of filtering performance usually borrows relevant indicators in the field of feature classification and information retrieval. Specifically, suppose there are a total of N customers in the test set. For the convenience of description, the variables are defined as shown in Table 1.

Where $N = A + B + C + D$, the performance of the filtering system can be measured by defining the following indicators:

(1) Recall $= A/A + C \times 100\%$, which is the "check-out" rate of high-quality customers, reflects the ability of the filtration system to find quality customers. The higher the recall rate, the fewer the "quality" customers.

(2) Precision $= A/A + B \times 100\%$, which is the "checking" rate of high-quality customers, reflects the ability of the filtering system to "find the right" quality customers. The higher the correct rate, the less likely the average customer is to be judged as a quality customer.

(3) Accuracy $= A + D/N \times 100\%$, which is the "checking" rate for all customers.

(4) Error rate: $= 1 - \text{Accuracy}$, which is the "error rate" for all customers.

(5) F value: $F = (\beta^2 + 1)$ $(\text{Prcision} \times \text{Recall})/\beta^2 \times \text{Prcision} + \text{Recall} \times 100\%$. The recall rate and accuracy rate can be synthesized as an index by F value, so that F value can fully reflect the performance of the filtering system. β is the weight factor, and $\beta = 1$ is usually used in applications.

The specific test process and analysis are as follows:

Table 1: Relevant variables for filtering performance evaluation.

	Actually for high-quality customers	Actually for general customers
The filtering system is considered to be a high-quality customer	A	B
The filtering system is considered to be a general customer	C	D

(1) The effect of feature set selection on filtering performance is to investigate the effect of customer's structural characteristics on filtering performance. This section compares the filtering performance of the maximum entropy method with Bayesian method in three cases: using only the number of customers' annual consumption, using only the cumulative amount of customers' consumption, and using all customer characteristics. The results are shown in Figures 2 and 3.

In the figure, N_Bayes represents the Bayes method that uses only the characteristics of the customer's annual consumption count, and N_ME represents the maximum entropy method that uses only the characteristics of the annual consumption times. C_ Bayes denotes the Bayes method that only uses the characteristics of accumulated consumption amount, C_ ME denotes the maximum entropy method that only uses the characteristics of accumulated consumption amount, A_Bayes denotes the Bayes method that uses all customer characteristics, A_ ME denotes the maximum entropy method that uses all customer characteristics.

By analyzing the data in Figures 2 and 3, we can draw the following conclusions: Firstly, from the perspective of recall rate, under the same feature set, the recall rate of maximum entropy method is better than the Bayes method, and the maximum entropy method has greater advantages. From the point of view of accuracy, the maximum entropy method has poor results except when the annual consumption number characteristics are used alone. In other cases, the results of the maximum entropy method are not much different from those of the Bayes method. Finally, from the perspective of F1, the maximum entropy method using all features has the best filtering effect, and the error rate is the lowest in this case.

When using the same filtering method, whether the maximum entropy method or Bayesian method, using the customer's annual consumption characteristics can effectively improve the filtering performance. The filtering performance is the best when using the characteristics of the customer's annual consumption number and the customer's cumulative consumption amount, and the worst when only using the characteristics of the customer's cumulative consumption amount, which fully illustrates the difference between high-quality customer filtering and general classification. According to the results of this experiment, the experiments in the following chapters will collect all the features of customers as customer feature sets.

(2) The influence of characteristic function on filtration performance. In this section, we will compare the filtering performance of different definitions of feature functions. Taking the basic characteristics of customers and the characteristic functions in the process of consumption as binary function, word frequency function, TF-IDF value, and χ^2, we use the Bayesian method and maximum entropy method to carry out comparative experiments. The results are shown in Figures 4 and 5.

In the figure, BVBaye represents the Bayes method in the case of using binary features, WFBayes represents the Bayes method in the case of word frequency features, ×2Bayes represents the Bayes method in the case of statistics, TI-Bayes represents the Bayes method in the case of TF_IDF, BVME represents the maximum entropy method in the case of using binary features, WFME represents the maximum entropy method in the case of using word frequency features, ×2ME represents the maximum entropy method in the case of using χ^2 statistics, and TI-Bayes represents the maximum entropy method in the case of using TF-IDF.

Through the analysis of Figures 4 and 5, we can see that when the word frequency feature function is compared with the binary feature function, the filtering performance of the word frequency feature function will be improved. The main reason is that the word frequency feature function can reflect the purchasing behavior of customers more truthfully, and it is more suitable for the realization of customer filtering based on the shopping process. The error rate of the maximum entropy method is the lowest when using the word frequency feature function.

When the maximum entropy method is used, the performance of word frequency is similar to that of the χ^2 statistical feature function and TF-IDF feature function. Although some indexes of χ^2 statistics feature function and TF-IDF feature function may be better than word frequency feature function, they are much larger than word frequency function in terms of computation. In addition, from the comprehensive index F1, the maximum entropy method is also the best. Therefore, in order to reduce the computational complexity, the frequency feature function can be used to replace the χ^2 statistical feature function and TF_IDF feature function. In this case, it will not lead to serious performance degradation. The results of the above experiments are combined with the experimental results in (1).

This paper combines experimental results with multimedia, and finally displays the data on the multimedia platform. The following picture shows the login page of the multimedia system.

After logging into the system, users can directly view the data mining results of the retail business, as shown in Figures 6 and 7:

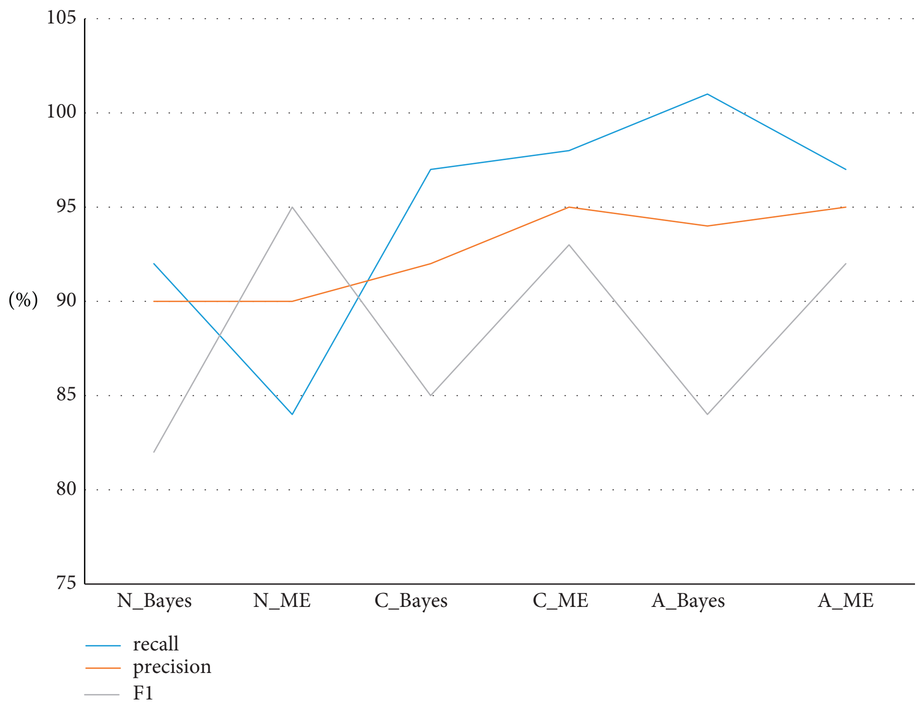


Figure 2: The impact of customer feature set selection on Recall, Precision, and F1.

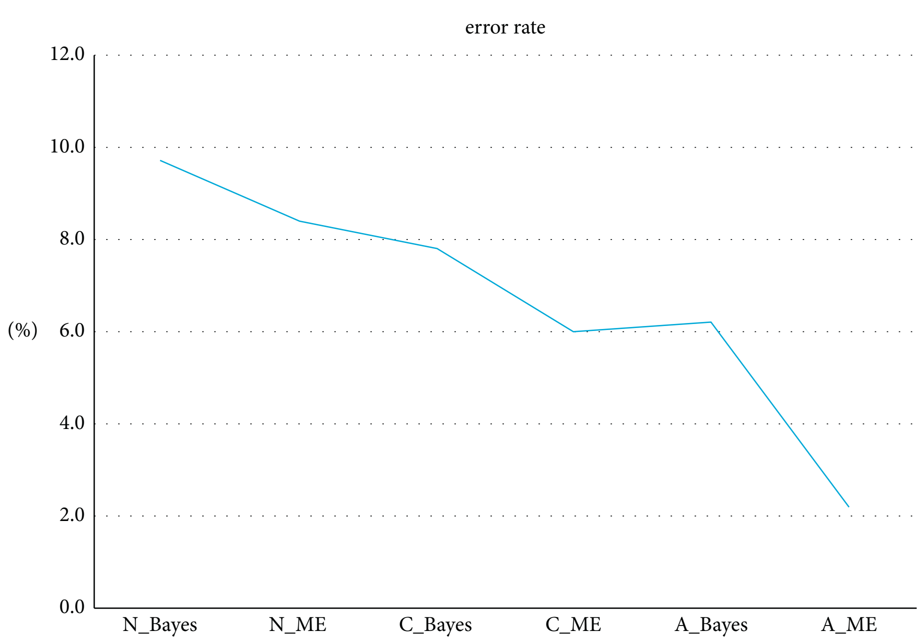


Figure 3: The impact of customer feature set selection on error rate.

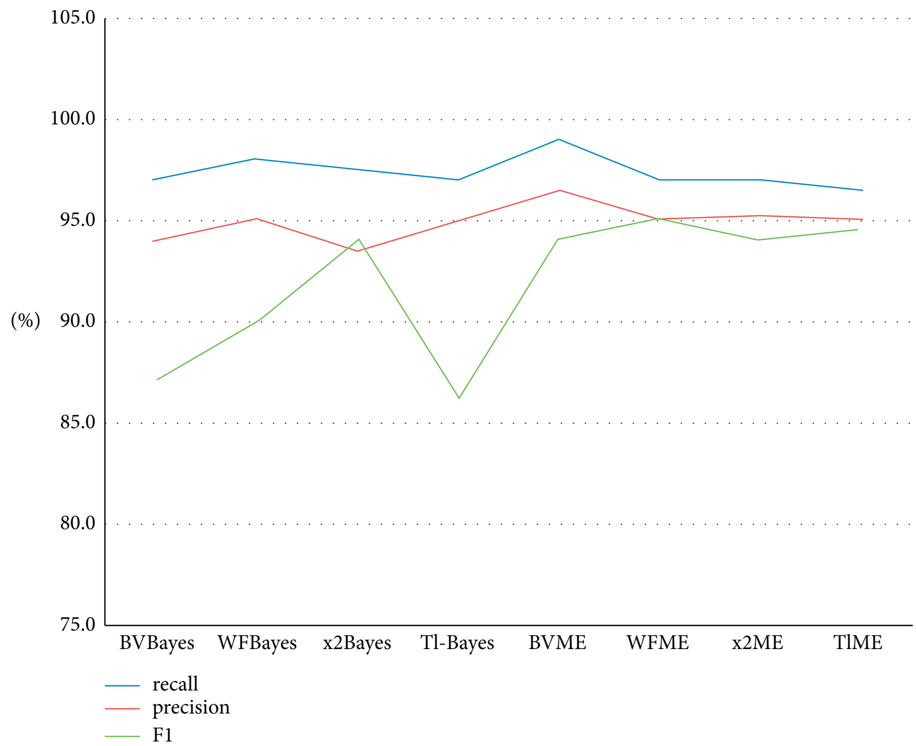


Figure 4: The influence of the selection of characteristic functions on the values of Recall, Precision, and F1.

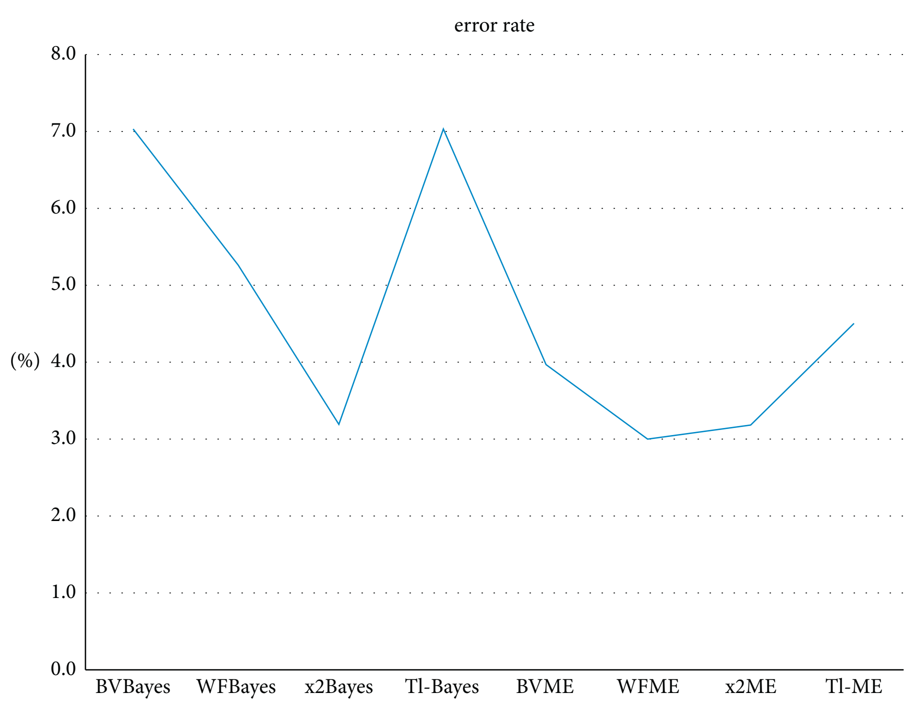


Figure 5: The influence of feature function selection on error rate.

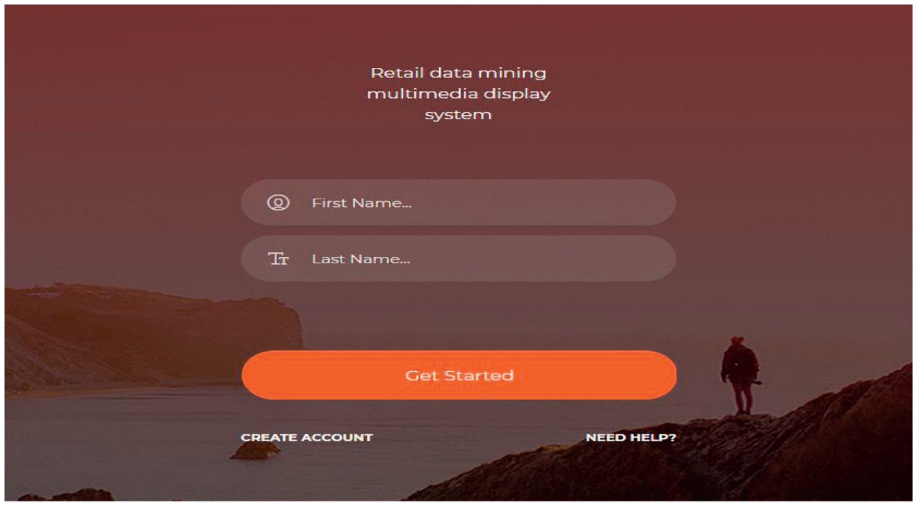


FIGURE 6: Multimedia system login page.

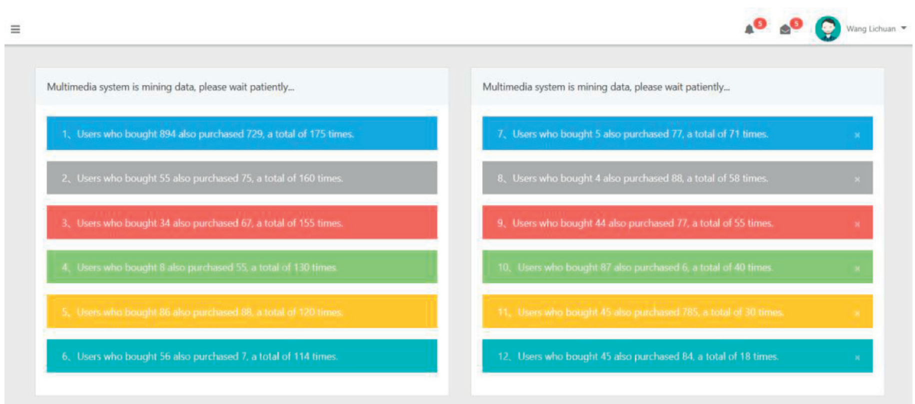


FIGURE 7: Multimedia data mining interface.

5. Conclusions

The application and analysis of data mining technology in the customer relationship analysis of retail industry mainly includes the design and analysis of the customer value prediction model of the retail industry, correlation analysis of customer purchase frequency, and decision tree mining model based on OLAP. Based on the analysis of existing customer data in the retail industry, a customer value prediction model is established by the decision tree algorithm to discover the different values of different types of customers, predict new customer data, and discover potential profitable customers, so as to make them become value customers that can create profits for enterprises. According to the classical *a priori* association analysis algorithm, the relationship between customers and commodity sales analysis is analyzed, and the results are applied to cross-selling or a combination marketing of commodities. Decision tree mining model based on OLAP can be used for dimension analysis and data aggregation. Decision tree mining model based on OLAP can be used for dimension analysis and data aggregation. Design of simple inference engine based on customer knowledge. The reasoning engine in this paper is a simple reasoning based on the knowledge and information obtained from the previous analysis. In this paper, the rule representation of design, the design of knowledge base, the strategy of reasoning, and the process of reasoning engine implementation are given. This paper has achieved some staged results. The results of OLAP multidimensional analysis and display based on customer data, customer value prediction model, and correlation analysis have certain value and practical significance. However, compared with some large-scale software, there are still gaps, which need to be further improved in future research. Mainly the following aspects have to be improved: (1) Because of the limitations of the mining platform, the types of algorithms available are limited. There are only two kinds of algorithms that can be used in the mining platform selected in this paper. Therefore, in future research and development, we should try to introduce new algorithms and establish new mining models. Through comparing the effects of different models, we can improve them continuously. (2) In this paper, maximum entropy is introduced into customer relationship analysis of retail industry. According to the data, there is no formed system. Because of the short development time, the system in this paper is still in the testing stage and has not been integrated into the intelligent decision support system. In future research, the system should be integrated and perfected to realize intelligent human-computer interaction function and provide decision-makers with an intelligent reasoning engine for decision-making opinions and strategies. At present, the introduction of data mining technology into customer relationship management system research has become a hot topic for insiders. Although we choose different platforms and algorithms, we hope to find a more practical software to really meet the needs of decision-makers. The purpose of this paper was to satisfy the requirement of deep-level analysis for decision-makers, and the results have certain practicability and value.

Data Availability

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

Conflicts of Interest

The author(s) declare no potential conflicts of interest with respect to the research, author-ship, and/or publication of this article.

Acknowledgments

This work was supported by the 2021 Philosophy and Social Science Planning Science Popularization Project of Yunnan Province, "Research on the Responsibility System and Performance Evaluation Mechanism for the Popularization of Social Sciences in Yunnan Province (SKPJ202154)."

References

[1] L. Bahl, P. Brown, P. de Souza, and R. Mercer, "A tree-based statistical language model for natural language speech recognition," *IEEE Transactions on Acoustics, Speech, & Signal Processing*, vol. 37, no. 7, 1989.

[2] L. B. Adam, F. B. Peter, A. D. P. Stephen et al., "The Candide system for machine translation," in *Proceedings of the workshop on Human Language Technology*, Plainsboro, NJ, USA, March 1994.

[3] E. Black, F. Jelinek, J. Lafferty, D. M. Magerman, and R. Mercer, "Salim Roukos, towards history-based grammars: using richer models for probabilistic parsing," in *Proceedings of the workshop on Speech and Natural Language*, Harriman, NY, USA, February 1992.

[4] D. T. Brown, "A note on approximations to discrete probability distributions," *Information and Control*, vol. 2, no. 4, pp. 386–392, 1959.

[5] Z. Lv and H. Song, "Trust mechanism of feedback trust weight in multimedia network," *ACM Transactions on Multimedia Computing, Communications, and Applications*, vol. 17, 2021.

[6] P. F. Brown, V. J. D. Pietra, P. S. A. Della, and R. L. Mercer, "The mathematics of statistical machine translation: parameter estimation," *Computational Linguistics*, vol. 19, no. 2, 1993.

[7] P. F. Brown, J. Cocke, A. Stephen et al., "A statistical approach to machine translation," *Computational Linguistics*, vol. 16, no. 2, pp. 79–85, 1990.

[8] P. Brown, V. Della Pietra, P. de Souza, and R. Mercer, "Class-based N-gram models of natural language," *Proceedings, IBM Natural Language ITL*, vol. 18, pp. 283–298, 1990.

[9] P. F. Brown, P. S. A. D. Della, V. J. D. Pietra, and R. L. Mercer, "A statistical approach to sense disambiguation in machine translation," in *Proceedings of the workshop on Speech and Natural Language*, pp. 146–151, Pacific Grove, CA, USA, February 19-22, 1991.

[10] Y. Zeng, G. Chen, K. Li, Y. Zhou, X. Zhou, and K. Li, "M-skyline: taking sunk cost and alternative recommendation in consideration for skyline query on uncertain data," *Knowledge-Based Systems*, vol. 163, no. 1, pp. 204–213, 2019.

[11] M. Thomas, *Cover, Joy A. Thomas, Elements of Information Theory*, Wiley-Interscience, New York, NY, USA, 1991.

[12] I. Csiszár, "I-divergence geometry of probability distributions and minimization problems," *Annals of Probability*, vol. 3, no. 1, pp. 146–158, 1975.

[13] Z. Lv, R. Lou, J. Li, and H Song, "Big data analytics for 6G-enabled massive internet of things," *IEEE Internet of Things Journal*, vol. 8, no. 99, 2021.

[14] I. Csiszar, "A geometric interpretation of Darroch and Ratcliff's generalized iterative scaling," *Annals of Statistics*, vol. 17, no. 3, pp. 1409–1413, 1989.

[15] L. Csiszár and G. Tusnády, "Information geometry and alternating minimization procedures," *Statistics & Decisions, Supplemental Issue*, vol. 1, pp. 205–237, 1984.

[16] J. N. Darroch and D. Ratcliff, "Generalized iterative scaling for log-linear models," *The Annals of Mathematical Statistics*, vol. 43, no. 5, pp. 1470–1480, 1972.

[17] S. D. P. Pietra, V. J. D. Pietra, J. Gillet, J. D. Lafferty, H. Printz, and L. Ures, Inference and estimation of a long-range trigram model,," in *Proceedings of the Second International Colloquium on Grammatical Inference and Applications*, pp. 78–92, Alicante, Spain, September 1994.

[18] X. Li, H. Liu, W. Wang, Ye Zheng, H. Lv, and Z. Lv, "Big data analysis of the internet of things in the digital twins of smart city based on deep learning," *Future Generation Computer Systems*, vol. 128, pp. 167–177, 2021.

[19] D. P. Stephen, D. P. Vincent, and J. Lafferty, *Inducing Features of Random Fields*, Carnegie Mellon University, Pittsburgh, PA, USA, 1995.

[20] A. P. Dempster, N. M. Laird, and D. B. Rubin, "Maximum likelihood from incomplete data via theEMAlgorithm," *Journal of the Royal Statistical Society: Series B*, vol. 39, no. 1, pp. 1–22, 1977.

[21] S. Guiasu and A. Shenitzer, "The principle of maximum entropy," *The Mathematical Intelligencer*, vol. 7, no. 1, 1985.

[22] E. T. Jaynes, "Probability theory as logic," in *Maximum Entropy and Bayesian Methods*, W. T. Grandy and L. H. Schick, Eds., pp. 1–16, Kluwer, St. Louis, MO, USA, 1990.

[23] C. H. Wu, Z. Yan, S. B. Tsai, W. Wang, B. Cao, and X. Li, "An empirical study on sales performance effect and pricing strategy for e-commerce: from the perspective of mobile information," *Mobile Information Systems*, vol. 2020, Article ID 7561807, 8 pages, 2020.

[24] F. Jelinek and R. L. Mercer, "Interpolated estimation of Markov source parameters from sparse data," in *Proceedings, Workshop on Pattern Recognition in Practice,* Amsterdam, The Netherlands, 1980.

[25] J. Lucassen and R. Mercer, "An information theoretic approach to automatic determination of phonemic baseforms," in *Proceedings of the, IEEE International Conference on Acoustics, Speech and Signal Processing*, San Diego, CA, March 1984.

[26] B. Merialdo, "Tagging text with a probabilistic model," in *Proceedings of the, IBM Natural Language ITL*, pp. 161–172, Paris, France, 1990.

[27] A. Nádas, R. Mercer, L. Bahl et al., "Continuous speech recognition with automatically selected acoustic prototypes obtained by either bootstrapping or clustering," in *Proceedings of the, IEEE International Conference on Acoustics, Speech and Signal Processing*, pp. 1153–1155, Atlanta, GA, April 1981.

[28] I. S. Sokolnikoff and R. M. Redheffer, *Mathematics of Physics and Modern Engineering*, McGraw-Hill Book Company, 2nd edition, 1966.

[29] J. Shore and R. Johnson, "Axiomatic derivation of the principle of maximum entropy and the principle of minimum cross-entropy," *IEEE Transactions on Information Theory*, vol. 26, no. 1, pp. 26–37, 1980.

[30] F. J. Och and H. Ney, "Discriminative training and maximum entropy models for statistical machine translation," in *Proceedings of the 40th Annual Meeting on Association for Computational Linguistics. Association for Computational Linguistics*, Philadelphia, PA, USA, October 2002.

[31] L. Adam, V. Pietra, and S. Pietra, "A maximum entropy approach to natural language processing," *Computational Linguistics*, vol. 22, no. 1, 2002.

Hindawi
Scientific Programming
Volume 2022, Article ID 5418622, 9 pages
https://doi.org/10.1155/2022/5418622

Research Article

Exploration on the Application of New Media Interactive Art to the Protection of Traditional Culture

Lingling Guo and Lipeng Zhang

Nanchang Institute of Science and Technology, Nanchang 330000, Jiangxi, China

Correspondence should be addressed to Lingling Guo; guoguo6668882021@163.com

Received 12 January 2022; Revised 11 February 2022; Accepted 28 February 2022; Published 23 March 2022

Academic Editor: Ahmed Farouk

The background of information age promotes the rapid development of interactive art with new media. The interactive art of new media combines modern photography with the Internet and other technologies. The emergence of new art interacting with media not only reflects the progress and development of media technology but also reflects the tremendous progress of media art, which provides more ways for the development of art and is conducive to improving the diversity of people's art and cultural activities. This paper summarizes the characteristics of interactive technology and new media and analyzes the application of interactive art of new media in the protection and dissemination of traditional culture. Interactive art is a virtual space that provides artists and engineers with interactive experience through technology platform. Interaction takes place in different areas and guides visitors to create it in different ways. In addition to being applied in many commercial fields of modern society, this art form has also been applied in the field of culture as an important means of communication of traditional culture. Through literature collection, data analysis, and questionnaire survey, it can be concluded that the application of new media interactive art in the protection of traditional culture can not only repair and replicate damaged traditional cultural resources but also display, preserve, and disseminate rare cultural resources.

1. Introduction

With the continuous development of digital technologies represented by "big data," "Internet of Things," "cloud computing," "artificial intelligence," "virtual reality," etc., the application of "4G+" and "Internet+" is becoming more and more extensive, and the influence of "new media" on all aspects of our life is increasing day by day. The important components of a country's comprehensive strength often include culture, politics, economy, and military. The role of culture in it is increasing day by day, and countries are also placing more and more importance on the construction of culture. As the most advanced communication media at present, new media is an important way of cultural communication [1], which encourages the promotion of cultural industries. We should actively use advanced technology and modern production methods to upgrade the traditional cultural creation and dissemination mode and expand the cultural industry chain. In order to promote the development of traditional culture, that is, to enrich the channels of traditional culture and promote the inheritance of traditional culture, we adopt advanced digital technology and thinking mode. In the 1960s, European and American artists began to use electronic communication technologies such as television and video as their performing and artistic media and developed new art categories. Unlike traditional graphic art, sculpture art and architectural art, this new art category, which combines technology and art, is called new media art. Soon, new media art developed rapidly with the help of the TV media network. New media art greatly improves the audience's participation in art works and the interaction between users and works [2]. In 1996, Mark Tribe defined new media art as a general term for works of art, such as CD-ROM, New Art, Digital Video, and Net Radio. Roy Ascott believes that the art of new media mainly involves circuit transmission and computer generation. Susan Acret believes that new media art is a very broad term. Its main feature is the use of advanced technical language in art works, including online virtual art created by a computer, Internet and video technology, visual arts, and multimedia interactive devices and operations. Professor Lu Xiaobo of Tsinghua University defines the art of new media as based on information technology and knowledge, one can have real-time interaction and experience skills with text, voice, and image as carriers, which is based on modern information technology, emphasizing the exploration of concepts, art, and ideology.

In recent years, China's cultural industry has developed rapidly, and the role of new media in the dissemination and promotion of cultural industry has become increasingly important. The new cultural industry dominated by new media will soon become the new driving force of China's future market. The Central Committee of the Communist Party of China and the State Council clearly put forward the proposal of Several Opinions on Deepening the Reform of Cultural System that "the promotion of cultural industry should be actively promoted," actively utilizing advanced technology and thinking mode, using digital technology and advanced media environment, to promote the development and upgrading of cultural industry [3]. To a certain extent, we have enriched the channels of communication of traditional culture and improved the way of transmission and inheritance of traditional culture. Utilizing the application benefits of the interactive art of new media provides an important technical guarantee for the researchers of history and culture. After the confirmation of new media art, art exhibitions around the world are welcomed. In addition to the new media art that can be displayed in domestic new media art exhibitions, various forms of new media art make use of Internet technology to produce network art, perform video installation art, and create a virtual one. Art enriches the directness and dynamics of new art forms [4]. In such a cyberspace, even if it is impossible to present tangible objects to the audience, the work can also call on the audience to participate in an interactive way. Users can play all kinds of IDs at any time, receive transmitted information, participate in virtual interaction, and create use communities. New media reports provide more explanations and more interactive definitions for new media art. Roy Ascott, the pioneer of new media art, who created an environment different from traditional media in the era of new media art, said that the most striking feature of new media art is its connectivity and interaction. Contact requires integrating potential customers into immersive systems, and interaction requires the active participation of potential customers and communication with work, others, and creators. In a sense, the connection and interaction of the new media art have changed the unique state of the work, destroyed the original logic of the work, and enabled the audience to participate in the work, thus leading to the change of the consciousness and structure of the work. Relationships, ideas, and logic will be reorganized. New media platform is more complex than traditional media, with a better visual effect, interaction, and strong social communication ability [5]. Therefore, the new media has gradually become an effective carrier for the transmission and inheritance of traditional culture. It can also promote the development and upgrading of the cultural industry chain. Compared with the protection and dissemination of other traditional cultural resources, the interactive art of new media protects other traditional cultural resources in different forms.

The concept of new media is indeed very broad. Broadly speaking, new media is a communication system different from traditional media, including new technology for digital media, audience participation behavior, and division of labor of new organizations [6]. From relying on real objects and technologies to radio technology and digital technology mixed with real and virtual technology, all of these are inseparable from social development and the progress of science and technology, and with the improvement of material and spiritual levels, it also suggests how to obtain information. In the art of the new media environment, it does not rely on the new media platform to disseminate or merely display cutting-edge art but implies a new art mainly involving interaction, which seems incomprehensible at the vanguard and general social level [7]. It is called "interactive art," because it has the future-oriented interdisciplinary characteristics, requires a lot of knowledge, requires the active participation of the audience, requires the close integration among individuals, and requires the closer integration of various media and individuals. Culture is a unique phenomenon of human society and a product of human social practice. According to the definition of British anthropologist Edward Taylor, culture is "knowledge, belief, art, law, morality, customs, and members of society." It is a complex whole, including abilities and habits. In the final analysis, various cultures of the country and the nation have accumulated for many years, and traditional culture is the core of the national spirit formed by the long-term integration of cultures [8]. The formation of traditional culture is a system and complexity, which leads to the greatest characteristics of traditional culture. The formation of traditional culture is the result of historical precipitation and accumulation, and there are complex relationships between different parts of traditional culture. However, at the same time, this relationship is not disorderly but has certain operational rules. For example, the state and work of a country are their beliefs. They are directly affected by customs.

Western countries believe in Christianity, Arab countries in Islam, and Southeast Asian countries in Buddhism. In music, painting, and literary works, they are deeply impressed by religious imprints. National artworks are different, and because of certain natural environments, such as topography and climate, they have been associated with certain lifestyles of local people since ancient times [9]. On the basis of protecting traditional culture, it is difficult for traditional protection and dissemination to meet people's actual needs. The interactive art of new media and its unique mode of communication have greatly promoted the protection and dissemination of traditional culture and played an important role in the protection of traditional culture.

Traditional culture is a cultural accumulation developed over many years. The scope of Chinese traditional culture is very wide, including not only ancient writing, music, drama, and calligraphy but also traditional festivals. These cultures have an impact on people's lives mainly through written records or customs.

Due to the early birth of these traditional cultures, there are many differences with the way of life of today's people. Affected by these differences, the following difficulties have arisen in the transmission of traditional culture:

(1) Difficulty generating a sense of identity: At present, there is a lack of correct traditional culture education in society. Many young people regard traditional culture as dross and have no sense of identity in their hearts.

(2) Invasion of foreign cultures: With the trend of economic integration, the cultures of various countries are constantly blending. Under this circumstance, the invasion of foreign culture has made our young people have higher and higher expectations for various Western festivals, but they have little expectation for their own traditional festivals. It can be seen from this that traditional culture has not been fully accepted by contemporary young people. At this time, new media can be used to promote the dissemination of traditional culture, so as to eliminate the gap between the "old" culture and the "new" generation.

New media has expanded the spread of traditional culture. In the past, the protection of traditional culture was mainly initiated by government departments because even if the traditional media reports on arts such as paper-cutting and drama, they will not be able to attract the attention of the public due to the narrow audience and limited communication scope of traditional media. However, because the communication style of new media is more in line with the preferences of contemporary people, it can stimulate everyone's desire to protect traditional culture and urge everyone to actively understand traditional culture [10].

Although the new media has contributed its own strength to the dissemination of traditional culture, there are still some deficiencies in the dissemination process that cannot be ignored. For example, due to the large amount of information content in the new media, it is mixed with a lot of vulgar culture, which reduces the influence of traditional culture. Moreover, there are many new media in order to cater to the curiosity of users, and the content of the articles written tends to be entertaining and lacks seriousness too much. As a platform where everyone can express their opinions, new media makes various groups in society hedge their opinions [11]. This is also an inevitable phenomenon of cultural convergence in the development of new media. If things go on like this, it will reduce the public's independent thinking ability and make them lack the original aesthetic ability, and it will be difficult for them to appreciate the elegant culture.

Culture is relative to nature, generally refers to the achievements of civilization created by human beings, and is a part of human creation, the sum of all material and spiritual products. Culture does not always exist; it is produced from the existence of people and accompanied by humanization. In the long history of humanization, the development of culture is like a seed growing into a towering tree. We all know that culture is something unique to human beings, and the animal world is a world that cannot be called culture. Only human beings can have culture, and this culture will be constantly updated and produced with the development of human society. A new culture is like the relationship between a seed and a big tree. It is also because of this that culture needs to be disseminated, and the dissemination of culture is highly systematic, multi-faceted, and inextricably linked to everything.

The structure of cultural communication mainly involves five aspects: communicator, receiver, media, value demand, and cultural information [12]. Among them, the disseminator is the communication subject who creates the culture; the receiver is the object or audience of cultural acceptance, and the receiver may be the enjoyer and carrier of the culture after the dissemination and can also re-disseminate the culture; the media is the means, method, technology, and communication, and the use of media has become popular; the scope of cultural communication without media will be greatly limited because cultural communication is different from physical commodities. Its value demand is mainly the need and possession of values; cultural information refers to different information resources and information content [13].

The survival and development of society are inseparable from culture, because culture plays an important role in the entire society, and the function of culture affects the entire society, ranging from a small individual, an organization, to the entire human society, affected by various cultures. For example, for the whole society, culture has a cohesive force and a value orientation, which the whole society should abide by; the same is true for organizations, such as corporate culture, etc., and for individuals, the cultural environment affects the growth of a person and makes a big impact.

Cultural communication in the current new media environment has caused changes in the various elements of cultural communication. As far as communication subjects and receivers are concerned, the media is no longer only limited to some specific government departments or party and government agencies to release information. Ordinary receivers can also become the producers, processors, and publishers of information. New media has changed communication: the subject–object relationship between the receiver and the receiver. The sources of cultural information in the new media environment tend to be diversified. With the help of the powerful integration and performance capabilities of digital technology, new media can transform complex and difficult-to-understand scientific theories, experimental procedures, and scientific discussions into information that the audience can understand. It can spread the culture wider. Due to the wider object, content, and scope of dissemination, people with cultural differences have different understandings and needs of different cultures. The cultural content may be processed and innovated in the process of dissemination, and the process of cultural dissemination also affects people. It changes the cultural value demands.

The development of new media cannot exist independently of social production and life. The same is true for the development of cultural communication. The development of new media and the development of cultural communication are interrelated individuals, and there is dialectic between them. In the process of development of new media, in order to play a better role in communication, it requires constant technological and form updates to meet the needs of cultural development. There has been further development in both content and form. From this perspective, they are interacting. The development of new media promotes the development of culture. On the contrary, the development of culture promotes the development of new media technology. The development of current culture depends on the wide spread of new media. We must pay attention to the important power of new media in cultural communication, and we must pay attention to the power of emerging media as we treat traditional media.

2. Methods

2.1. Document Analysis. "Documentation" refers to any carrier that records relevant knowledge and all materials, including books, newspapers, papers, archives, and scientific research reports, through words, pictures, symbols, audio, and video recordings. It also includes cultural property, films, audio and video recordings, slides, and other material in physical form, as well as written material, CD, and other data in electronic form. Literature is of great value in the development and research of human society, history, and culture. Previous research results have been absorbed and borrowed because human society is likely to develop so rapidly. In order to have sufficient information, educational research needs literature research, acquisition of research trends, and understanding of previous and previous research results. Document research is an essential step in any research work. Document research method is an old method of studying life science, and it is one of the most basic methods in educational science research. Document research methods refer to the collection, identification, and combination of documents. Through literature research, scientific understanding of facts, understanding of educational facts, and exploring educational phenomena are formed. Through the domestic scholar's research on the application of new media interactive art to the protection of traditional culture, this paper summarizes the current research situation, determines the research direction, and organizes the discussion on the influence of new media on traditional culture.

2.2. New Media. New media provides users with services such as information and entertainment through the use of Internet technology and electronic devices such as computers and mobile phones as carriers. For example, Weibo, WeChat, and other social software with many users belong to the category of new media. Because they all need the help of the Internet, they can provide users with various services.

The reason why new media has a good development prospect is that it has the following characteristics:

(1) Interactive: Through the use of new media, the communication needs between information publishers and receivers can be met, and users can express their opinions in a timely manner and communicate with others.
(2) Diversity: Compared with the single communication method of traditional media, new media can spread information through videos, images, expressions, etc. The various communication channels add interest to users and can attract users' attention.
(3) Convenience: Relying on mobile phones, computers, and other carriers, new media can release news content anytime and anywhere, regardless of the geographic location and time. This move is just in line with the current faster and faster pace of life, and people can use fragmented time to browse information.

2.3. Cultural Research Method. Media and Cultural Research Methodology: "Cultural Research" was proposed against the background of academic resistance, social relations, and social significance dispersion. This paper uses the method of "cultural research" to interpret and analyze the traditional culture and reveals the ideology and discourse behind the text under the local cultural background in the real world. At the same time, from the perspective of new media interactive art, this paper explores and organizes its impact on traditional culture and analyzes the importance of multimedia interactive art in the protection of traditional culture.

2.4. Data Analysis Method. Through collecting, summarizing, and analyzing the relevant data of multimedia technology in the protection of traditional culture, this paper grasps its laws and characteristics, combines them with the current situation of traditional culture, and boldly predicts and prospects the future development trend of traditional culture with the assistance of new media interactive art.

2.5. Questionnaire Survey. Questionnaire survey is a research method, which consists of a list of questions along with choices, which many investigators use to collect information. Researchers design a unified questionnaire based on the purpose of the survey and ask the selected respondents for information and opinions, so as to understand the respondents' views and opinions on a certain problem or phenomenon. With the help of online and on-site questionnaires, this study aims to understand the current situation of Chinese excellent traditional culture in the context of new media and the impact of new media. According to the principle of unified data induction, we can ensure that all kinds of survey results are compared at the same time and find out the problems by objective analysis, so as to complete the summary, planning, and research of the causes and thus determine the formulation of solutions.

3. Experiments

Only through practice can we understand things correctly. In order to understand all aspects of Chinese excellent traditional culture in the new media era more objectively, we have carried out relevant investigations and analyzed the results. Through this survey, we can understand the positive and negative impact of the new media on the inheritance of Chinese excellent traditional culture. On this basis, we analyze the existing problems and seek measures to strengthen the inheritance. This survey is conducted in two ways: first, on-the-spot investigation. According to the number of questionnaires, 635 questionnaires were collected and 550 valid questionnaires were selected. The effective recovery rate reached 87.4%, which could meet the needs of this study. The second is to use the new media platform to show the advantages of online question-and-answer and send questionnaires to other platform terminals through question-and-answer settings. After the survey is completed, the platform will automatically collect information and calculate data, and investigators can wait until the platform delivers the results. The method has the advantages of low cost, high efficiency, and accurate data.

At this stage, the scope of new media users is becoming wider and wider, and people receiving new media are becoming stronger and stronger. Smart phones have become an important tool for groups to receive and publish information. Weibo, Weixin, a major portal platform, etc., can be important sources of news for the group. People basically see new news every day. By acquiring this new form of media, the way of inheriting culture has been completely destroyed. This paper investigates the current situation of group use of new media, as shown in Figure 1.

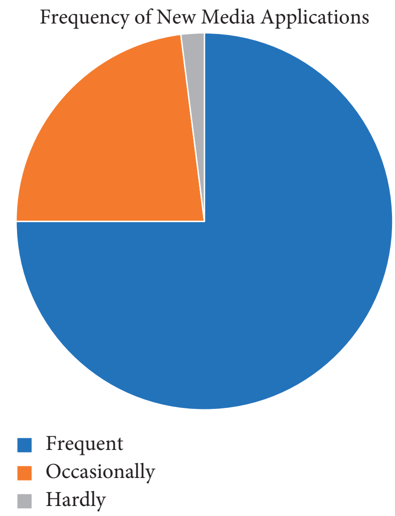


Figure 1: Frequency of new media applications.

As shown in Figure 1, 75% of people often use new media applications and know that they are highly dependent; 23% of them only use new media applications when they need them and do not rely on them; and 2% of them have few new media applications and think that they have no special needs for life and learning. From the above data, we can see that most people are inseparable from the new media in research and life and have a strong dependence.

In the dissemination of China's superior traditional culture, television and the Internet usually help to expand the knowledge of traditional culture by producing programs and movies related to China's excellent traditional culture, but only 13% of the people said they often saw related programs. Frequency is maintained once a week. The program is occasionally watched for 2–3 weeks, accounting for 47%. 40% seldom watch the program. They do not know which program advocates Chinese traditional culture (Figure 2).

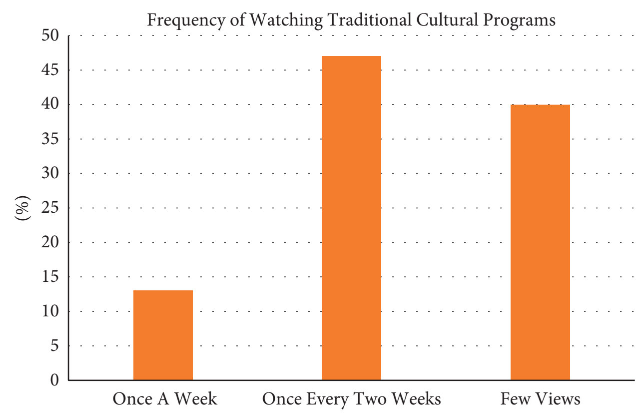


Figure 2: Frequency of watching traditional cultural programs.

As shown in Figure 2, it is not enough for the public to disseminate Chinese excellent traditional culture to the new media platform. Perhaps working hours are rather tense. Therefore, the attitude of those who study and inherit Chinese traditional culture should be strengthened.

Traditional media dissemination focuses on official media and unifies the dissemination of cultural content, which is abstract and inefficient. On the other hand, information dissemination methods in the new media era are very effective, which can be based on the characteristics of people's communication. Therefore, the current research on traditional cultural transmission methods is still focused on technology, mobile phones, and online media. At present, most traditional cultural studies are discussing the impact of the new media environment, as shown in Figure 3.

As shown in Figure 3, the new media constantly integrates into the developing traditional media, crosses the time and space boundaries, makes the new media realize complementary benefits, interacts with the traditional media, and disseminates the excellent traditional Chinese culture to give you an opportunity to do so, which is the combination of platform and channel. This is the advantage of new media to promote traditional culture in traditional society. By combining different forms of communication channels, traditional cultural resources can achieve better circulation and combination. In this way, new media platform can become the basis of the development of traditional culture and make information disseminate in the whole news model. For the target population, communication paths and examples have achieved good results. The combination of various communication channels makes the allocation,

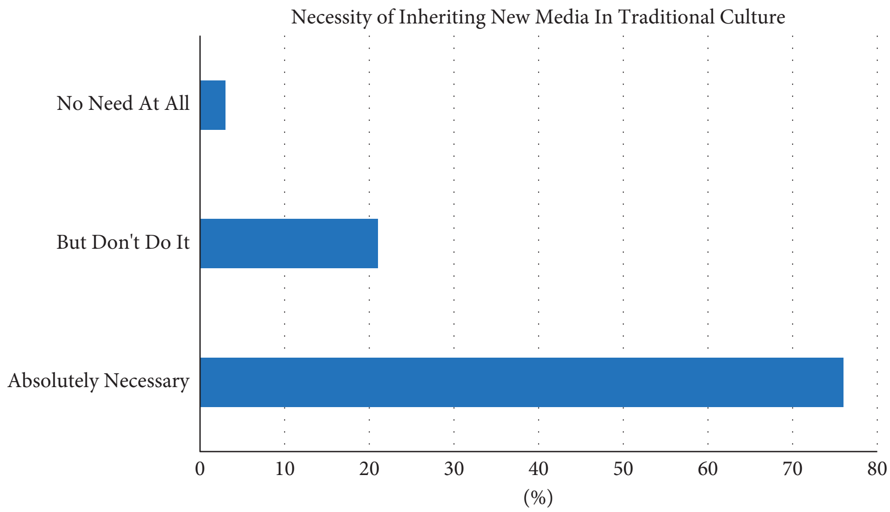


Figure 3: Necessity of inheriting new media in traditional culture.

opening, and utilization of traditional cultural resources more efficient, and traditional culture can reach the target population in a targeted and full-time manner. This creates a new way of communication and dissemination paradigm, which greatly promotes the dissemination of traditional cultural texts.

4. Results and Discussion

4.1. Virtual Exhibition Cultural Venues. In the process of disseminating traditional cultural resources, the exhibition mode, literature collection method, and tourism mode are mainly adopted. This traditional form of cultural exchange has its limitations, and it is difficult to meet the cultural needs of the masses. The biggest restriction is that visitors must visit the designated space. On the other hand, the actual physical space is limited, and the content that can be displayed is limited. The viewer can only change the perspective by moving. By applying the interactive art of new media to innovative design of cultural sites, the construction of virtual sites that can be navigated in the network can effectively expand the radiation surface of cultural sites [14]. China began to pay attention to the protection of traditional culture in order to promote the construction of modern socialist culture and inherit the essence of traditional culture. The display and dissemination of traditional culture includes the acquisition of library materials, exhibitions in tourist development zones, and exhibitions in fixed places. Among them, the library materials and exhibitions in fixed places are well known. The exhibition in the tourism development zone inherits the essence of Chinese traditional culture, integrates the human landscape and natural landscape, and shows the world the traditional culture. The dissemination of these three traditional cultures has certain limitations, and it is difficult to meet people's cultural needs. If visitors are geographically located relatively far away from their visits, they will have to spend a lot of energy and time on visitors, and the enthusiasm for visits may disappear [15]. Therefore, for tourists, whether they are tourist attractions or exhibition halls, their behavior is greatly limited by their geographical location. New media interactive art can successfully solve the shortcomings of traditional exhibitions, make full use of network technology, effectively establish virtual exhibition hall, make up for the shortcomings of traditional exhibitions, and meet the needs of tourists, as shown in Figure 4. Take the Palace Museum as an example to illustrate the function of new media interactive art virtual display cultural space. The Palace Museum is the largest museum of Chinese culture and art in China. Every day, many Chinese and foreign tourists come to China. However, Palace Museum has limited tourism capacity, and many places are unstoppable. Tourists are affected by the crowded and noisy environment during the limited visit period, which makes the experience difficult. In this case, the online Palace Museum was launched, which uses high-definition photography technology to store its exhibitions and famous buildings as data [16].

As shown in Figure 4, as long as the network can view these images and photos at any time, users need not worry about deadlines, so they can explore historical and cultural resources related to the exhibition. As a result, the Forbidden City has significantly improved its reception capacity, expanded its influence, and disseminated traditional culture without increasing the number of trees in the field. For example, the Palace Museum has a large collection of palace buildings and historical relics, with more than 10 million visitors per year and a population of over 40,000. These large passenger flows overwhelm places where historic buildings and cultural monuments cannot be preserved and may affect people's viewing experience [17]. Through the opening of online museums, the Palace Museum creates renowned buildings and collections in a digital way, enabling people to explore relevant photographs and influential data anytime and anywhere. The Palace Museum not only helps to reduce luggage but also promotes dissemination, which enlarges the influence of palace museums. At present, similar cultural space has been widely innovated. Many historical museums, traditional cultural sites, and so on have opened the network

Figure 4: Virtual forbidden city.

Figure 5: Reconstructing bamiyan buddha by 3D architectural projection technology.

window, providing a lot of convenience for people to explore and visit.

4.2. Restoration and Reproduction of Damaged Traditional Cultural Resources. It is difficult for researchers of history and culture to systematically study the history of cultural resources, because it is difficult to exert its application value compared with some damaged traditional cultural resources. However, with the emergence of new media interaction process, the technology successfully restored and reproduced the damaged traditional cultural resources, restored the historical and cultural characteristics at that time, and provided an important guarantee technology for the research work of historical researchers [18]. For example, Bamiyan Buddha was once an important historical relic in Afghanistan, and this cultural resource witnessed the early Buddhist civilization. But it was destroyed by the Taliban. According to the actual situation in Afghanistan, restoring the Bamiyan Buddha required a great deal of financial resources; the destruction of cultural resources has become more serious, making the recovery more difficult. Based on this situation, in 2015, Chinese scholars successfully realized the original appearance of Bamiyan Buddha through modern advanced three-dimensional architectural projection technology, as shown in Figure 5.

As shown in Figure 5, modern technology can not only realize the original reproduction of damaged cultural resources but also create three-dimensional models. The current recovery model not only achieves the expected goal but also significantly reduces the actual cost, with little risk of damage. As a rule, in the process of protecting traditional culture, it is necessary to make full use of modern advanced technology to reduce production costs and achieve ideal results [19]. Under the theory of traditional culture protection and communication, the application of new media interactive art is mainly for the purpose of traditional culture protection. Many valuable historical and cultural sites are aging and destroyed with the growth of age, and there are many repairs. Many traditional cultural resources cannot be disseminated and displayed. In this regard, the use of digital restoration technology can provide new technical methods for the protection of traditional cultural resources, and the construction of digital resources can promote the dissemination of traditional cultural resources. For example, Huihui Village in Anhui has a history of 4100 to 4300 years, with a total area of 500,000 square meters. It is a large construction farm. This includes many huge ceremonial bases, circular ruins, and other valuable pottery and stone tools [20]. Based on Zuo Zhuan and other relevant historical data, it is inferred that the village will become the place where the prince of the Dalai River will rule the water source, which has very important historical value. Restoring the scene digitally will enable more people to understand this long historical event and to interpret it more easily. Some digital restoration techniques can restore the site topography, building direction, and layout as well as the ritual process and figures at that time. For example, the animation of the scene of "Yu Hui" is more realistic and reproduces this historical event. Once published on the Internet, people can download and watch them any time, which will help promote the protection and dissemination of traditional culture.

4.3. Preservation and Dissemination of Rare Cultural Resources. At present, there are many ancient cultural resources, which not only have high research value but also provide important research materials for Chinese archaeologists to study ancient architectural style, architectural means, culture, and so on. History and culture are of great value. It is of great research value to obtain more valuable historical and cultural materials on the basis of Chinese historical and cultural researchers and with the help of current cultural heritage [21]. After a long history of river baptism, many cultural sites have not properly preserved mountains. The long rain and baptism make it difficult for researchers to examine and harvest valuable cultural resources from these heritage cultural resources. In the context of the new media era, the use of new media interactive art can avoid the damage caused by traditional physical restoration and research. At the same time, this technology allows you to recover resources that are traditionally difficult to recover. Therefore, many ancient Chinese research value resources have been duplicated, bringing the gospel to many historical and cultural researchers. For example, the Gutenberg Bible has been baptized for 500 years as a paper product, which is difficult to protect effectively with very fragile materials and difficult for historical and cultural researchers to obtain. But at the end of 2003, there were only 11 complete copies of the Gutenberg Bible [22]. However, the United States uses the latest information technology to compile digital e-books and publish them on its official website. As a result, more people can visit more works through the official website, which is conducive to the reproduction of the Gutenberg Bible.

There are four main protection modes of intangible cultural heritage, namely, legal protection mode, government-led protection mode, folk protection mode, and tourism development protection mode.

For a long time, China has been in a farming culture. In the farming society, "intangible cultural heritage" follows the laws of survival and development of its own culture, reflects the customs of the farming society, and has a long history and humanistic spirit. Corresponding to this, in the past cultural environment and farming society, the "intangible cultural heritage" inheritance model was formed and recognized by people. At present, China still inherits "intangible cultural heritage" by means of natural inheritance. Natural inheritance has the following characteristics: relying on the natural economy and farming society, the outstanding performance is the way of heart teaching and oral transmission and master-apprentice inheritance, mainly by groups or individuals.

The person in charge of the inheritance uses the method of heart teaching and oral transmission so that the inheritor can obtain the real skills and the effect is good. Therefore, this transmission method is effective. China has gone through a long period of farming culture and natural economy. Correspondingly, the natural inheritance of "intangible cultural heritage" has also played an effective and long-term role in the preservation and continuation of intangible cultural heritage. China's intangible cultural heritage can continue to this day, and to a certain extent, it has a great relationship with the use of natural inheritance methods.

Now, although the natural inheritance method has played a great role in the inheritance of intangible cultural heritage, many problems have also been revealed due to social development and economic improvement, which includes lack of inheritance power. Under normal circumstances, when the "intangible cultural heritage" is inherited naturally, the main body of the inheritance is a natural person. In a farming society, the ability to continue the activities of inheriting the "intangible cultural heritage" is related to the inheritor's interest in it, but the key is whether the inheritor is willing. After the skills are learned, they can support their families. But, now in the era of market economy, some artists who inherit "intangible cultural heritage," after possessing the skills, not only get no return but they will spend too much energy and financial resources on them, so that they can be inherited, for the sake of morality. It is impractical and not beneficial to let them continue regardless of their own lives.

5. Conclusion

Compared with the traditional media in the past, the new media is not limited by time, space, and scope and can almost achieve the effect of preparation and universal use. At the same time, the new media collects text, image, sound, video, and other forms in the process of disseminating traditional culture, which reduces the audience's sleepiness, caused by the exploration of traditional cultural information, and relaxes the audience in a sense, effectively extracting the essence of traditional culture [23]. We can see that the positive significance of new media in the process of disseminating traditional culture cannot be underestimated. First, the new media provides an extension of traditional culture. Before the new media industry matures, the protection of traditional culture is mainly the responsibility of relevant government departments. Because newspapers, television, and other media have fewer audiences, traditional media cover clay, paper-cut, and other well-known crafts, limiting the scope of dissemination, excluding the public. However, with the maturity of new media technology, the richness of content and the enthusiasm of communication will satisfy the readers' reading habits, stimulate the audience's interest in traditional culture, and encourage the audience to understand the development of traditional crafts voluntarily. Through the linking system of the new media system, audiences have established channels for in-depth understanding of traditional culture and dispersed various folk groups to protect traditional Chinese culture. Secondly, new media has brought innovation engine to traditional culture. Because of the nature of network communication, new media has the advantages of wide dissemination, rapid updating, and infinite style. Therefore, in the process of communication, traditional culture can make use of these advantages to innovate and make the content of traditional culture more extensive. For example, many museums and historical perspectives in China have built-in WeChat public numbers and micro-blogs, which use traditional and boring traditional cultural knowledge to enrich interesting typesetting and present it to the audience in the form of pictures and colors, promoting cultural knowledge, not reducing traditional culture any more, and publicizing it in a form that the public is willing to accept. In addition, many video websites have created vertical platforms of traditional culture, such as Pear Video's History Channel, which creates traditional historical stories as cartoons and introduces audiences to an easy-to-use way [24].

New media is used as a carrier to create a new platform for the dissemination of traditional culture. The creative area of "Canal 5" has its own public number, which is a concrete manifestation of the combination of traditional culture, modern new media, and public relations. It is also an innovation of traditional culture. We must vigorously promote traditional culture through various news media platforms and mass media so that the public can acquire a variety of traditional culture in daily life, enrich people's cultural prosperity, and create a harmonious and friendly atmosphere in the neighborhood. The original architectural features of factory buildings are hardware construction and renovation, the construction of Canal No. 5 Visual Art Center, Changzhou Painting Party Memorial Hall, attic workspace, etc., using "100th Anniversary Photography of Centennial Birthday." "100 Years Yongcheng Change Photography Exhibition" and other representative works have attracted a large number of cultural innovators with unique artistic atmosphere, providing a new platform for cultural dissemination, such as Changzhou Hengyuanchang, Changzhou No. 5 Woollen Mill, Changzhou Shipping, Changzhou Canal No. 5 Industrial and Commercial Archives Expo Center. These cultural centers combine new media with traditional culture, expand the transformation and publicity of traditional culture, and enhance its commercial value. It has comprehensive functions of historical protection, inheritance of traditional crafts, and operation of creative industries. For example, the second floor of the archives shows some industrial products in the old industrial age of Changzhou. The third floor shows the development of Changzhou in the past hundred years. There are many interactive electronic products in the museum: 360-degree viewing touch screen of Changzhou, two audio-visual devices of Changzhou State intangible cultural heritage—Changzhou Yi, Tianning Temple Sanskrit, Tianxi Opera, and so on. QR codes are attached to each exhibition, scanning the two-dimensional code on the mobile phone to get a better understanding of the history of this exhibition. To deal with traditional culture, we need to pay attention to essence, distortion, innovation, and recreation. Therefore, we must use the influence of new media to promote traditional culture and selectively promote traditional culture. Therefore, the combination of traditional culture and new media is a task that must be completed to meet the needs of the development of the times. In a word, the application of new media interactive art is of great significance to the protection and dissemination of traditional culture. After the restoration and reproduction of traditional cultural resources are completed, advanced new media technologies can be disseminated through the Internet. In this case, it can not only meet the needs of traditional cultural protection but also bring new viewing experience to the audience. Traditional cultural and artistic design products are closely linked with the audience and enhance the effect of traditional cultural communication.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] A. K. Singh, X. Liu, and H. Wang, "Recent advances in multimedia security and information hiding," *Transactions on Emerging Telecommunications Technologies*, vol. 32, no. 2, Article ID e4193, 2021.

[2] Y. Yang and W. Yanli, "Applied research on interactive art of new media based on traditional culture protection and communication," *Journal of Xichang University: Social Science Edition*, vol. 30, no. 1, pp. 67–70, 2018.

[3] Y. Wang, "Application of Traditional Culture Elements in Interactive Media Design," *Digital World*, vol. 1744, no. 2, p. 341, 2018.

[4] D. Dai, Tubo, and H. Xia, "Study on the value of Chinese traditional culture in new media art education," *Art Science and Technology*, vol. 28, no. 12, p. 16, 2015.

[5] X. Peng, "Research on the integration of new media art and Chinese traditional culture," *Art Science and Technology*, vol. 10, p. 28, 2014.

[6] G. Zhao, "A Brief Analysis of the Role of New Media in the Inheritance of Chinese Traditional Culture," *Today's Media*, vol. 55, no. 8, pp. 125-126, 2015.

[7] X. Xu, "Rebuilding and innovation of Chinese traditional culture by new media," *Journalism Research Guide*, vol. 8, no. 4, p. 171, 2017.

[8] W. Wenjing, "On the communication of interactive art to traditional culture in the digital media environment: take the palace museum as an example," *Art Science and Technology*, vol. 29, no. 8, 2016.

[9] L. Liang and H. Hui, "The Role and Significance of New Media in Traditional Culture Communication --- Take Yueju Opera as an Example," *Media*, no. 11, pp. 56–58, 2014.

[10] H. Ko and G. Marreiros, "Smart media and application," *Concurrency and Computation: Practice and Experience*, vol. 33, no. 2, Article ID e5491, 2021.

[11] Z. Lv and H. Song, "Trust mechanism of feedback trust weight in multimedia network," *ACM Transactions on Multimedia Computing, Communications, and Applications*, vol. 17, 2021.

[12] Y. Zhang, Q. He, Y. Xiang et al., "Low-cost and confidentiality-preserving data acquisition for internet of multimedia things," *IEEE Internet of Things Journal*, vol. 5, no. 5, pp. 3442–3451, 2017.

[13] P. Yu, F. Zhou, X. Zhang, X. Qiu, M. Kadoch, and M. Cheriet, "Deep Learning-Based Resource Allocation for 5G Broadband TV Service," *IEEE Transactions on Broadcasting*, vol. 66, no. 4, 2020.

[14] C. Liang and F. Yan, "Exploration of the characteristics and countermeasures of traditional culture communication in the new media era," *China Cultural Forum*, vol. 2010, no. 4, pp. 118–121, 2010.

[15] J. Wan, "Exploration of the integration of new media art and traditional culture," *Art Science and Technology*, no. 8, pp. 76-77, 2015.

[16] X. Jiang, "The application of new media art in the protection of cultural heritage," *Journal of Jilin Institute of Education*, no. 3, pp. 89-90, 2010.

[17] X. Tang, "Interactive exploration of new media art," *Yihai*, no. 12, pp. 130-131, 2013.

[18] X. Chen, "On the protection of traditional culture," *Commodities and Quality*, vol. 15, no. s8, p. 176, 2011.

[19] X. Chang, "Inheritance and Protection of Intangible Cultural Heritage and Folk Art-- UI and Application Development of Traditional Culture," *Jiannan Literature: Classic Reading*, pp. 214–216, 2013.

[20] Y. Li, "On the Application and Dissemination of Traditional Culture in Multimedia Display Design," *China Newspaper Industry*, no. 2, pp. 148-149, 2012.

[21] X. Ruan, "Using multimedia technology to infiltrate traditional Chinese culture teaching," *Curriculum Education Research*, vol. 33, p. 88, 2015.

[22] Q. Zhu, Li Kang, and R. Zhou, "Brief discussion on the combination of multimedia technology and traditional culture," *Art and Technology*, vol. 26, no. 3, p. 40, 2013.

[23] Anonymous, "Traditional culture should not only Be protected, but also inherited," *Zhongguancun*, no. 1, p. 125, 2016.

[24] Anonymous, "Applied research of new media interactive art based on traditional culture protection and communication," *Research and Practice of Innovation and Entrepreneurship Theory*, vol. 1, no. 17, pp. 111-112, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 6240313, 12 pages
https://doi.org/10.1155/2022/6240313

Research Article

Application of Regional Culture in Landscape Architecture Design under the Background of Data Fusion

Yuxuan Dai

School of Architecture Art and Design, Xi'an Peihua University, Xi'an 710125, Shaanxi, China

Correspondence should be addressed to Yuxuan Dai; 150659@peihua.edu.cn

Received 15 December 2021; Revised 10 January 2022; Accepted 26 January 2022; Published 19 March 2022

Academic Editor: Ahmed Farouk

With the rapid development of urban construction, the process of urban regeneration and new urban development is the process of fully integrating regional culture into garden design. From the current point of view, the landscape design of modern urban construction has become a problem that solves the necessity of thinking and detailed discussion. The purpose of this article is to study how to display the special signs of regional culture in the city and ultimately enable the symbiosis of regional culture and the surrounding environment. This article puts forward the importance of regional culture in landscape architectural design under the background of data fusion and how to let regional culture penetrate into landscape architectural design. Based on the algorithm of investigation method and data fusion, it can be learned from the research results of investigation method that human beings have never stopped exploring the regional culture. In today's globalization, it highlights the characteristics of regional culture and advocates regional design and local culture. The combination of design is very necessary. In the experimental results of the data fusion algorithm, it can be known that when the evidence is the same, even if the weight adjustment is correct, the final conclusion is still close to the actual situation. It can be seen that, based on the data fusion algorithm, we can also know that regional cultural elements are becoming more and more important for landscape architectural design. In the experimental results of this article, in 2019, different age groups have the highest regional culture, which is as high as 38%, which is an increase of 12% over 2018. According to the data of the survey and research, it can be seen that the demand for regional culture for 15–30 years of age is between 30% and 50%, and the demand for regional culture for 50–75 years of age is between 53% and 70%. The demand for this age group is the highest. This shows that only by rationally using urban cultural resources, fully exploring the possibility of regionalization, and expanding the urban culture on the basis of the organic combination of the two can the regional cultural characteristics of the urban landscape be more and gradually clear. The spirit of the city is consolidated, thereby promoting the healthy development of the city. Only by digging the essence of regional culture can we create landscape design works with regional characteristics and significance.

1. Introduction

Since the 1990s, with the rapid development of computer networks and the advancement of the global economic integration process, human society has been undergoing earth-shaking changes: with the advent of the information age, economic globalization and informatization have expanded to various fields; and, in its unique way to affect the entire society, human society will gradually usher in a brand new era. Since the beginning of the new economic era in the 21st century, landscape design under China's regional culture has been facing new challenges. In recent years, with the continuous development of urban resources and the expansion of urban population, urban space has become more crowded. Precious historical and cultural buildings and neighborhoods have been destroyed in various degrees in the acceleration of urban change and development. This will not only destroy the precious regional culture but also make it impossible to inherit. The boundaries between time and space, reality and virtuality, subject and object are getting closer and closer, and the dualistic thinking is gradually blurred.

The data fusion center fuses information from multiple sensors; it can also fuse information from multiple sensors and the observation facts of the human-machine interface (this fusion is usually a decision-level fusion); extract the symptom information, under the action of the inference engine; match the symptoms with the knowledge in the knowledge base; make fault diagnosis decisions; and provide them to users.

With the development of the real estate market, the land and space resources of various waterfront areas have not been planned as public open spaces in the city to provide services for the public.

The situation of the "global village" has become increasingly clear. The rich material and spirit of folklore, humanities, spirit, customs, and so forth are the prerequisites for promoting the regional cultural landscape. They use the unique time-space relationship as the background to highlight the unique regional personality, thereby promoting the development of the landscape industry and then generating unique regional character. Whether the urban landscape can inherit the regional culture in the urban process is a difficult problem faced by the current landscape design, and the landscape works with regional cultural characteristics are the excellent carriers of the regional culture. The landscape design with regional cultural characteristics has the individual characteristics of "this is different from the other." Landscape design is a comprehensive field including the complex interweaving of aesthetics, ecology, geography, architecture, and other related fields. Regional culture has unique vitality, which has great guiding significance for landscape design. Specifically, the significance of studying this subject has the following points: (1) Protect, inherit, develop, and optimize regional culture, enhance regional memory, and establish regional image (logo). The geographical feature is the accumulation of history and the condensation of culture. It is the organic unity of the external image and internal spirit of the region. It is a complex of material life, national spirit, cultural tradition, geographical environment, and so forth of the city. The creative design of regional culture and landscape and the maturity of conflict determine the personal characteristics and taste characteristics of the region and have an impact, reflect the value of regional memory, can summarize the regional spirit, and establish a regional image mark. (2) By analyzing the lack of regional cultural characteristics in the above urban landscape, we have to consider and analyze the regional characteristics of urban landscape design. The charm of a city depends on whether it has a unique cultural temperament. Analyzing the current situation of domestic urban landscape design research, the research content mainly focuses on the relationship between regional culture and landscape design. From the problems that appear in domestic landscape design today, the purpose of landscape design must reflect culture.

With the development of society, many people are interested in regional cultural characteristics and have conducted research. In order to meet the needs of dynamic graphic design of video packaging, Bond tried to construct a framework for extracting cultural elements with regional characteristics. First, it summarizes the existing methods of extracting regional cultural elements and expands the existing methods from the time dimension. Then a new framework for extracting cultural elements with regional characteristics is shown, and applying them to the design of cultural video packages in these areas can effectively improve the cultural connotation of the design objects and better display and disseminate effects [1]. With the rapid development of China's market economy, regional characteristic cultural elements have become more and more important for companies to enhance their market competitiveness and occupy a favorable market share. However, with the development of society and the improvement of people's aesthetic pursuit, the commercialization of regional culture has become more and more serious. This forced it to change the corporate brand image and regain the favor of the market. Based on this, Park and Gutchess combined the relevant knowledge and concepts of fuzzy theory, from the perspective of regional characteristic cultural elements, explored the development of regional characteristic cultural elements, and aimed to design a set of regional characteristic cultural designs that are different from the past competitors, so as to achieve the shaping of the company's distinctive brand image and improve its market competitiveness. This article first collects a large amount of data through the literature survey method and systematically and comprehensively introduces the fuzzy theory [2]. Hu introduced the design process and main content of Longhu's Gaobeidian Train New City project, which won the Excellence Award in the 55th International Competition hosted by the International Federation of Landscape Architects (IFLA). Taking into account the separation of traditional cultural heritage from modern society and the disappearance of traditional culture, SUN and Hu proposed the design concept and strategy of connecting traditional culture and modern landscape through flexible landscape design. The genes of traditional culture can raise the awareness of people who respect and protect traditional culture [3]. Everyone's demand for regional culture and landscape design has increased dramatically, and it has continued to expand in the past few years. Despite the rapid expansion speed, people have not paid enough attention to the quality of landscape design and regional culture according to people's preferences. Yokoya et al. revealed people's preference for landscape design quality and regional culture. Using the photo questionnaire, the results point to three main dimensions: the green dimension, the seating dimension, and the quality of landscape design and regional culture, among which the green dimension has obtained the highest preference. The green dimension includes water features, trees, plants, and shrubs. In addition, legibility and continuity affect people's preference for open space in shopping malls. Compared with the commercial dimension, people prefer leisure space, which involves the commercial equipment of the shopping center. Research suggests that shopping malls should be designed as real public spaces with sufficient public areas [4]. Rochelle and Bigley inspected the research results of the School of Landscape Architecture at North American University and compared them with a 1998 study. A questionnaire was mailed to all 457 assistant professors, associate professors, and professors listed by the Council of Landscape Architecture Education (CELA). The results show that productivity in all categories has improved. The average number of journal articles published by each faculty member has almost doubled, from 0.48 to 0.93. Compared with the 1998 study, the publication of conference papers has almost tripled, from 0.87 to 2.25 per faculty member per year. In addition, the number of respondents with a doctorate has increased by nearly 15% to 42%. Although productivity has increased, the research tends to focus on topics that are of little interest to practicing professionals. The top five research topics frequently used by professionals and the top five fields where they think more research is valuable do not appear in the top five topics studied by CELA members [5]. Biswas et al. first reviewed the theories and methods of landscape architecture heritage protection at home and abroad and studied landscape architecture heritage from the aspects of policies and regulations, investment management, talent training, and popular science education and then discussed the issue of landscape architecture heritage protection in China: lack of legislation, weak awareness of heritage resources, overexploitation of heritage resources, and gaps in heritage resource management and monitoring. Finally, it is proposed that the Chinese government authorities should pay more attention to heritage management, talent training, and capital investment, combined with advanced management methods in developed countries, and explore a landscape heritage protection management model suitable for China's national conditions from the ideological method and level [6]. As one of the three basic theories of Chinese landscape architecture, landscape ecology provides a powerful tool for leading landscape architecture from experience to evidence-based. By systematically reviewing the literature, Chang et al. discussed the advantages and necessity of the application of landscape ecology theories and methods in landscape design and summarized the research hotspots and progress of interdisciplinary research, including research topics, the scientific basis of planning or design, and the impact of landscape performance on improving humanity, as well as the impact of well-being. We put forward the priority topic of the combination of landscape ecology and landscape architecture to meet the needs of planning and design in practice, study the coupling system of landscape pattern and ecological process, and solve the problem of human settlement environment [7]. The current architecture school is introducing innovative teaching methods, hoping to improve the quality of education. Makowska introduced the modification of the teaching method of the hand-painted course based on a case study of a landscape architecture student from the School of Architecture of the Krakow University of Technology. The choice of innovative themes used there has a significant impact on the development of students' creativity. The independent formation of original opinions taught them how to constructively criticize and promote the search for new and original solutions. The research results prove the following conclusions: Experimental empirical research confirms the hypothesis about the importance of methodology and selected topics for the development of students' imagination [8]. From the scholars' discussion, we can know that, with the rapid development of China's market economy, regional characteristics and cultural elements have become more and more important for companies to enhance their market competitiveness and occupy a favorable market share. At present, the lack of regional culture has led to a lack of soul in landscape architectural design, and regional culture needs to be taken seriously.

The innovations of this article are (1) how to perfectly integrate regional cultural elements into the landscape architectural design when designing landscape architecture, so that the designed buildings have both modern architectural concepts and local regional cultural characteristics, so that the building has a humanistic sentiment, and (2) applying data fusion algorithms to the research of landscape architectural design. In other applications, data fusion algorithms are often used as a way to solve combinatorial optimization problems. However, this paper specifically aims at the inherent characteristics and advantages of data fusion algorithms, finds out the necessity of complementing regional culture and landscape architecture design, applies the characteristics of the algorithm itself to simulate the behavior of landscape architectural design, and obtains a better landscape architectural design with regional cultural characteristics. In a certain area, the imprint of history and culture always implies the deep friendship of the locals, with strong interpersonal and human running-in power. As an important component of the culture of the dynasty, the garden bred the historical context of the area where it was located and was the cohesion and inheritance point of the culture of the dynasty. In the garden landscape design, respect the local history, culture, and folk customs, and organically combine tradition and modernity.

2. Data Fusion Algorithm

The generation and application of data fusion are based on multiple levels of theoretical and practical knowledge, such as decision-making theory and network technology. Some complex data fusion applications developed in the military application field can also be applied to urban planning, resource management, pollution monitoring and analysis, and climate, crop, and geological analysis in the civilian sector to ensure effective information sharing among different agencies and departments. At this stage, there are still many controversies about this aspect of theories, and the existing systems have varying degrees of loopholes. As the scope of data fusion applications becomes more extensive and its importance gradually becomes more prominent, many scholars have begun to match certain specific fusion theories with real-life application scenarios and put forward feasible algorithms. According to the purpose of data fusion application, it is basically divided into two categories. The first category is to ensure the certainty of the collected data and remove uncertain parameters. This method is to fuse the same environmental information collected by different sensors, which is similar to the parameter estimation problem of mathematical statistics. The second category is to identify and classify the detection target. The root of this type lies in pattern recognition, and the execution process is usually as follows: First, the sensor judges a part of the information and makes a decision, sends all the information after the decision to the fusion center, and makes the final decision. The decision-level fusion mostly uses Bayes discriminant decision-making and Dempster–Shafer evidence reasoning.

2.1. Bayes Fusion

2.1.1. Bayes Rule. Bayesian classification is a general term for a class of classification algorithms. These algorithms are based on Bayes theorem, so they are collectively called Bayesian classification. Naive Bayesian classification is the simplest and most common classification method in Bayesian classification. Bayes rule means that, on the basis of determining the likelihood ratio, increasing the observed value will update the previous maximum likelihood estimate. According to formula (1), when new observations are added, the posterior probability can be obtained according to the prior probability of the given hypothesis [9].

$$R\left(E_i|U_j\right) = \frac{R\left(A_j|U_i\right)\cdot R\left(U_i\right)}{R\left(A_j\right)}. \quad (1)$$

2.1.2. Bayes Reasoning. Assuming that sensors 1, 2, . . ., m collect observations about the target object, the target object is required to have n hypothetical events, and n are independent of each other to form a complete set. According to this premise, there are four processes for data fusion. Any sensor can get a judgment based on its own observations and select a hypothetical event for the detection target [10]. According to the classification algorithm for sensor k, the probability of identifying event *Er* under the premise that the actual occurrence of the event is *Ed* is

$$R_k\left(U_d|U_r\right), \quad (k = 1, 2, \ldots m). \quad (2)$$

In the sensor, $R_k\left(U_d|U_r\right)$ means that there are as many sensors as there are in the $n \times n$ matrix. After fusing all sensor information, the updated joint probability is obtained, as shown in the following equation:

$$R\left(U_r|U_{d1}, U_{d2}, \ldots, U_{dk}, U_{dm}\right) = \frac{R\left(U_{d1}, U_{d2}, \ldots, U_{dk}, U_{dm}|U_r\right)\cdot R\left(U_r\right)}{R = \left(U_{d1}, U_{d2}, \ldots, U_{dk}, U_{dm}\right)}. \quad (3)$$

In the above formula, $k = 1, 2, \ldots, m$ is the discriminant situation obtained by the k-th sensor. Since all assumptions are independent of each other, we have the following:

$$R\left(U_{d1}, U_{d2}, \ldots, U_{dk}, \ldots, U_{dm}|U_r\right) = \prod_{i=1}^{n} R\left(U_{dk}|U_r\right). \quad (4)$$

2.2. Classical Dempster–Shafer Evidence Theory

2.2.1. Characteristics of Dempster–Shafer Evidence Theory. The theory mainly comes from two aspects of thinking:

(1) Starting from a subjective level, judge the probability of occurrence of related problems according to the probability of occurrence of a problem [11].

(2) When multiple arguments supporting the argument come from multiple independent levels, combining this part of the argument can support the argument more powerfully and obtain more accurate decision-making results. Although this theory is similar to Bayes theory, both are based on the consideration of weighting hypothetical events. But, compared with the two methods, this method has two differences; one is that it can display the “unknown” status. For example, this method can clearly indicate the state of things, and when it is unsure, it can also indicate the intermediate state of not knowing whether there is a car or there is no car [12]. Second, the theory does not require high accuracy of the event probability distribution function. When accurate information cannot be obtained, it can still support detection. Based on the above two differences, D-S theoretical logic is more scientific, and the decision-making process is more realistic.

2.2.2. Basic Concepts of Dempster–Shafer Evidence Theory. In the D-S reasoning system, the recognition framework Θ contains all mutually exclusive and complete events.

$$\Theta = \left\{\omega_1, \omega_2, \ldots, \omega_n\right\}, \quad (5)$$

where $\omega_1 = (i = 1, 2, \ldots, n)$ represents all events.

In theory, there are three functions: basic probability distribution function, trust function, and likelihood function.

The DS evidence theory is based on the basic probability distribution function. An evidence corresponds to a function. The evidence function maps the power set of the recognition frame to the [0, 1] interval, zero elements are mapped to 0, and the full subset of the recognition frame is mapped to 1.

$$S: 2^{\Theta} \longrightarrow [0, 1]. \quad (6)$$

Formulas can be used to show the nature of the evidence function, as shown in the following equation:

$$\begin{cases} S(\phi) = 0, \\ \sum_{o \in 2^{\Theta}} S(0) = 1, S(0) \longrightarrow [o, 1]\left(O \in 2^{\Theta}\right). \end{cases} \quad (7)$$

In the formula, if 0 has a nonzero evidence function value, at this time, 0 will become a focal element of S, and the value of $S(0)$ represents the degree to which the evidence of S supports 0. The trust function $W(O)$ and the likelihood function Q are shown in the two following equations:

$$W(O) = \sum_{w|w \in o} S(B), \quad (8)$$

$$Q(O) = \sum_{W|W \cap O \neq \varphi} S(B). \quad (9)$$

The relationship between the above two formulas is shown in the following formula:

$$\begin{cases} Q(O) = 1 - W\left(O^Y\right), \quad O^Y = \Theta - O, \\ Q(O) \geq W(O). \end{cases} \tag{10}$$

The above formula belongs to the complement set and because it can be based on the second property of the evidence function, it can be inferred that the confidence function can be used to define the likelihood function [13].

2.3. Summary of Dempster–Shafer Algorithm. Dempster–Shafer evidence theory has many advantages and disadvantages. The main advantages of Dempster–Shafer evidence algorithm are as follows: (1) This theory supports information that represents an "intermediate state," and there will be no negative impacts caused by hard decisions. (2) The theory does not need to know the precise prior probability and conditional probability in advance, and the statistical process is relatively simple [14]. (3) The theory does not require that all hypothetical events must be in an independent relationship, and it is more in line with the actual situation. (4) The fusion result will not be affected by the fusion sequence.

The main disadvantages of the Dempster–Shafer evidence algorithm are as follows:

(1) All lines of evidence are required to be independent of each other

(2) There is a probability of conflict between different lines of evidence

(3) There is a potential exponential explosion in the amount of calculation

2.4. Reliability Fusion Algorithm Based on Data Source. In order to further improve the accuracy of the final result, different weight values can be assigned according to the reliability of different data sources, instead of treating each data source as equally important. That is, more weight is given to data sources with high reliability, and less weight is given to the contrary. This method is the "Reliability Revaluated Dempster–Shafer Fusion algorithm" [15].

If the data source conforms to the formula principle, then

$$\begin{cases} S_u(O) \in [0,1], \\ S_v(O) \in [0,1], \end{cases} \quad O \in \Theta. \tag{11}$$

In the above formula, S represents the subset within the framework, and the reliability of u and v is expressed by the following formula:

$$r_u, r_v \in [0,1]. \tag{12}$$

Formula (12) can give the definition of the weight coefficients of data sources u and v as G_u and G_v, respectively.

$$\begin{cases} \sigma = \max\left(r_u, r_v\right), \quad \sigma \neq 0, \\ F_u = \dfrac{r_u}{\sigma}, \\ F_v = \dfrac{r_v}{\sigma}. \end{cases} \tag{13}$$

On the basis of knowing the weight coefficients of u and v and the original evidence function, a new evidence function can be obtained:

$$\begin{cases} S_u'(O) = F_u S_u(O), \\ S_v'(O) = F_v S_v(O), \end{cases} \quad O \in \Theta,\ O \neq Ig. \tag{14}$$

Ig represents the largest subset of Θ. In the formula, it means that no evidence is considered. The larger the value of the function, the higher the degree of ignorance of evidence in decision-making. The smaller the value, the lower the degree of ignorance.

2.5. Use Dempster–Shafer to Make Inferences. In the context of multiple data sources, any data source can obtain different judgments within the same recognition framework based on the set evidence function, that is, the evidence function. The method of combining the evidence functions in a certain way is called the Combination Rule [16]. The premise of the application of this law is that each data source has high reliability. If this premise is not met, the law does not apply. Refresh the evidence function according to the three following formulas:

$$\begin{aligned} x(o) &= x_1 \oplus x_2 \oplus \ldots x_n(o) \\ &= \frac{\sum_{o_1 \cap o_2 \cap \ldots o_n = o} \prod_i^n = 1 x_i\left(o_i\right)}{1 - y}, \\ x(\Phi) &= x_1 \oplus x_2 \oplus \ldots x_n(\Phi) = 0, \\ y &= \sum_{o_1 \cap o_2 \cap \ldots o_n = \Phi} \prod_{i=1}^{n} x_i\left(o_i\right), \quad y \neq 1, \end{aligned} \tag{16}$$

where x_i represents the evidence function of the data source i, + is the element of the power set, and y represents the normalization constant.

2.6. Ways to Make Decisions about Goals. For the 0 interval, its size is mainly defined by the values of the two functions. Judging by evidence, the possibility of event 0 exists in the interval. Based on the conclusion of the function, the best decision estimate can be obtained. According to the theoretical content of the trust function, determine the maximum trust function and obtain Q_i, so as to maximize the value of the function [17].

$$X_{\max} = Y(O_i), \left(O_i \in 2^{\theta}\right). \quad (17)$$

According to the theoretical content of the likelihood function, determine the maximum likelihood function and obtain Q_i to maximize the value of the function.

$$X_{\max 1} = Y_1(O_i), \left(O_i \in 2^{\theta}\right). \quad (18)$$

2.7. Regional Cultural Elements and Landscape Design Complement Each Other. With the rapid development of today's society, is it feasible to continue to use the past design techniques in modern design? Traditional design urgently needs the integration of local cultural characteristics to meet the needs of modern design development. In response to this situation, some Chinese experts and scholars have put forward new insights on urban landscape and regional cultural construction [18]. For example, Ma Xiao edited "Traces of the City-Regional Culture and Urban Landscape," "Urban Landscape" was edited by Wei Xiangdong and Song Yanhuan, and "Architectural Culture and Regional Features" was edited by Zhao Xinliang. They all elaborated on their new theories and methods and provided a reference for us to better study regional culture and landscape design in the future.

The technical path of this article is to first investigate, measure, analyze, summarize, and classify regional urban landscape design cases, as shown in Figure 1, and then conduct on-site investigations, collect physical pictures, and make written records, as the basic data for the research of this subject. Then, it conducts an effective rationality analysis of existing cases and studies feasible methods that combine regional culture with urban landscape design [19]. The frame of Figure 2 is the general process of this paper.

In Figure 3, the land must be coordinated with nature, modernity, and history and culture. Landscape design should not be limited to regional nature. The expression and innovation of regional characteristics must be based on the region. When implementing landscape design, the principles that need to be followed are as follows: First is the principle of integrity. The landscape is a complex environmental system composed of multiple elements. Because the transformation of one of these elements will affect the overall effect of the landscape, the landscape design must grasp the overall situation. Second, consider the principle of multiple goals. Landscape design can not only design the "landscape"

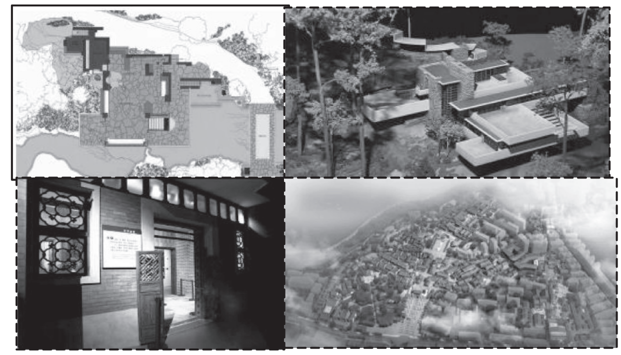


Figure 1: Regional cultural landscape map.

level but also cover water management technology projects, landscape shape art projects, and people's psychological and physical needs. The landscape area, as a cognitive place where people have a psychological consensus, can get a sense of belonging and security from it. Third is the principle of sustainable development. Landscape design should be guided by ecological principles, adjust the relationship between natural environment and artificial landscape, maintain waterfront biodiversity and landscape diversity, and respect natural geography and climate. The land and materials are properly planned to create a sustainable landscape. Fourth is the principle of hydrophilicity. In the landscape design, a hydrophilic landscape facility is designed with the waterside as the center, so that the surrounding people can experience the landscape space.

With the acceleration of China's urbanization process, the development of social economy, and the increasing living standards of the people, people are paying more and more attention to the environment, focusing on ecology, and yearning for nature and are eager to have a green space of their own. As an artificial natural space, the courtyard has become people's dependence.

As shown in the hand-drawn drawing of landscape architectural design in Figure 4, in the process of landscape construction, it is necessary to inherit the historical background of the region, construct the coordination of urban culture, and inherit the characteristic culture. Regional landscape design is mainly based on the search for executable and convenient elements to construct the landscape and then expand the space utilization rate, improve the environment, and search for historical memory on the basis of landscape tracking and development. In this principle, the main points of this article also reflect the region.

As shown in Figure 5, Suzhou gardens use a metaphorical approach to create landscape elements. The design of regional landscapes can also adopt this approach to metaphorically transform landscape design elements including regional culture to express the meaning of regional culture. In modern landscape design, abstract metaphors are often integrated with specific things such as historical culture, historical legends, and celebrities, giving the landscape a cultural connotation and expressing the spiritual connotation of the landscape more clearly.

As the saying goes, "the world's famous mountain monks account for more." It can be seen from Figure 6 that Buddhism

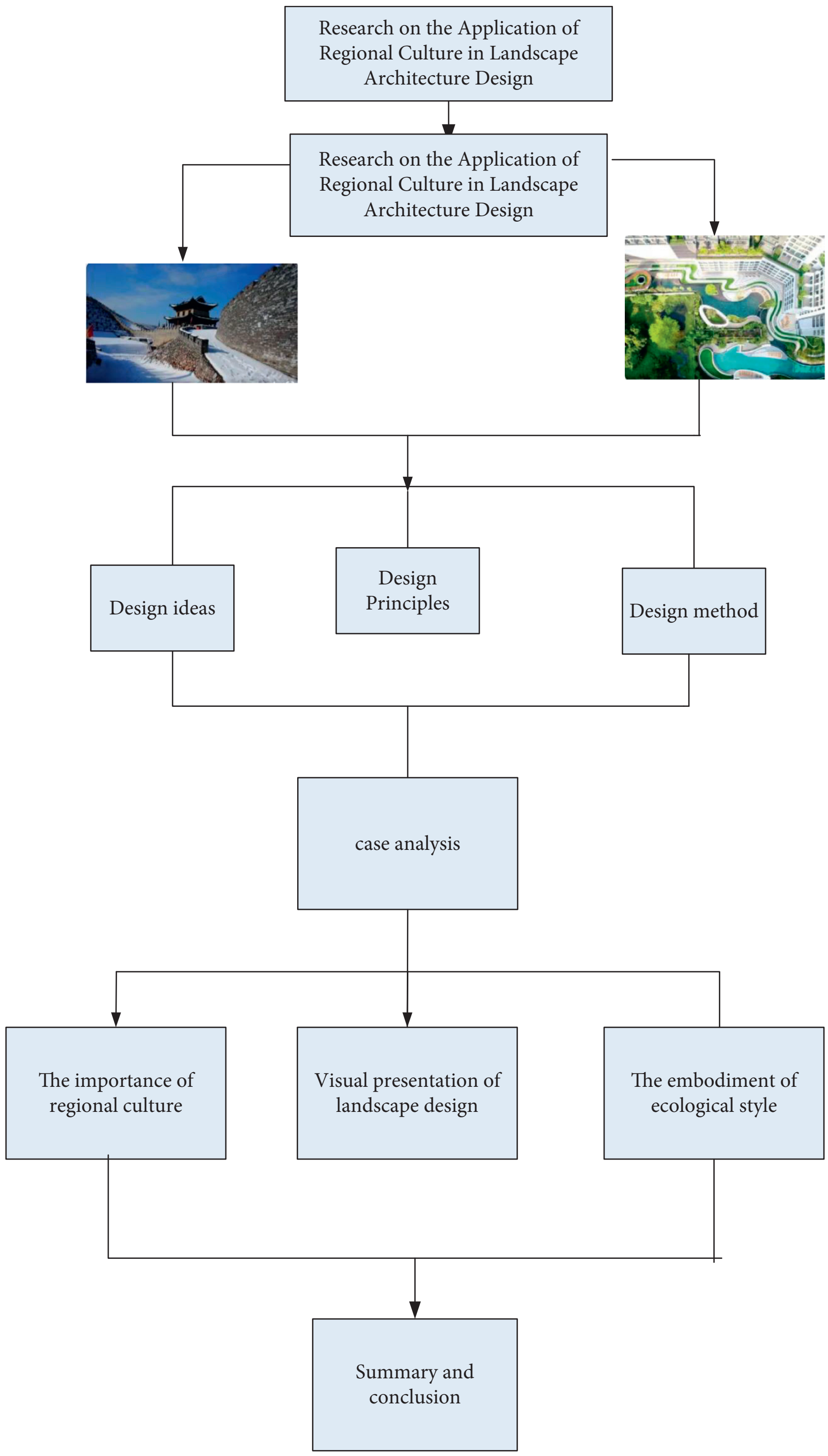


Figure 2: Research framework flow chart.

has developed in China for thousands of years, and its architecture has always followed the laws of Sinicization, emphasizing historical style and ancient architectural art according to the architectural form, style, and function of each historical era. Nowadays, there are many buildings that are famous tourist attractions. In terms of site selection and environmental planning, special consideration is given to the coordination and integration of human landscapes and natural landscapes, with nature as the prerequisite, seeking a symbiosis plan with the environment and the unity of the environment.

Landscape symbols generally refer to symbolic landscapes. The landscape form is related to and corresponding to a specific meaning. It can be a combination of complex factors or a single-factor landscape.

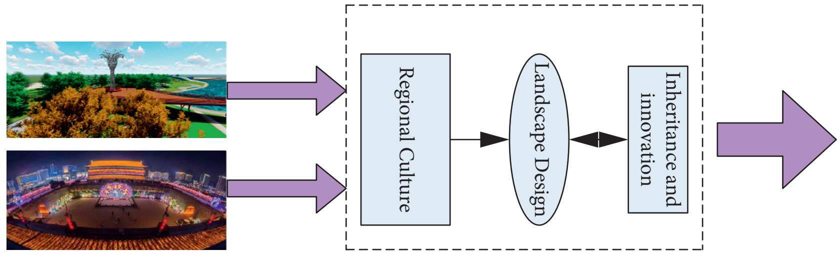


FIGURE 3: The relationship between regional culture and landscape architecture design.

FIGURE 4: Hand-drawn drawing of landscape architecture design.

FIGURE 5: Suzhou gardens.

As shown in Figure 7, design symbols have always been an art language recognized by people, a medium of communication and information, and a carrier of artistic creation. This article starts with related semiotic concepts and mainly discusses the artistic characteristics and application of symbols in landscape design.

3. Experiment and Analysis

3.1. Investigation and Analysis of Landscape Design. Generally speaking, social survey research can be divided into four stages, namely, preparation stage, investigation stage, analysis stage, and summary stage. The preparation

Figure 6: Buddhist landscape architecture map.

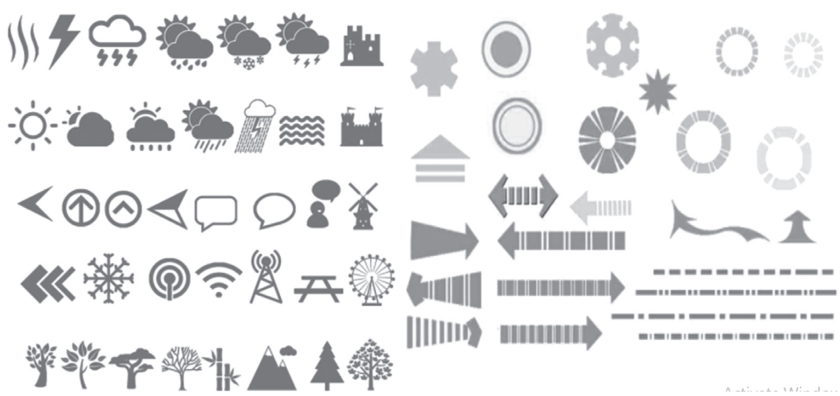


Figure 7: Landscape symbol.

stage includes three aspects of work: determining the subject, designing the survey plan, and making specific preparations. The essence of landscape design is to present the deep cultural, ideological connotation and atmosphere of the site and even the region. The ethnic culture, customs, and traditional crafts in the region are transformed into landscape symbols and used in landscape architectural design [20]. Due to the nostalgia of history and the memory of the past, some scenes of historical events and sacred stories can be expressed in flat or three-dimensional space [21]. What it conveys may be a certain era, environment, scene, or event, which makes the viewer's understanding of the concept of regional culture more concrete, as well as the memory, nostalgia, thinking, and perception of the information conveyed by the landscape during the viewing process. Figure 8 is the result of a survey of nearby tourists of different ages.

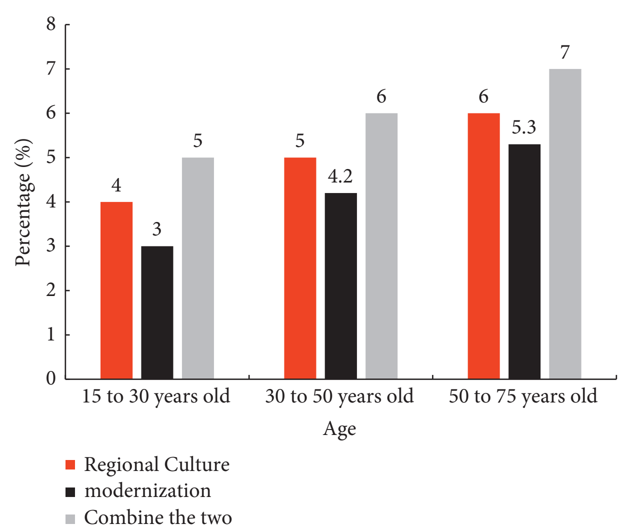


Figure 8: Tourist survey bar chart.

It can be seen from Figure 8 that although young tourists have less demand for regional culture than those aged 30–50 and 60–75 years, they are more inclined to integrate regional culture into landscape architectural design. The higher age group has more demand for regional culture than the lower age group, but, on the whole, everyone tends to incorporate regional cultural elements into landscape architectural design.

With the continuous development of urban cultural construction, cultural landscape has become an important part of urban cultural construction. The article starts with the extraction of regional cultural elements and summarizes the application methods of regional cultural elements in

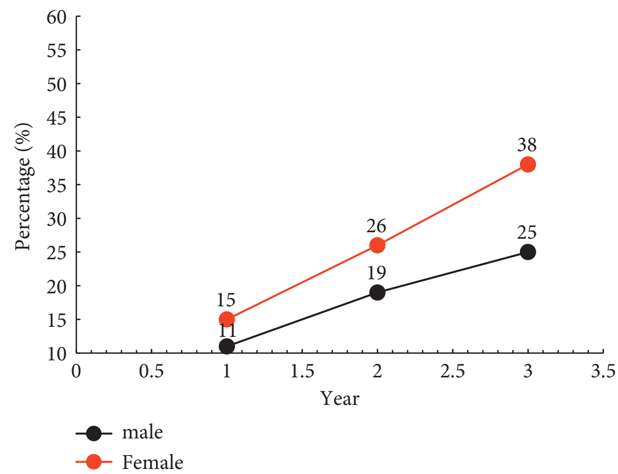


Figure 9: 2017–2019 broken-line statistical chart of the needs of different genders for regional culture.

landscape design and provides specific details for urban cultural landscape design. The implementation provides constructive theoretical support. In recent years, with the continuous development of urban resources and the expansion of urban population, urban space has become more crowded. Many precious historical and cultural buildings and blocks have been damaged in various degrees in the acceleration of urban change and development [22]. The wave of urban construction and the alternation of the old and the new will not only destroy the precious regional culture but also make it impossible to inherit it. This article uses the demand of different gender groups for regional culture in the three years from 2017 to 2019 to form the broken-line chart in Figure 9.

It can be seen from Figure 9 that, with the growth of the years, the demand for regional cultural elements to be added to the landscape architectural design is also increasing, with the highest in 2019. Human beings have never stopped exploring the regional culture. In today's globalization, it is necessary to highlight the characteristics of regional culture and advocate the combination of regional design and local cultural design [23].

3.2. Results and Analysis of Data Fusion Algorithm. When the reliability coefficient changes, the evidence function and confidence function will also change [24]. Adjust the coefficient to 0.9 to 0, and the results are shown in Table 1. When the reliability coefficient is 0, it means that, in the entire function, the data source e is completely ignored. At this time, only the data source i plays a role, and the final result is also determined by its evidence function [25].

As shown in the specific data shown in Table 1, when the reliabilities of the two data sources are equal, the evidence function after the fusion gives fact "1" the trust degree, and the evidence function of the data source i gives the support of "1" as 0.972. The reliability of data source e is reduced to 0.4; then $S(1)$ is increased to 0.2, and Bel(1) is also significantly improved, from 0.514 to 0.816. Therefore, according to the situation before and after comparison, it can be seen that, after reducing the e reliability coefficient of the data source, the final result is more in line with the actual situation [26]. In addition, there is another assumption if the two data sources themselves are the same, as shown in Table 2.

Then, after changing the reliability of e under this condition, the results obtained are shown in Table 3.

According to Table 3, after changing the reliability of the data source e, although the evidence function's support for fact "1" is reduced, $S(1)$ is still greater than the sum, and Bel(1) is still greater than 0.9. From this, it is concluded that when the evidence is the same, even if the weight adjustment conflicts, the final conclusion is still close to the actual situation [27]. It can be seen that, based on the data fusion algorithm, we can also know that regional cultural elements are becoming more and more important for landscape architectural design.

4. Discussion

This paper analyzes the research progress of regional culture and landscape architecture design, expounds the related concepts of regional culture and landscape architecture, studies related theories of landscape architecture design based on regional cultural characteristics, and explores landscape architecture design methods rich in regional culture. Through the analysis of famous landscape cases at home and abroad, the importance of regional culture to landscape architectural design is discussed. Finally, the integration of regional culture in the landscape architectural design of ancient and modern China is taken as an example to explore the relationship between the two.

This article also makes reasonable use of data fusion algorithms. As the scope of data fusion applications has become more extensive and its importance has gradually become more prominent, many scholars have begun to match certain specific fusion theories with real-life application scenarios and propose feasible algorithms. According to the purpose of data fusion application, it is basically divided into two categories. The first category is to ensure the certainty of the collected data and remove uncertain parameters. According to the algorithm, regional culture is an indispensable part of landscape architectural design.

Table 1: Fusion results of adjusting the reliability of the data source e under the conflict of evidence.

Reliability factor	Weight coefficient	Evidence function value 0	Evidence function value 1	Evidence function value 0 or 1	Trust function value 0	Trust function value 1	Trust function value 0 or 1
$x_i = 0.8$	$Y_i = 1$	0.386	0.386	0.286	0.543	0.543	0.267
$x_e = 0.7$	$x_e = 1$	0.386	0.386	0.286	0.543	0.543	0.267
$x_i = 0.8$	$Y_i = 1$	0.386	0.386	0.286	0.543	0.543	0.267
$x_e = 0.6$	$x_e = 0.66$	0.235	0.864	0.052	0.235	0.843	0.052
$x_i = 0.8$	$Y_i = 1$	0.235	0.864	0.052	0.235	0.843	0.052
$x_e = 0.2$	$y_e = 0.22$	0.235	0.864	0.052	0.235	0.843	0.052
$x_i = 0.8$	$Y_i = 1$	0.2	0.7	0.4	0.3	0.4	0.1
$x_e = 0$	$x_e = 0$	0.2	0.7	0.4	0.3	0.4	0.1

Table 2: Evidence of consistency.

Power set	0	1	0 or 1
s_e	0.2	0.7	0.2
s_i	0.2	0.7	0.2

Table 3: Fusion results of adjusting the reliability of data source e under the condition of consistent evidence.

Reliability factor	Weight coefficient	Evidence function value 0	Evidence function value 1	Evidence function value 0 or 1	Trust function value 0	Trust function value 1	Trust function value 0 or 1
$x_i = 0.8$	$Y_i = 1$	0.043	0.687	0.021	0.328	0.024	0.023
$x_e = 0.7$	$x_e = 1$	0.043	0.687	0.021	0.328	0.024	0.023
$x_i = 0.8$	$Y_i = 1$	0.043	0.687	0.021	0.328	0.024	0.267
$x_e = 0.6$	$x_e = 0.66$	0.654	0.831	0.082	0.232	0.055	0.074
$x_i = 0.8$	$Y_i = 1$	0.654	0.831	0.082	0.232	0.055	0.074
$x_e = 0.2$	$y_e = 0.22$	0.654	0.831	0.082	0.232	0.055	0.074
$x_i = 0.8$	$Y_i = 1$	0.2	0.7	0.4	0.3	0.4	0.1
$x_e = 0$	$x_e = 0$	0.2	0.7	0.4	0.3	0.4	0.1

Through the various cases in this article, we learned that the use of metaphors to create landscape elements and the design of regional landscapes can also adopt this method to metaphorically express regional cultural connotations with landscape design elements containing regional culture. In modern landscape design, abstract metaphors are often integrated with specific things such as historical culture, historical legends, and celebrities, giving the landscape a cultural connotation and expressing the spiritual connotation of the landscape more clearly.

5. Conclusions

This article mainly starts from regional culture and landscape architectural design and discusses the relationship between the two and how to integrate regional culture into landscape architectural design. Based on the data fusion algorithm, it can be learned that only when unique regional culture and historical events are inherited by urban landscape design under the circumstances can landscape design give the most basic cultural importance. Regional culture is essential to garden design. Do not blindly imitate or copy, so as not to cause similarities and repetitions in urban landscape construction. Fully understand the effective integration of regional culture and regional environment, and look for elements with regional characteristics from the regional culture, religious beliefs, and natural environment of urban landscape design. The research on the application of regional culture in landscape creative design involves a wide range of related scientific fields. The concept of the term culture has always been disputed. The author is not talented, the world is still shallow, the academic theory and business ability are relatively weak, and it is inevitable that there will be fallacies. There are still certain problems in the design work. At the same time, the author is constantly discovering and solving problems and strives to be the best.

Data Availability

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Conflicts of Interest

The author states that there are no conflicts of interest.

References

[1] M. H. Bond, “Culture-level dimensions of social axioms and their correlates across 41 cultures,” *Journal of Cross-Cultural Psychology*, vol. 35, no. 5, pp. 548–570, 2016.

[2] D. Park and A. Gutchess, “The cognitive neuroscience of aging and culture,” *Current Directions in Psychological Science*, vol. 15, no. 3, pp. 105–108, 2016.

[3] D. S. Hu and S. Xiaofeng, "Modern translation of classical gardens: Landscape design conception and strategy of gaobeidian train new town in konghu," *Journal of Landscape Research*, vol. 12, no. 1, pp. 4–8+11, 2020.
[4] N. Yokoya, P. Ghamisi, J. Xia et al., "Open data for global multimodal Land use classification: Outcome of the 2017 IEEE GRSS data fusion contest," *IEEE Journal of Selected Topics in Applied Earth Observations & Remote Sensing*, vol. 11, no. 5, pp. 1363–1377, 2018.
[5] L. K. Rochelle and A. G. Bigley, "Organizational culture in high reliability organizations: An extension," *Human Relations*, vol. 48, no. 7, pp. 771–793, 2016.
[6] S. Biswas, R. Pardeshi, N. D. Reddy et al., "Comparison of PCR with direct examination of bone marrow aspiration, myeloculture, and serology for diagnosis of visceral Leishmaniasis in immunocompromised patients," *International Journal of Biological Macromolecules*, vol. 81, no. 3, pp. 951–959, 2016.
[7] Q. Chang, W X. Su, and H. Wang, "Research progress on application of landscape ecology in landscape architecture," *The journal of Applied Ecology*, vol. 30, no. 11, pp. 3991–4002, 2019.
[8] B. Makowska, "Innovative methods in teaching improve the creativity of landscape architecture students," *World Transactions on Engineering and Technology Education*, vol. 17, no. 3, pp. 343–348, 2020.
[9] S. Q. Improvement, "Committee opinion no. 683: Behavior That undermines a culture of safety," *Obstetrics and Gynecology*, vol. 129, no. 1, pp. e1–e4, 2017.
[10] Caron, E Duflos, D Pomorski, and P Vanheeghe, "GPS/IMU data fusion using multisensor Kalman filtering: Introduction of contextual aspects," *Information Fusion*, vol. 7, no. 2, pp. 221–230, 2017.
[11] M. Li, W. Lou, and K. Ren, "Data security and privacy in wireless body area networks," *IEEE Wireless Communications*, vol. 17, no. 1, pp. 51–58, 2016.
[12] A. A. Muthuveeran and N. Ibrahim, "Risk management challenges in Malaysia's landscapa architecture project," *Environment-Behaviour Proceedings Journal*, vol. 5, no. 14, pp. 179–186, 2020.
[13] G. Stauskis, "Identifying key criteria for quality assessment of landscape architecture projects," *Architecture and Urban Planning*, vol. 16, no. 1, pp. 5–11, 2020.
[14] X. Zhang, C. Zhou, and S. Zhang, "The environmental social and governance (ESG) responsibilities of landscape architecture firms," *E3S Web of Conferences*, vol. 143, no. 3, Article ID 02045, 2020.
[15] Z. Teqja and A. Dervishaj, "Landscape architecture education in Albania -the challenge of having a studio and research-based program," *European Academic Research*, vol. 7, no. 10, pp. 4866–4881, 2020.
[16] X. Zhao, "Application of 3D CAD in landscape architecture design and optimization of hierarchical details," *Computer-Aided Design and Applications*, vol. 18, no. S1, pp. 120–132, 2020.
[17] R. M. Firdaus, M. H. Rasidi, and I. Said, "The understanding of river and community resilience studies in perspective of landscape architecture," *Journal Arsitektur dan Perencanaan (JUARA)*, vol. 4, no. 1, pp. 72–89, 2021.
[18] J. H. Hong, H. B. Park, J. M. Yoon, and D. P. Kim, "Improvement strategy & current bidding situation on apartment management of landscape architecture," *Journal of the Korean Institute of Landscape Architecture*, vol. 48, no. 4, pp. 41–54, 2020.
[19] L. Kirchmair, "Shifting the focus from an international towards a more regional cultural heritage protection in the middle east and north africa," *Verfassung in Recht und Übersee*, vol. 53, no. 3, pp. 267–285, 2020.
[20] D. G. Kim, J. Y. Son, and U. Y. Baek, "Case study of regional cultural contents development using peacock fan intangible cultural asset," *Journal of the Korea Entertainment Industry Association*, vol. 14, no. 5, pp. 87–102, 2020.
[21] J. J. Aul, K. W. Anderson, R. M. Wadowsky et al., "Comparative evaluation of culture and PCR for the detection and determination of persistence of bacterial strains and DNAS in the chinchilla laniger model of otitis media," *Annals of Otology, Rhinology & Laryngology*, vol. 107, no. 6, pp. 508–513, 2016.
[22] R. T. Corlett, "The role of rewilding in landscape design for conservation," *Current Landscape Ecology Reports*, vol. 1, no. 3, pp. 127–133, 2016.
[23] H. Nakayama, H. Tsubouchi, and E. Gohda, "Stimulation Of DNA synthesis in adult rat hepatocytes in primary culture by sera from patients with fulminant hepatic failure," *Res*, vol. 6, no. 4, pp. 231–237, 2017.
[24] W. Liao, X. Huang, F. V. Coillie et al., "Processing of multiresolution thermal hyperspectral and digital color data: Outcome of the 2014 IEEE GRSS data fusion contest," *IEEE Journal of Selected Topics in Applied Earth Observations & Remote Sensing*, vol. 8, no. 6, pp. 2984–2996, 2017.
[25] A. Scognamiglio and F. Garde, "Photovoltaics' architectural and landscape design options for Net Zero Energy buildings, towards Net Zero energy communities: spatial features and outdoor thermal comfort related considerations," *Progress in Photovoltaics: Research and Applications*, vol. 24, no. 4, pp. 477–495, 2016.
[26] R. Othman, S. Kasim, and S. Z. A. Kasim, "Assessment of plant materials carbon sequestration rate for horizontal and vertical landscape design," *International Journal of Environmental Science and Development*, vol. 7, no. 6, pp. 410–414, 2016.
[27] H. Liu, J. Jiao, and N. Zhang, "Research on nonlinear thinking of landscape architecture design based on computer-aided parametric model," *International Journal of Multimedia and Ubiquitous Engineering*, vol. 11, no. 8, pp. 333–344, 2016.

Hindawi
Scientific Programming
Volume 2022, Article ID 2490033, 8 pages
https://doi.org/10.1155/2022/2490033

Research Article

Innovation and Development of Cultural and Creative Industries Based on Big Data for Industry 5.0

Lian Huang and Yi Jia

College of Landscape Architecture and Art Design, Hunan Agricultural University, Changsha 410000, Hunan, China

Correspondence should be addressed to Yi Jia; jiayi09@hunau.edu.cn

Received 19 December 2021; Revised 9 January 2022; Accepted 31 January 2022; Published 15 March 2022

Academic Editor: Ahmed Farouk

While art design is based on innovation and creativity, information technology is advancing by leaps and bounds for Industry 5.0. Big data technology has achieved breakthrough development, and the big data era that has followed has begun. Promoting the resources, technology, thinking big data is the general trend. It is an important expression of creative thinking, which is closely connected with art design and studies the relationship between design and art. As the starting point for research, the average growth rate of China's cultural and creative industries is as high as 26.08%, which is not only limited by the growth rate of traditional industries. More results show that, in 18 years, radio, television, and Internet information services, which are rapidly developing, accounted for 27.9%, 21.8%, and 20.3%, while the advertising, exhibition, tourism, and leisure industries have also steadily increased, and they accounted for 9.6% and 7.1% of the total share. These research results show that the design art and cultural and creative industries are complementary.

1. Introduction

With the promotion of smart terminals, the concept of the cultural creative industry was first proposed by the British in its cultural industry development document. Refer to those who rely on personal creativity, skills, and talented wisdom, creation and promotion of cultural resources were referred to, thereby creating potential wealth and employment opportunity industry. Its core content is culture and creativity, and it is an emerging industry developed in the context of global economic integration, as well as a new industry development direction. Innovation in upgrading and model development is of great significance. As the name implies, cultural creativity is the combination of "culture" and "creativity," emphasizing the core of culture and creative ideas and focusing on human knowledge, inspiration, and imagination. Science and technology, industrial economy, and higher education have distinctive characteristics of the era of the knowledge economy.

The cultural industry has thus ushered in a huge opportunity. Big data optimizes the industrial value chain; integrates communication subjects, communication channels, and audience resources in multiple dimensions to facilitate media integration; and integrates market information to improve the price mechanism and supply and demand mechanism of the cultural market and credit reporting mechanism. The term art design originated in Britain in the nineteenth century. At that time, the rise of the industrial revolution rapidly changed the original social structure of human society, making humans move from an agricultural and handicraft society to an industrial society, and a city-centered commodity economy developed vigorously. As people's needs for the spiritual and cultural level have also increased, art design has developed as a bridge between people, products, the environment, and society [1, 2]. Britain, with its strong economy as its pillar, has made great achievements. British art design has different styles in different historical periods, forming artistic styles such as decorativism, constructivism, Op technology, and postmodernism [3]. The cultural accumulation is formed by the aesthetic style deduced by art design, and then creative industries are connected to the industry, and, through the assistance of science and technology, as well as the formation and use of intellectual property, a cultural creative industry is gradually formed. In the field of the art design, individual creativity is highly respected. Only designers with an innovative spirit can innovate ideas in the form of works and design unique works. Only with core art creation can there be culture and art [4]. At present, China's economic development and transformation depend on the development of cultural industry [5]. First, it can greatly promote the level of theoretical knowledge in China's cultural creativity and, more importantly, promote the development of cultural-related industries, so as to provide support for China's economic construction. Second, it is possible to refine the cultural industry from the basic connotation identification and differentiate the cultural industry from the outer edge. Such refinement and differentiation are extremely reasonable and advantageous for the development of our society. Third, more and more countries have discovered the important value of the cultural creative industry in modern society and raised it to the height of national strategy. The relationship between design art and development is studied.

Heritage resources provide deep historical reasons. Luciana Lazzeretti once analyzed the development of local cultural heritage resources and cultural and creative industries. On this basis, it is proposed to vigorously develop ceramic cultural and creative industries, cultivate a large-scale industrial agglomeration area, form an industrial chain, and realize the efficient transformation of heritage, as well as using cultural and creative industries as resources, ultimately enhancing cultural taste, and creating urban distinctive brands [6, 7]. David Wright used the modern creative cultural industry as a framework to conduct an in-depth analysis of the Fuzhou lacquerware industry. First, he combed the development history of Fuzhou lacquerware, outlined the problems facing the current lacquerware industry revitalization, and proposed that the core of future development might be from the viewpoint of lacquerware cultural industry transformation, recognized the importance of establishing a good image of Fuzhou lacquerware culture, and put forward rationalization suggestions from market analysis, product design, and market development [8]. Zhouqing Luo used the theory of culture, economics, and regional development to introduce the connotation of sports culture and creative industries [9]. Min Qu once constructed a policy evaluation system. The results show that Beijing's cultural and creative industry policy has played its role, and the implementation effect is good. However, from the perspective of the laws of industrial development, it was adjusted to achieve the decisive role of the market in resource allocation through legislation [10].

More and more countries have discovered the important value of the cultural creative industry in modern society and raised it to the height of national strategy. The research in this paper finds that they affect each other. As the starting point for research, the average growth rate of China's cultural and creative industries is as high as 26.08%, which is not only limited by the growth rate of traditional industries. More results show that, in 18 years, radio, television, and Internet information services, which are rapidly developing, accounted for 27.9%, 21.8%, and 20.3%, while the advertising, exhibition, tourism, and leisure industries have also steadily increased, and they accounted for 9.6% and 7.1% of the total share.

2. Proposed Method

2.1. Related Theories of Cultural and Creative Industries

2.1.1. The Concept of Creative Industries. Creativity and creative industries have received unprecedented attention; whether it is the government or the enterprise or whether it is a business operator or a designer, the creative industry is a topic that everyone loves [11]. Creativity is the imagination and creativity of people, and the creative industry is the creativity and imagination of raw materials. Creative people like novelty. Not only does their creativity enrich their personal life, but at the same time they will turn their dreams, imaginations, and ideas into works of art. This will also enable enterprises to make profits and achieve great success. It can be seen that creativity has huge creative potential.

New economy, science and technology, and art and culture create wealth for society and provide extensive employment [12, 13]. The cultural creative industry is a developmental and diverse concept.

2.1.2. Essential Characteristics of Creative Industries. By the British Creative Industries Task Force: "industries that have their development [14]," the analysis of the creative industries is defined in the "China Creative Industry Development Report." Based on buying and selling creative products, "creative industry" is formed [15].

Reflecting Creativity. Innovation is the core connotation and essential characteristic of creative industries [16]. Innovation rejects imitation and repetition, emphasizing rich imagination, novel and unique feelings, and experiences. In the creative design of products, we pay attention to unique vision and creative thinking and form a unique concept in the form and content of the design. It is a new creation of traditional products or a recreation and promotion of traditional products. Being irreplaceable always reflects the originality of its core content value. The creativeness of creative industries also runs through many links such as production models, business approaches, sales methods, and media.

Embodying Culture. It covers strong "cultural" characteristics [17]. Lack of cultural activities vitality and the lack of pop culture cannot bring high cultural added value, nor can they create considerable economic benefits.

Reflecting the Scientific and Technological Nature. The creative industry is inseparable [18]. It has developed into a set of virtual technologies, which has greatly released the creative potential of human beings.

Reflecting Integration. The creative industry is separated from the design and development agencies that originally belonged to various industries and formed an independent industry under the environment of rising consumer cultural demand, 2016. Therefore, the creative industry's permeability to the cultural industry is particularly prominent, and, in the creative design process, it can infiltrate culture, creativity, and services and grasp them comprehensively, reflecting a strong integration.

(5) Reflecting the Characteristics of "Industry Chain." "Creative Industries" are inseparable from the "industrialization," thereby creating more and higher economic value [19].

2.2. Purpose and Significance of Creative Industries

2.2.1. Improve China's Position in the Global Industry Chain. For a long time, we have relied on cheap labor to process raw materials and lacked core technologies with independent intellectual property rights, which has kept China at the bottom of the global industrial chain [20]. With the economic transformation and upgrading, we need to change the status quo of the industry and enhance our own industrial value. The creative industry mainly enhances value through the two engines of technological innovation and cultural creativity. Scientific and technological innovation can enhance the function and use value of products, while cultural creativity can add new concepts and spiritual values. Incorporating cultural connotation into product design and giving people a wealth of imagination and experience aroused the cultural identity of consumers and further opened up the market.

2.2.2. The Need for the Transformation of China's Economic Development Model. Creative industry is an inevitable product of the development of the country's economic and cultural construction and scientific and technological level to a certain stage. It does not refer to a certain type of industry. New industries had intellectual capital, cultural capital, and social capital as their operating methods [21]. The significance is not to reclassify the industrial content involved but to emphasize the new economy, technology, and culture. Industrial structure is a change in the way of thinking, an innovation in the economic development model, and a subversion of the traditional industrial development logic. The model shifts to an intensive development model, from a single output model to a knowledge and creative-intensive development model.

2.2.3. The Optimization and Upgrading of the Industrial Structure Require the Development of Creative Industries. Accelerating the pace of industrial structure upgrading and also enabling enterprises to obtain more business opportunities and markets have led to the continued prosperity of the entire economy [22]. Moreover, the development of creative industries has promoted the concept of nonmaterial elements to create value and promoted the transformation of the concept of socioeconomic resources from a simple material resource to a concept that attaches equal importance to material and nonmaterial resources, thereby driving the adjustment of the industrial structure.

2.3. Essential Differences between Creative Industries and Traditional Industries. The creative industry is closely related to the traditional cultural industry. On the one hand, the creative industry originates from the traditional industry and is an extension of the traditional industry. The creation of any kind of creative activity is inseparable from the accumulation of human civilization but the recreation on the basis of the traditional wisdom-filled traditional culture. Without the traditional foundation, the creative industry will become a water without a source and a tree without a root. On the other hand, cultural and creative industries are higher than traditional cultural industries [23]. It no longer simply clings to the concepts and categories of traditional cultural industries in the past, and it is an emerging industrial form. This article mainly analyzes and compares creative industries and traditional industries. The specific differences are reflected in the following aspects.

2.3.1. From the Materiality Attribute of Industry. The creative industry, with its creative production concepts and the use of human wisdom, pays more attention to nonmaterial cultural industries, such as the ideology and cultural spirit of products. Creative industries are often called cultural and creative industries in the form of time structure or ideology [24]. The traditional industry is an individual simple, materialized production industry, which is a simple reproduction of a product. According to cultural industry itself [25], more emphasis on materiality and more space are provided [26]. The physical form of structure exists but is reflected in the intangible assets of intellectual property, which generally have strong dematerialization. This nonphysical product makes product circulation break through the constraints of objective factors such as time and space, which not only widens the field of product circulation but also improves the profitability of the product [27].

2.3.2. From the Perspective of the Organizational Structure of the Industry. Industry in the traditional sense generally refers to similar enterprises organizing production in accordance with the general processes, lacking horizontal connections with each other, as well as industrial organization forms often reflecting the characteristics of vertical integration [28] and forming a new consumer market. The same or different industries converge and develop, and the industrial clusters that provide creative services to all industries have broken the boundaries of traditional industries in organizational form [29].

2.3.3. From the Value of the Industry. The creative industry organizes production processes through the distribution of industrial value chains, forming a concentric circle with creativity or intellectual property as the core and production and sales as the periphery [30]. From the perspective of the value of the industrial chain, creative design and marketing services are at the highest end of the industrial value chain. Its resources are human wisdom, independent research and development capabilities, and independent innovation processes. It has its own brand and core technology as early as possible and gradually reaches high value-added, high growth, high output, and high employment, which are the four “high” characteristics [31].

2.3.4. From the Perspective of Industrial Product Orientation. Most of the products produced in traditional industries focus on the functional value or use value of the product to meet the material and physiological needs of consumers as the basic purpose. The creative industry production is people-oriented and demand-oriented to change the concept of products, especially the sense of cultural identity, to meet the spiritual and psychological needs of consumers to obtain the market and profits [32]. The change from product orientation reflects that the creative industry stimulates consumers’ purchase potential through the creative design of products, forms a new consumer market, improves social quality, and promotes sustained economic growth.

2.3.5. From the Technical Point of View of the Industry. It relies more on new technologies, such as animation, fashion, network, media, film, and television, while traditional industries are more a single technology processing. Through the development of high-tech industries, we can not only reduce the resource consumption of unit GNP. For example, in the traditional industrial value chain, the new value chain needs to be integrated through the network, but this integration of resources is an important driving force for China’s traditional physical industry. Another example is the construction of traditional industrial value chains, which requires the establishment of multiple forms of enterprise information platforms, technology platforms, and sales platforms; in the process of value chain adjustment and reconstruction, enterprises need to establish multichannel information collection mechanisms: information technology is used to extend and improve the scope of the enterprise’s internal value chain. Creative industries have higher technical requirements and can bring greater wealth to creative industries through science and technology.

3. Experiments

3.1. Data Source Selection and Data Processing. Considering the availability and consistency of the data, this article selects the culture. Some provinces have difficulty in obtaining data. Therefore, when conducting research and analysis, the provinces that have difficulty in obtaining data are eliminated. Since the main cultural and creative industries in China are clustered in China’s major large and medium cities and towns, and there are few rural areas and data are missing, the data of input and output indicators required for empirical analysis in this paper are replaced by urban data. The fixed asset investment in each subsystem of the cultural and creative industry in this article is derived from the 2014–2018 China Fixed Assets Investment Yearbook. The number of people and total labor compensation in each subsystem of the cultural and creative industry are from 2014 to 2018 (China Labor Statistics Yearbook).

3.2. Research Methods. The main research methods are literature review method and case study method. Through the analysis of domestic and foreign literature on cultural and creative industries, the literature method is used to conduct research, advanced foreign experience is compared with China’s actual situation, and the real environment of the region is analyzed and researched, and then the cultural and creative industries are comprehensively studied.

Interdisciplinary Comprehensive Theoretical Research Method. The cultural and creative industry is a complex social practice activity involving many disciplines, such as anthropology, history of art concepts, communication, marketing, economics, psychology, and semiotics. Through comprehensive interdisciplinary research, we will find that some of the middle areas after the edges of disciplines are often the areas where the collision of thoughts is the most intense but where the truth blends together, because “innovation in thinking is often the result of avoiding border police and stepping into other territories.” These disciplines will provide valuable theoretical support. Creative industries are set from an artistic perspective but do not give up aesthetics, sociology, anthropology, psychology, and advertising perspectives of science and communication. There are multiple perspectives, multiple thoughts, and multiple research methods. It is difficult to unify methods and ideas and focus on a single topic study.

4. Discussion

4.1. Impact of Design Art on the Value-Added of Cultural and Creative Industries. Design itself is a blend of culture and reality and is the cultural and artistic expression of designers through realistic materials and tools. Comparing the growth rates of cultural and creative industries and GDP, the results are shown in Table 1 and Figure 1.

As can be seen from Table 1, it is not only limited by the growth of traditional industries. The speed is also electronic information industry, which is also an emerging industry. As shown in Figure 1, the scale of China’s cultural and creative industries in 2017 and 2018 was as high as 863.4 billion yuan and 10751 billion yuan.

4.2. Analysis of the Relationship between the Market Structure of Design Arts and Cultural and Creative Industries. Design art through the aesthetic appeal cleverly combines the actual use value with the aesthetic value and improves the cultural creative products from the design concept and then promotes the development of the entire industry, which has become an important breakthrough. With creative skills and talents, it can obtain high value-added wealth through marketing and development. Art design is based on creation and innovation and is an important expression of creative thinking. The cultural and creative industry is closely

Table 1: Comparison of growth rates of cultural and creative industries and GDP in 2014–2018.

Year	Growth rate of cultural and creative industries (%)	GDP growth rate (%)	Growth rate of electronic information industry (%)
2014	27.8	13.0	18.2
2015	24.4	9.6	14.6
2016	20.9	8.7	4.5
2017	32.8	10.1	25.2
2018	24.5	9.2	21.4

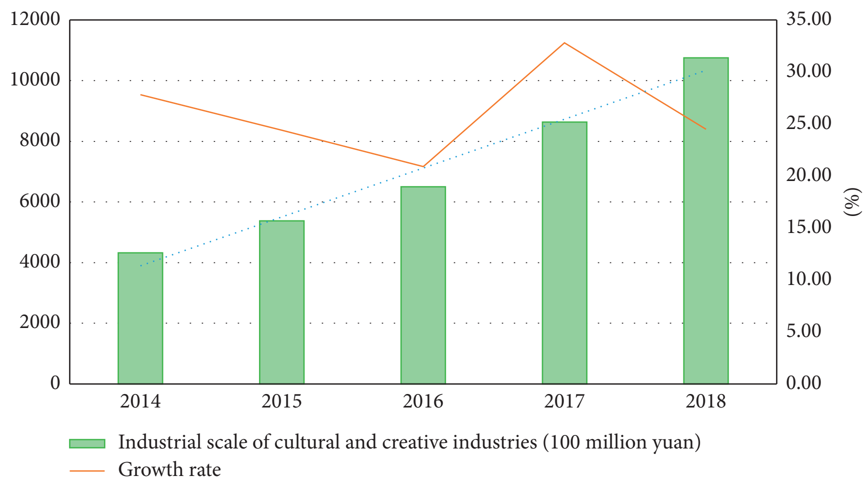


Figure 1: Comparing the growth rates of cultural and creative industries and GDP, as well as industrial scale and growth rate of China's cultural and creative industries in 2013–2018. The scale of China's cultural and creative industries in 2017 and 2018 was as high as 863.4 billion yuan and 10751 billion yuan.

connected with art design. From the design of cultural products, as well as brand packaging to the promotion of the company's own image, it all involves art design creativity. High added value brought by art design to the product and the promotion of the optimization are keys for enterprises to improve economic efficiency and market competitiveness. As a component of the cultural and creative industry chain, art design plays an important role that cannot be ignored in its development. The cultural creative industry provides a broad application space for art design to go to the market and points out the direction of development of art design for large-scale industrialization. A comparative analysis of each subsector of the cultural and creative industries in the past 18 years is shown in Figure 2.

It can be seen from Figure 2 that, in 18 years, radio, television, and Internet information services were rapidly developing, accounting for 27.9%, 21.8%, and 20.3%, while the advertising, exhibition, tourism, and leisure industries have also steadily increased, and they accounted for 9.6% and 7.1% of the total share, which have a relatively small share, including cultural and arts, design services, and art transactions. Subindustries have developed rapidly.

4.3. Innovative Perspective of Researching Design Arts and Cultural Creative Industries. Art is also an innovative development based on reality. A new interpretation of the cultural industry through an innovative perspective has become a perfect meeting point for the combination of design art and cultural creative industries. The creative product display after incorporating design art is shown in Figure 3.

As can be seen from Figure 3, the creative products after incorporating the design art have largely improved the overall visual comfort. In this creative product, not only the concept of design art but also the essence of our traditional culture is incorporated. In the field of art design, individual creativity is highly respected. Only designers with an innovative spirit can innovate ideas in the form of works and design unique works. Therefore, it can be said that art design is the upstream of the cultural creative industry. Only with core art creation can there be culture and art. A certain aesthetic appeal mainly conveyed by artistic creativity in design often deviates from the universal sensory image, and the aesthetic image it creates often becomes a unique form of existence because of its novelty. This unique aesthetic image, through its own uniqueness, directly and profoundly affects the hearts of the audience and produces a generally strong aesthetic identity and aesthetic shock.

4.4. Impact of the Vigorous Development of Cultural and Creative Industries on Design Art. Figure 4 shows the paper-cutting art of cultural and creative products in China, and Figure 5 shows the creative cultural crafts.

From Figures 4 and 5, we can see that the art of design and the culture and entrepreneurship industry are mutually reinforcing. They promote and influence each other. The concept of cultural creativity is integrated into the art of design, making art design more culturally attractive, and

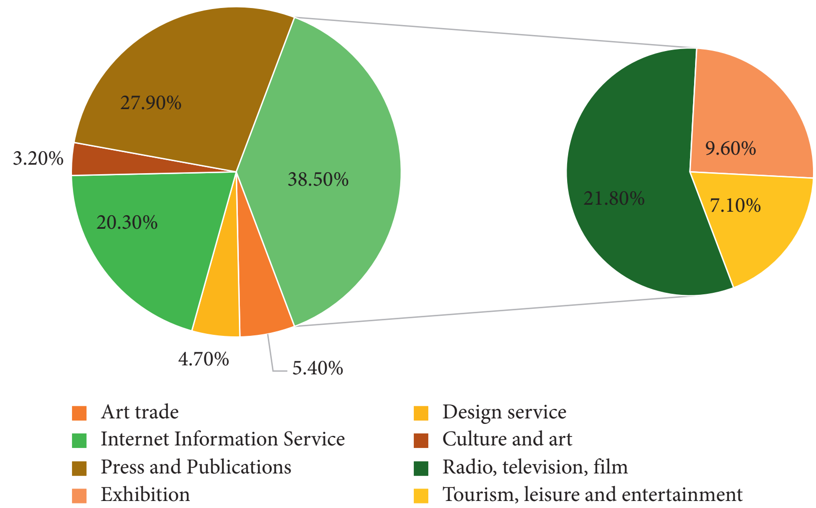


Figure 2: Market structure of China's cultural and creative industries in 2018. In 18 years, radio, television, and Internet information services were rapidly developing.

Figure 3: Creative products integrated with design art concept, from which the creative products after incorporating the design art have largely improved the overall visual comfort.

Figure 4: Paper-cutting art of cultural and creative products in China.

Figure 5: Cultural and creative crafts.

cultural creativity and the art of design make products more aesthetic. Design art is the perfect combination of art and reality to make art from the sacred temple to universal significance. Integrating innovative and creative cultural ideas into practical needs and becoming an exchangeable item can largely provide opportunities for the development of design art, provide fertile soil for creation, and provide a creative market environment for design art. Thirdly, it has also brought unavoidable adverse effects to design art. Design art needs to maintain its relative independence and has its own development trend in social and economic development. However, the overexpanded cultural and creative industry will interfere with the healthy and independent development of design art. Economically, market regulation will cause design art to deviate from elegance, which is not conducive to the development of design art. On the social side, too rich and chaotic cultural tributaries will hinder the development of design art.

4.5. Innovative Perspective of Researching Design Arts and Cultural Creative Industries. Art is also an innovative development based on reality. A new interpretation of the cultural industry through an innovative perspective has become a perfect meeting point for the combination of design art and cultural creative industries. The creative product display after incorporating design art is shown in Figure 3.

As can be seen from Figure 3, the creative products after incorporating the design art have largely improved the overall visual comfort. In this creative product, not only the concept of design art but also the essence of our traditional culture is incorporated. In the field of art design, individual creativity is highly respected. Only designers with an innovative spirit can innovate ideas in the form of works and design unique works. Therefore, it can be said that art design is the upstream of the cultural creative industry. Only with core art creation can there be culture and art. A certain aesthetic appeal mainly conveyed by artistic creativity in design often deviates from the universal sensory image, and the aesthetic image it creates often becomes a unique form of existence because of its novelty. This unique aesthetic image, through its own uniqueness, directly and profoundly affects the hearts of the audience and produces a generally strong aesthetic identity and aesthetic shock.

5. Conclusions

High-level innovative talents are the key. The goal of big data technology in the cultural industry is its application. Launching a special project of cultural industry big data, creating a cultural industry experimental park, and giving play to its demonstration effect will help promote the application and optimization of big data. In addition, the research in this article finds that integrating design and artistic concepts into cultural and creative products can make products more visually appealing, while integrating cultural and creative concepts into design and art makes products more culturally connotative. In the future, more works should focus on how to integrate the cultural and creative concepts into products for Industry 5.0. Furthermore, more data and analysis should also be provided to support this field. Meanwhile, how to combine these with artificial intelligence and intelligent industry is also a challenge, which needs more attentions and needs to be developed in the future.

Data Availability

The data used to support the findings of this study are currently under embargo, while the research findings are commercialized. Requests for data, 6/12 months after publication of this article, will be considered by the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by Hunan new liberal arts research and reform practice project, Innovation and Entrepreneurship Education Center of Colleges and Universities.

References

[1] H. Paul, "The new berlin: offbeat, disruptive, and imperiled," *World Policy Journal*, vol. 34, no. 2, pp. 99–108, 2017.

[2] R. Mcelroy and C. Noonan, "Television drama production in small nations: mobilities in a changing ecology," *The Journal of Popular Television*, vol. 4, no. 1, pp. 109–127, 2016.

[3] J. Švarc and M. Dabić, "Evolution of the knowledge economy: a historical perspective with an application to the case of europe," *Journal of the Knowledge Economy*, vol. 8, no. 1, pp. 1–18, 2017.

[4] J. Duan and H. Long, "City creative index and its empirical analysis," *Journal of Shenzhen University Science and Engineering*, vol. 32, no. 3, pp. 296–305, 2015.

[5] T. Gupte and M. Sinha, "Design and evaluation of artificial cornea with core–skirt design using polyhydroxyethyl methacrylate and graphite," *International Ophthalmology*, vol. 38, no. 3, pp. 1–9, 2017.

[6] L. Lazzeretti and F. Capone, "Erdem Seçilmiş. In search of a Mediterranean creativity. Cultural and creative industries in Italy, Spain and Turkey," *European Planning Studies*, vol. 24, no. 3, pp. 568–588, 2016.

[7] K. Gundolf, A. Jaouen, and J. Gast, "Motives for strategic alliances in cultural and creative industries," *Creativity and Innovation Management*, vol. 27, no. 3, pp. 1–13, 2017.

[8] O. D. David Wright, "Cultural policy: management, value and modernity in the creative industries routledge 2014 166 pp. £65.00 (hardback) £29.99 (paperback) book review," *British Journal of Sociology*, vol. 67, no. 3, pp. 569-570, 2016.

[9] Z. Luo and J. Dai, "Synthetic genomics: the art of design and synthesis," *Sheng wu gong cheng xue bao = Chinese journal of biotechnology*, vol. 33, no. 3, pp. 331–342, 2017.

[10] M. Qu, S. Yu, and D. Chen, "State-of-the-art of design, evaluation, and operation methodologies in product service systems," *Computers in Industry*, vol. 77, no. 8, pp. 1–14, 2016.

[11] C. Robinson, "Design and innovation," *Journal of Pla Academy of Art*, vol. 131, no. 8, pp. 654–660, 2015.

[12] D. Atkinson, "Without criteria: art and learning and the adventure of pedagogy," *International Journal of Art and Design Education*, vol. 36, no. 2, pp. 141–152, 2016.

[13] T. J. Niemi, H. Joseph, A. Guillaume, and T. Kokkonen, "Role of spatial anisotropy in design storm generation: experiment and interpretation," *Water Resources Research*, vol. 52, no. 1, pp. 69–89, 2016.

[14] S. Boehm, "Facilitating comprehension, connection and commitment to environmentally responsible design," *International Journal of Art and Design Education*, vol. 34, no. 1, pp. 73–88, 2015.

[15] M. Compton and S. Barrett, "A brush with research: teaching grounded theory in the art and design classroom," *Universal Journal of Educational Research*, vol. 4, no. 2, pp. 335–348, 2016.

[16] E. Avilés-Ochoa and P. M. Canizalez-Ramírez, "Cultural industries and economic growth. A model to study the emergence of creative clusters," *Journal of Clinical Ultrasound*, vol. 43, no. 47, pp. 185–216, 2015.

[17] K. Borseková, D. Cole, and K. Petríková, "Nostalgic sentiment and cultural and creative industries in regional development: a Slovak case study," *Quaestiones Geographicae*, vol. 34, no. 2, pp. 53–63, 2015.

[18] S. Biasotti, A. Cerri, and B. Falcidieno, "3D artifacts similarity based on the concurrent evaluation of heterogeneous properties," *Journal on Computing & Cultural Heritage*, vol. 8, no. 4, pp. 1–19, 2015.

[19] E. W. Stephanie and L. Zamberlan, "Design pedagogy for an unknown future: a view from the expanding field of design scholarship and professional practice," *International Journal of Art and Design Education*, vol. 36, no. 1, pp. 106–117, 2017.

[20] K. A. S. Immink and K. Cai, "Design of capacity-approaching constrained codes for DNA-based storage systems," *IEEE Communications Letters*, vol. 22, no. 99, p. 1, 2018.
[21] M. Waldman, R. Fraczkiewicz, and D. C. Robert, "Tales from the war on error: the art and science of curating QSAR data," *Journal of Computer-Aided Molecular Design*, vol. 29, no. 9, pp. 897–910, 2015.
[22] M. W. Tara, "A developing research-oriented pedagogy for undergraduate teaching in art and design," *International Journal of Education Through Art*, vol. 12, no. 3, pp. 257–270, 2016.
[23] Y. Le, "A study of the exhibition design of the geological museum: exemplified by the geological museum of China," *Acta Geoscientia Sinica*, vol. 38, no. 2, pp. 304–312, 2017.
[24] C. De Alwis, A. Kalla, Q. V. Pham et al., "Survey on 6G frontiers: trends, applications, requirements, technologies and future research," *IEEE Open Journal of the Communications Society*, vol. 2, pp. 836–886, 2021.
[25] M. A. Togou, T. Bi, K. Dev et al., "DBNS: a distributed blockchain-enabled network slicing framework for 5G networks," *IEEE Communications Magazine*, vol. 58, no. 11, pp. 90–96, 2020.
[26] P. K. R. Maddikunta, Q. V. Pham, B. Prabadevi et al., "Industry 5.0: a survey on enabling technologies and potential applications," *Journal of Industrial Information Integration*, Article ID 100257, 2021.
[27] A. A. Shah, N. A. Bhatti, K. Dev, and B. S. Chowdhry, "MUHAFIZ: IoT-based track recording vehicle for the damage analysis of the railway track," *IEEE Internet of Things Journal*, vol. 8, no. 11, pp. 9397–9406, 2021.
[28] R. Hu, S. Zhou, Y. Liu, and Z. Tang, "Margin-based Pareto ensemble pruning: an ensemble pruning algorithm that learns to search optimized ensembles," *Computational Intelligence and Neuroscience*, vol. 2019, Article ID 7560872, 12 pages, 2019.
[29] R. Zhu, S. Ye, Z. Tang et al., "Influence of compact Memristors' stability on machine learning," *IEEE Access*, vol. 7, Article ID 47472, 2019.
[30] R. Hu, Z. R. Tang, X. Song, J. Luo, E. Q. Wu, and S. Chang, "Ensemble echo network with deep architecture for time-series modeling," *Neural Computing & Applications*, vol. 33, no. 10, pp. 4997–5010, 2021.
[31] Z. Tang, Y. Chen, Z. Wang, R. Hu, and E. Q. Wu, "Non-spike timing-dependent plasticity learning mechanism for memristive neural networks," *Applied Intelligence*, vol. 51, no. 6, pp. 3684–3695, 2021.
[32] Z. Tang, R. Zhu, P. Lin et al., "A hardware friendly unsupervised memristive neural network with weight sharing mechanism," *Neurocomputing*, vol. 332, pp. 193–202, 2019.

Hindawi
Scientific Programming
Volume 2022, Article ID 6268430, 9 pages
https://doi.org/10.1155/2022/6268430

Research Article

Motion Blur Fuzzy Blind Removal Algorithm for Character Images in Gradient Domain and Deep Learning

Guoheng Ren,[1] Wei Wang,[1] Hanyu Wei,[2] and Xiaofeng Li[3]

[1] *School of Network Engineering, Zhoukou Normal University, Zhoukou 466001, Henan, China*
[2] *School of Mathematics and Statistics, Zhoukou Normal University, Zhoukou 466001, Henan, China*
[3] *School of Continuing Education, Zhoukou Normal University, Zhoukou 466001, Henan, China*

Correspondence should be addressed to Guoheng Ren; rrenguoheng@zknu.edu.cn

Received 24 December 2021; Revised 29 January 2022; Accepted 14 February 2022; Published 11 March 2022

Academic Editor: Ahmed Farouk

The imaging device is susceptible to factors such as the subject or the shooting environment when imaging, and complex variable blurring occurs in the final imaging. In most cases, we not only do not have the conditions to re-shoot a clear image but also do not know the specific parameters of the variable blur in advance. Therefore, the purpose of this study is to propose a motion blur fuzzy blind removal algorithm for character images based on gradient domain and depth learning. Deep learning is to learn the inherent laws and representation levels of sample data, and the information obtained during these learning processes is of great help to the interpretation of data such as text, images, and sounds. The algorithm used in this study is to preprocess the image by using guided filtering and L0 filtering and send the preprocessed gradient domain image block to the designed convolutional neural network for training. Extract the trained model parameters and realize the fuzzy kernel estimation and image. Image deblurring is performed using the TV regular term during image restoration. The experiment proves that the algorithm can effectively suppress the ringing effect and reduce the noise, and the motion blur effect is better. In this study, the MLP method, the edge detection method, and the proposed method are discussed, respectively. The PSNR values of the three motion blur removal methods are 26.49, 27.51, and 29.18, respectively. It can be seen that the motion blur removal method proposed in this study can effectively remove image motion blur.

1. Introduction

With the rapid development of science and technology, various photographic equipment have sneaked into all aspects of human life and have become a common existence in daily work and life. For example, journalists cannot do without professional cameras and almost one smart phone in life. Electronic surveillance cameras are more ubiquitous, and satellites at work provide a large number of remote-sensing images, and the use of drones is becoming more and more popular [1]. With the proliferation of highly developed network technologies, these imaging devices produce a large number of images at all times. These images not only enrich and facilitate people's lives but also play a pivotal role in improving production quality, safeguarding property, and life safety [2]. However, in the actual imaging process, due to factors such as focal length, jitter, perceived target motion, and atmospheric turbulence, the obtained images often have some ambiguity [3]. The image quality degradation caused by the blurring of the image and the lack of image detail information not only brings inconvenience to people's production and life but also causes economic losses and security loopholes in serious cases [4]. In most cases, people do not have the conditions to re-shoot clear images. First, the cost of replacing hardware equipment is high; second, the actual and objective conditions are harsh, such as images captured for news events, images of suspects photographed in surveillance, images of illegally driven vehicles, etc. [5]. In this case, it is necessary to eliminate image blur by a certain technical means to restore clear images and restore image quality, which has a broad market prospect [6]. At the same time, in blind image deblurring, the blur kernel needs to be estimated before restoring a clear image. The estimation of the blur kernel is one of the core problems of blind image deblurring, and it is also a difficult problem in blind image deblurring.

In recent years, thanks to the continuous improvement of computer hardware technology, the improvement of computer vision theory, and the rapid development of machine learning, especially deep learning algorithms, image blur removal technology has made considerable breakthroughs in theory and application. The fields of medicine, transportation, astronomy, criminal investigation, and military play an important role [7]. With the continuous development of related technologies, image deblurring technology is bound to be more widely used, and it is bound to undertake more important work to meet people's more stringent technical requirements [8]. The blurring process of images is usually modeled as the process of convolution of fuzzy kernels with clear images [9]. The single image deblurring process can be seen as the inverse of the image blurring process, namely, deconvolution [10]. Solving a corresponding single clear image from a blurred image is a typical ill-posed problem. First is the uncertainty of the equation solution during deconvolution, that is, the most difficult singular solution in image restoration. There are multiple solutions to the deconvolution equation [11]. Early image deblurring studies often assume that degenerate models or fuzzy convolution kernels are known, mainly in mathematical models and algorithms. In the premise that the fuzzy kernel is known, the image is reversed, which is called unblind deblurring [12]. In most cases, the information of the fuzzy kernel will not be provided in advance, and the only information we have is an image with unknown blur. Compared with the deblurring problem under the condition of fuzzy kernel, blind deblurring is a serious ill-posed problem and a more challenging practical problem. It has a wider application range [13], so the fuzzy blind removal technique is based on single image. In recent years, it has received more and more attention from the academic community. In addition, early image deblurring studies focused more on the uniform blurring of images, which in the actual production and life are usually variable or inconsistent [14]. In other words, each pixel of the blurred variable image has different blur conditions. Furthermore, the focal length setting is incorrect when shooting, and the out-of-focus blur will appear in some of the imaged images [15]. Compared with the invariant blur, the case of variable blur is more common, and since it is impossible to adopt a unified fuzzy model for the whole graph, the recovery is more difficult [16]. The exploration of image deblurring technology, especially the exploration of image fuzzy blind removal technology with the above two problems of fuzzy kernel unknown and fuzzy kernel variable, has great theoretical research significance not only in academia but also in society and has a very high practical application value [17]. The use of image restoration technology to restore the degraded image can enable the lost or degraded image to be restored.

The innovations of this paper are as follows. (1) A blind image motion blur removal algorithm based on gradient domain and deep learning is proposed. (2) The algorithm combines image gradient domain preprocessing and CNN network methods, avoiding the shortcomings of directly using deep learning methods and ignoring image prior information. (3) Compared with other algorithms, this algorithm can effectively suppress the ringing effect and reduce noise and has better motion blur effect.

The text of this study is organized as follows. Section 1 summarizes the research background and significance of the variable fuzzy blind removal problem and briefly expounds the innovation of this study. The main research contents and arrangement of the study are explained. In Section 2, firstly, the current research status of variable blur blind removal is illustrated in detail. Then, the principle of deblurring and image preprocessing are briefly introduced. The gradient domain method and the image blur blind removal algorithm based on gradient domain are introduced in detail. Finally, the image blur blind removal algorithm based on deep learning is introduced. The three common image blur types studied in this study are briefly introduced, namely, Gaussian blur, motion blur, and out-of-focus blur. The convolutional neural network method is described in detail. An image motion blur blind removal algorithm based on gradient domain and depth learning is proposed, which provides relevant research work support for the following methods. Section 3 first introduces the dataset of this study, then introduces the hardware configuration and software environment of the experiment, and finally introduces the objective evaluation index of image quality used in this study. Section 4 firstly shows the effect picture of the noise blurred image after image preprocessing, then compares the influence of the size and number of the filter on the experimental effect, respectively, and then lists the noise blurred image. After comparing the effects of the algorithm, the PSNR values of the images processed by different methods are compared. In Section 5, the main research work of this study is summarized, and the advantages and disadvantages of this method are summarized.

2. Proposed Method

2.1. Related Work. Zhang et al. proposed a novel two-channel convolutional neural network (DC-CNN) framework for accurate spectral spatial classification of hyperspectral images (HSI). In this framework, one-dimensional CNN is used to automatically extract hierarchical spectral features, then two-dimensional CNN is used to extract spatially related hierarchical features, and then softmax regression classifier is used to combine spectral and spatial features and finally predict classification result. In order to overcome the limited training samples available in HSI, they proposed a simple data enhancement method, which effectively improved the HSI classification accuracy. For comparison and verification, they tested the proposed method and other three HSI classification methods based on deep learning on two real-world HSI datasets. The experimental results show that our DC-CNN-based method is much better than the latest method [18].

Kou et al. believed that the guided image filter (GIF) is a well-known local filter because of its edge retention characteristics and low computational complexity. Unfortunately, GIF may be affected by halo artifacts because the local linear model used in GIF does not adequately represent images near certain edges. They proposed a gradient domain GIF by combining explicit first-order edge-aware constraints. Edge-aware constraints allow edges to be better preserved. To illustrate the efficiency of the proposed filters, their proposed gradient domain GIFs are used for single image detail enhancement, tone mapping of high dynamic range images, and image saliency detection. Theoretical analysis and experimental results have proved that their proposed gradient domain GIF can produce better composite images, especially near the edge of the halo appearing in the original GIF [19].

Navarro et al. believed that motion blur is the basic clue to perceiving moving objects. This phenomenon appears as a visible trajectory along the trajectory of the object and is the result of a combination of relative motion and light integration that occurs in film and electronic cameras. In this work, they analyzed the mechanisms for generating motion blur in recording devices and methods for simulating motion blur in computer-generated images. Over time, light integration is one of the most expensive processes for simulating in high-quality rendering, so they have an in-depth review of existing algorithms and categorized them in the context of a formal model to highlight their differences, strengths, and limitations. They eventually completed the report and presented a number of alternative categories that will help the reader determine the best technology for a particular situation [20].

2.2. Image Deblurring

2.2.1. Image Deblurring Principle. The image is blindly deblurred, that is, the fuzzy kernel is unknown, and the clear image x and the blurred kernel k need to be obtained from the blurred image y. The blind deblurring problem can transform the solved fuzzy kernel into a nonblind deblurring problem. There are many reasons for image blurring, including optical factors, atmospheric factors, artificial factors, and technical factors. It is of great significance to deblur images in daily production and life. Among them, image restoration technology is a very important processing technology in the field of image processing. Similar to other basic image processing technologies such as image enhancement, it also aims to obtain a certain degree of improvement in visual quality. The difference is that the image restoration process is actually an estimation process, and the degraded image needs to be restored according to some specific image degradation models:

$$\min_x \|y - x \otimes k\|_2^2 + \lambda \Psi_1(x), \tag{1}$$

where $\otimes$ denotes the convolution operation. The first part is the data fidelity term, which is constrained by the L2 norm; the second part is the a priori regular constraint term, which is related to the original clear natural image, λ is the constraint term the parameter that balances the ratio between the data fidelity terms, and the selection of the regular term is related to the selected image prior.

2.2.2. Image Preprocessing. Image preprocessing is to separate each text image and hand it over to the recognition module for recognition. This process is called image preprocessing. First, the filtered image is guided as a base image to reduce the effects of noise and unwanted detail. Then, the L_0 filtered gradient domain image and the corresponding clear image are taken as samples, and the designed CNN is trained. In this study, both the guided filtering and the L_0 filtering are applied to the clear image, which can suppress irrelevant details, enhance the sharp edges of the image, and improve the robustness of the fuzzy kernel estimation. Enhancing useful information in an image, which can be a distortion process, aims to improve the visual effect of the image.

2.3. Image Blind Deblurring Algorithm Based on Gradient Domain

2.3.1. Blind Deblurring Algorithm Based on Gradient Domain Image. The gradient domain method is basically a transform domain method and still performs three basic steps of image space conversion, modified gradient field, and image reconstruction. This section describes each part of the proposed gradient domain natural image enhancement method in detail.

(1) Image space conversion: the first step in the gradient domain method is to transform the space in which the image is located, transforming the image from the original space to the gradient space. In order to better detect the edges and suppress noise, the Sobel gradient operator is used to calculate the gradient of the original image $f(x, y)$.

(2) Modify the gradient field: the key part of the transform domain method to obtain the processing effect is to process the information in the transform space. Just as the frequency domain method multiplies the spectrum by a transfer function to process the frequency information, the gradient domain is also multiplied by the gradient field by a transform function to get the desired gradient field. If the original image is $f(x, y)$, the gradient function of the original image is $G(x, y)$, and the desired gradient function is expressed as $Gnew(x, y)$, and the processing can be expressed as

$$G_{\text{new}}(x, y) = \phi(x, y) * G(x, y), \tag{2}$$

where $\phi(x, y)$ is a transformation function.

Modification of the gradient field requires selection of the corresponding transformation function based on the desired transformation result. The general method does not necessarily achieve the best results for a specific problem. It is necessary to formulate a corresponding transformation strategy according to the actual situation and flexibly use the gradient domain enhancement method.

It is known from the mathematical knowledge that the function of $y = x * c^{-x}$ is characterized by the fact that the amplitude of the zero point and the near zero region does not exceed 1, and as x increases, y increases sharply in a region to reach a value much larger than one and then decreases rapidly and tends to zero. The value of y in the region at the front and rear ends of the x-axis does not exceed 1, which is weakened in the transfer function, and the value of y in the intermediate range is greater than 1, which is an enhancement characteristic, and the range of the enhancement interval is small. Considering the processing effect and complexity of the function, we decided to use the function like $y = x * c^{-x}$ as the transformation function of this study. In order to make the weakening area reduction effect more obvious, the enhancement part enlargement multiple is larger, and there is a faster change speed when the amplitude rises and falls, and the function self-multiplication is adopted, that is, the self-product product of the value less than 1 is smaller. The principle of a larger self-product of a value greater than 1 sets the transformation function. Thus, the transformation function formula is defined as

$$\phi(x, y) = a * \left(\|G(x, y)\| * b^{-\|G(x,y)\|} \right)^c, \tag{3}$$

where $||G(x, y)||$ is the gradient mode at the pixel point (x, y) of the original image, a, b, and c are constant, and $a > 1$, $b > 1$, and $c > 1$.

The function has two thresholds N_1, N_2 such that

$$\begin{cases} 0 \le \phi(x, y) < 1, & 0 \le \|G(x, y)\| \le N_1, \\ \phi(x, y) \ge 1, & N_1 \le \|G(x, y)\| \le N_2, \\ 0 < \phi(x, y) < 1, & \|G(x, y)\| \ge N_2. \end{cases} \tag{4}$$

The interval $[0, N_1)$ is called a smooth interval, the interval $[N_1, N_2]$ is called an enhancement interval, and the interval $(N_2, +\infty)$ is called an attenuation interval. In $\phi(x, y)$, the enhancement range and interval size of the enhancement interval can be controlled by the constants a, b, and c. Due to the different performance of the acquisition system equipment, the gradient distribution of the acquired image of the person is also different.

(3) Image reconstruction: after processing the original gradient field, it is necessary to reconstruct the image with a new gradient field. In theory, reconstructing an image is as simple as integrating the new gradient function $Gnew(x, y)$. However, the transformed gradient field may not be a conservative field; there is no image corresponding to this gradient field. The direct integration of this gradient field is not the result. Therefore, we use the principle of least squares to reconstruct the gradient field. Image reconstruction technology was initially used in radiological medical equipment to display images of various parts of the human body, namely, computed tomography technology, or CT technology for short, and it was gradually applied in many fields.

Let there be an image $g(x, y)$ whose gradient field is closest to $Gnew(x, y)$; then, $g(x, y)$ can be obtained by minimizing the following integrals:

$$\iint \left(\left(\frac{\partial_g}{\partial_x} - G_{\text{new}x} \right)^2 - \left(\frac{\partial_g}{\partial_x} - G_{\text{new}y} \right) \right) \mathrm{d}x\mathrm{d}y. \tag{5}$$

The Poisson equation can be obtained by substituting $(\partial_g/\partial_x - G_{\text{new}x})^2 - (\partial_g/\partial_x - G_{\text{new}y})^2$ into the Euler–Lagrange equation:

$$\nabla^2 g = \text{div} G_{\text{new}}, \tag{6}$$

where ∇^2 is the Laplacian operator and div is the divergence.

2.4. Blind Deblurring Algorithm Based on Deep Learning. In the field of blind image removal, there are more and more methods based on deep neural network (DNN). DNN is used for fuzzy classification of fuzzy images, and according to the classification results, the corresponding generalized regression neural network (GRNN) is used to perform fuzzy kernel parameter regression.

2.4.1. The following Is a Description of the Fuzzy Type.

(1) Gaussian blur: the Gaussian fuzzy PSF is a two-dimensional Gaussian function, and the PSF is used to adjust the image pixel values to conform to the values of the two-dimensional normal distribution. Gaussian blur can generally be used to simulate atmospheric turbulence. From a mathematical point of view, the Gaussian blurring process of an image is the convolution of the image with the normal distribution. Since the normal distribution is also known as the Gaussian distribution, this technique is called Gaussian blur.

(2) Motion blur: the linear motion blur PSF describes the relative linear motion of the subject domain camera.

(3) Defocus blur: the defocus blur PSF can be represented by a disc-shaped mean wave filter, which is generally used for the same focal length of the subject at different depths of field when the simulation is taken, resulting in different degrees of blurring.

2.4.2. Fuzzy Kernel Estimation Based on Deep Network. The algorithm trains the network to estimate the blur parameters of each image patch by dividing the image into overlapping patches. In the first stage, the deep confidence network is used for pretraining and the DNN is fine-tuned to identify the fuzzy type. In the second phase, multiple GRNNs are trained to predict the corresponding types of fuzzy parameters. In the fuzzy classification and estimation part, the algorithm is divided into three steps: fuzzy block feature extraction, DNN training, and GRNN training. The flowchart of the algorithm is shown in Figure 1:

Among them, B1, B2, and B3 are Gaussian and motion defocus blur, respectively, and P1, P2, and P3 represent predicted values, respectively.

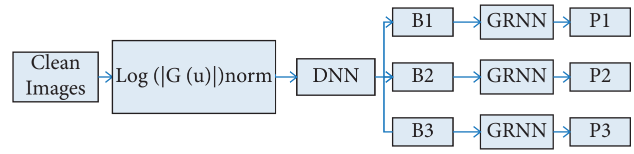


Figure 1: Fuzzy kernel estimation algorithm.

2.5. Deep Convolutional Network Structure. The method is divided into three processes. The first step is to use the CNN to estimate the fuzzy kernel to change the distribution at the image block level and calculate the candidate set of the rotated image to expand the fuzzy kernel. The second step is based on the Markov random field model. The smoothing of the numerically dispersed motion blur parameter field is performed. In the third step, the motion blur based on the image block prior is used to remove the motion blur of the positive image.

The variable motion blur in the algorithm is defined as follows. The motion blur length l_p and the angle o_p of the blurred image I at the pixel position $p \in \Omega$ (Ω is image domain) are summarized by the motion vector $m_p = (l_p, o_p)$. Each motion vector defines a fuzzy kernel that is nonzero on the motion trajectory. The process of generating the blurred image is $I = k(M) * I_0$, which is obtained by convolving the original image I_0 with the variable fuzzy $k(M)$, where $k(M)$ is defined by the motion parameter field $M = \{m_p\} p \in \Omega$.

The algorithm is divided into three steps: block-level motion distribution estimation, motion parameter field construction, and variable blur removal.

The specific description of the steps is as follows.

2.5.1. Block-Level Motion Distribution Estimation.

(1) Training CNN estimating motion distribution: the small block with p as the center pixel is represented by ψ_p. The task of fuzzy kernel identification is to estimate the following conditional probability distribution, called "motion distribution:"

$$P\left(m = (l, o) | \psi_p\right). \tag{7}$$

Among them, $l \in S^l, o \in S^o$, and S^l and S^o are the set of values of the length and angle of the motion blur kernel, respectively, $S^l = \{1, 3, 5 \ldots\}$ and $S = \{0^o, 30^o, \ldots, 150^o\}$. For the case of =1, all values correspond to the same fuzzy kernel, that is, the unit fuzzy kernel.

(2) Expand candidate fuzzy kernel: recording the blurred image I clockwise rotation θ^o (rotation operator is R_θ) version is $R_\theta I$; then, crop the small pieces $\psi_p(I)$ and $\psi_p(R_\theta I)$ of the same size in the blurred image and the rotated blurred image, respectively. The two have the following relationship: if the fuzzy kernel recognition result of $\psi_p(R_\theta I)$ is $m(l, o)$, it can be inferred that $\psi_p(I)$, the corresponding fuzzy kernel, is $m(l, o - \theta)$.

2.5.2. Motion Parameter Field Structure. In the previous section, the block-level motion distribution estimation is performed through the CNN network. In order to refine the parameter estimation accuracy, the block-level motion distribution is merged into a dense motion fuzzy parameter field according to the MRF model.

When using CNN classification, all pixel locations of $\psi_p(I)$ patches are considered to have the same motion distribution. Correspondingly, for the pixel p having multiple motion distribution estimation results (because of dividing the overlapping small blocks), the weighted average of the motion distribution is performed, and the confidence of the motion vector $m_p = (l, o)$ defining the p-point is as follows:

$$C\left(m_p = (l, o)\right) = \frac{1}{Z} \sum_{q: p \in \psi_q} G_\sigma\left(\left\| x_p - x_q \right\|^2\right) P\left(m_p = \left(l, o | \psi_q\right)\right), \quad l \in S^l,\ o \in S^o_{ext}, \tag{8}$$

where p is the pixel location in ψ_p and x_p is the coordinates of the pixel p. For p that is closer to the ψ_p center point q, the Gaussian function $G_\sigma(\sigma = 10)$ provides a larger weight.

2.5.3. Variable Blur Removal. The gradient domain is now used to train the network. The input of the network is subjected to the guided filtering and the L_0 filtered gradient domain image and its corresponding blurred image, and the output is the edge information of the image. After the input picture is rotated by 90°, the edge information is extracted, which is the same as that obtained by extracting the edge information when not rotating. Therefore, the method only uses the vertical gradient to train the network and share the weights in the horizontal and vertical directions.

The structure of the CNN is divided into two parts: the first four layers of the network are mainly used to extract the main structure from the blurred image, suppressing irrelevant details; the latter four layers of the network are used to enhance the extracted structure and better restore the edges of the image. The output of CNN layer 5 is represented by pl, which is $\{f^5_m, m = 1, 2, \ldots, 5\}$. $\partial T_1(x)$ is the training data of the first stage real image of the network training, that is, the gradient domain image after the original image is guided and filtered; $\partial T_2(x)$ is the training data of the second stage real image of the network training, that is, the gradient domain image of the original image after L0 filtering. They all have only one channel. At the 5th level, a single channel, $P_5 = 1$, is used to train the two parts of the network. In order to solve the problem that the middle layer has only one channel and the training efficiency is not high, the method takes the weighted average of the feature map as the output value of the first stage, that is,

$$M_1(\partial y) = \sum_{m=1}^{5} \alpha_m f_m^5, \tag{9}$$

where α_m is a learnable coefficient.

The entire network training process loss value is

$$\text{loss} = \frac{1}{D}\sum_i \rho\left(f_\omega(\partial y_i) - \partial T_2(x_i)\right) + \lambda\rho\left(f_\omega(\partial y_i)\right), \tag{10}$$

where $\rho(z) = (z^2 + \varepsilon^2)^{1/2}$, ε takes 10^{-6}, λ is the weight of the regular term, and $f_\omega(\partial y_i)$ is the edge information obtained by network training.

3. Experiments

3.1. Dataset. The network training process uses the COCO-2014-training large-scale image library released by Microsoft, which provides a total of 83,000 images in 13 GB size and 60,000 instances of segmentation information in 80 categories corresponding to image numbers. The COCO image library is widely used in the field of image deep learning. Its content covers human landscape, natural scenery, plant flowers, and vehicles. We randomly select a character image as a clear training image.

3.2. Experimental Environment. Implemented in the Python scripting language, version Python 3.6.1, the deep network build uses the PyTorch 0.3.1 deep learning framework. The network training was performed on a desktop computer equipped with a 12G Nvidia GeForce GTX 1080ti GPU and Ubuntu 16.04.3 operating system (memory: 64G, clocked at 2.40 GHz, and CPU model: Intel(R)Xeon(R) E5-2620). The rest of the comparison experiments were done on a Windows 10 operating system desktop (memory: 8G, clocked at: 3.30 GHz, and CPU model: Intel(R) Core(TM) i5-4590). The image quality evaluation indicators were calculated using the Matlab source code and the Matlab toolkit provided by Eero.

3.3. Objective Image Quality Assessment. The existing image deblurring technique is used to restore the image. In fact, the technical level of the restoration result is completely consistent with the real image. Therefore, it is necessary to use a certain standard to evaluate the quality of the restored image, which requires the evaluation of image quality. A good IQA method can make a relatively comprehensive evaluation of image technology and has certain guiding significance. According to the image quality evaluation method, it is divided into a subjective evaluation method and an objective evaluation method.

The subjective evaluation algorithm subjectively scores images by human observers and is considered to be the most reliable method because humans are end users of images. However, observers are susceptible to the external environment, their own preferences, and cognitive levels during observation. Subjective evaluation methods are extremely unstable when the number of observers is not large enough. On the contrary, hiring a large number of observers for observation and scoring is too expensive and time consuming, making it an unrealistic choice for real-time systems. Therefore, in the study of this paper, an objective evaluation method is adopted.

4. Discussion

4.1. Motion Image Blind Deblurring

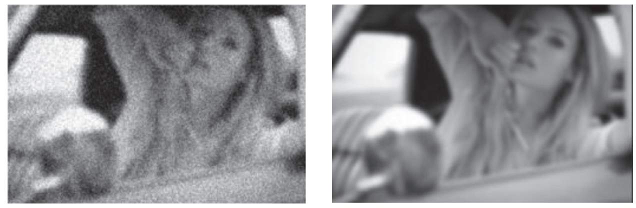
4.1.1. Image Preprocessing. On the basis of using the image to achieve image deblurring, it is proposed to preprocess the image by using guided filtering because the guide filtering can suppress the irrelevant details in the image and preserve the main structure of the image, as shown in Figure 2:

4.1.2. Influence of Filter Size on Training Results. The entire model was trained for 100,000 iterations. Figure 3 shows the effect of filter size on the training results. The entire network has a total of 8 layers, and the number of filters per layer is 128. In Figure 3, the green curve is obtained under filters of different sizes, the blue curve is obtained using a 5×5 filter throughout the network, and the red curve is a 7×7 filter used throughout the network acquired. The effect of filter size on training results is shown in Figure 3.

4.1.3. The Effect of the Number of Filters on the Training Results. The network of this experiment has a total of 8 layers. The size of each layer of filters is shown in Figure 4. The number of filters per layer is 64 and 32, respectively, which is compared with the number of filters per layer in this study. In Figure 4, the green curve is obtained when 128 filters per layer are used in this study, the red curve is obtained when 64 filters are used for each layer of the network, and the blue curve is obtained when 32 filters are used for each layer of the network. The effect of the number of filters on the training results is shown in Figure 4.

4.1.4. Deblurring Effect. Deblurring effect diagram using the algorithm proposed in this study is shown in Figure 5.

4.2. Comparative Analysis Based on Natural Image Blur Removal Algorithm. The research of image deblurring algorithm needs the support of theoretical knowledge such as mathematics, numerical analysis and signal processing. The complex operation of image deblurring depends on the computing power of the computer. With the rapid development of computers and the continuous improvement of



(a) (b)

Figure 2: Image preprocessing effect diagram. (a) Motion blurred noise image. (b) Guided filtered image.

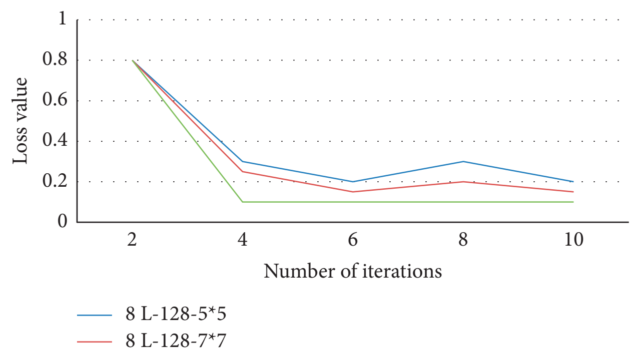


Figure 3: Effect of filter size on training results.

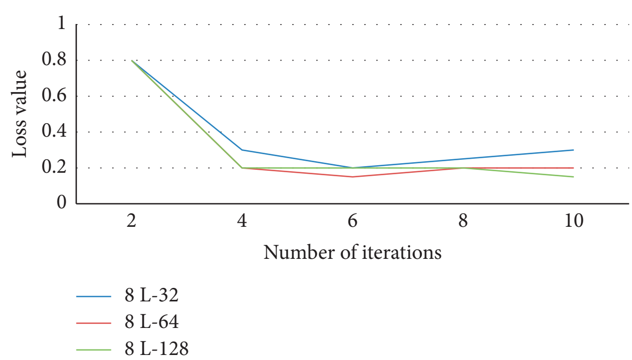
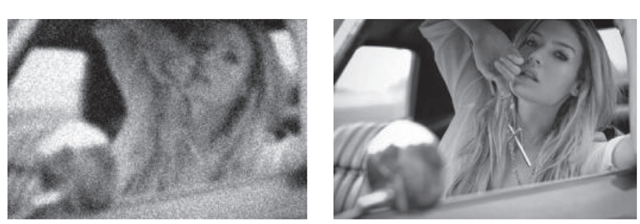


Figure 4: Effect of the number of filters on the training results.



(a) (b)

Figure 5: Deblurring effect diagram. (a) Blurred noise image; (b) remove the result of motion blur.

mathematical theoretical knowledge, people have made new breakthroughs in the study of image deblurring. The deblurring effect is compared with the multilayer perceptron (MLP) method and the edge detection method. The MLP method uses a multilayer perceptron to achieve image deblurring; the edge detection method combines the image structure with an optimization algorithm to apply image deblurring. The deblurring effects of different algorithms are

Table 1: PSNR values for different methods.

Original image	Fuzzy noise (Figure 5(a))	MLP method	Edge detection	Algorithm (Figure 5(b))
People	23.45	26.74	27.47	29.18

different, and the corresponding PSNR values are also different. Table 1 shows the PSNR values for the different methods:

It is known from Table 1 that the MSNR method and the edge detection method have little difference in removing the PSNR value of the motion blur, but the MLP method will amplify the noise, and the edge detection method may bring a ringing effect to the image.

5. Conclusions

(1) In this study, an image motion blur blind removal algorithm based on gradient domain and depth learning is proposed. CNN can learn the performance of image features for deblurring and design an effective CNN structure. Image gradient domain preprocessing and the CNN network combine the method to avoid the disadvantage of directly using the CNN network and ignoring the image prior information. Experiments show that the proposed method can not only effectively remove the image motion blur but also preserve the image details well; the amplification noise is not obvious, and the ringing effect is better suppressed.

(2) This study investigates and summarizes the work of the predecessors. The research background and significance of variable fuzzy blind removal are expounded. The current research status of deblurring based on priori and the deblurring method based on deep learning are introduced. The common fuzzy models and common quality evaluation indicators are briefly introduced. Two methods of variable fuzzy blind removal based on deep learning are deeply studied and three defects are found: relying on the traditional image restoration method, the running speed is slow; for different fuzzy types, the fuzzy parameter estimation network needs to be designed separately. Poorness: for the estimation of variable fuzzy kernel, block and fusion processing is needed, which affects the restoration effect and increases the complexity of the algorithm.

(3) This study provides an effective basis for image processing by comparing and analyzing the effects of different blind removal fuzzy algorithms.

The algorithm in this study can deal with blurred images with edges, but if the image is a text image, it is difficult for the algorithm in this study to restore it effectively. How to deblur the text-like image needs to be further studied in the future.

Data Availability

This study does not cover data research. No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by the Science and Technique Project of Henan (212102310397), the Special Project on Teaching Development Research and Practice of Zhoukou Normal University (JF2021001), the Teaching Quality Assurance Project of Zhoukou Normal University (J2021086), and the Key Scientific and Technological Project of Henan Province (22A520052).

References

[1] Q. Li, W. Lin, and Y. Fang, "No-reference quality assessment for multiply-distorted images in gradient domain," *IEEE Signal Processing Letters*, vol. 23, no. 4, pp. 541–545, 2016.

[2] W. Yang, Y. Chen, Y. Liu et al., "Cascade of multi-scale convolutional neural networks for bone suppression of chest radiographs in gradient domain," *Medical Image Analysis*, vol. 35, pp. 421–433, 2017.

[3] M. Kettunen, M. Manzi, M. Aittala, J. Lehtinen, F. Durand, and M. Zwicker, "Gradient-domain path tracing," *ACM Transactions on Graphics*, vol. 34, no. 4, pp. 1–13, 2015.

[4] Z. Mi, H. Zhou, Y. Zheng, and M. Wang, "Single image dehazing via multi scale gradient domain contrast enhancement," *IET Image Processing*, vol. 10, no. 3, pp. 206–214, 2016.

[5] P. Moeskops, M. A. Viergever, A. M. Mendrik, L. S. de Vries, M. J. N. L. Benders, and I. Isgum, "Automatic segmentation of MR brain images with a convolutional neural network," *IEEE Transactions on Medical Imaging*, vol. 35, no. 5, pp. 1252–1261, 2016.

[6] K. Sss, K. Ayush, and R. V. Babu, "DeepFix: a fully convolutional neural network for predicting human eye fixations," *IEEE Transactions on Image Processing*, vol. 26, no. 9, pp. 4446–4456, 2017.

[7] J. Kleesiek, G. Urban, A. Hubert et al., "Deep MRI brain extraction: a 3D convolutional neural network for skull stripping," *NeuroImage*, vol. 129, pp. 460–469, 2016.

[8] G. Wang, H. Chen, J. Zhou, and Y. Zhang, "Low-dose CT via convolutional neural network," *Biomedical Optics Express*, vol. 8, no. 2, p. 679, 2017.

[9] I. Wallach, M. Dzamba, and A. Heifets, "AtomNet: a deep convolutional neural network for bioactivity prediction in structure-based drug discovery," *Mathematische Zeitschrift*, vol. 47, no. 1, pp. 34–46, 2015.

[10] X. Liang, C. Xu, X. Shen, J. Yang, S. Liu, and J. Tang, "Human parsing with contextualized convolutional neural network," *IEEE Transactions on Pattern Analysis & Machine Intelligence*, vol. 39, no. 1, pp. 115–127, 2016.

[11] R. Chellappa, "Digital image processing and analysis," *Journal of Food Processing & Preservation*, vol. 19, no. 12, pp. 307–314, 2015.

[12] L. X. Buffoni, J. Coulombe, and M. Sawan, "Image processing strategies dedicated to visual cortical stimulators: a survey," *Artificial Organs*, vol. 29, no. 8, pp. 658–664, 2015.

[13] M. Couprie, F. N. Bezerra, and G. Bertrand, "Topological operators for grayscale image processing," *Journal of Electronic Imaging*, vol. 10, no. 10, pp. 1003–1015, 2015.
[14] R. T. Mullapudi, V. Vasista, and U. Bondhugula, "Polymage," *Acm Sigarch Computer Architecture News*, vol. 43, no. 1, pp. 429–443, 2015.
[15] C. A. G. Gonzalez, O. Wertz, O. Absil, D. Mawet, J. Milli, and P. Hinz, "VIP: vortex image processing package for high-contrast direct imaging," *The Astronomical Journal*, vol. 154, no. 1, p. 07, 2017.
[16] T. Sieberth, R. Wackrow, and J. H. Chandler, "Motion blur disturbs – the influence of motion-blurred images in photogrammetry," *Photogrammetric Record*, vol. 29, no. 148, pp. 434–453, 2015.
[17] W.-Z. Shao, H.-S. Deng, Q. Ge, H.-B. Li, and Z.-H. Wei, "Regularized motion blur-kernel estimation with adaptive sparse image prior learning," *Pattern Recognition*, vol. 51, no. C, pp. 402–424, 2016.
[18] H. Zhang, L. Ying, Y. Zhang, and Q. Shen, "Spectral-spatial classification of hyperspectral imagery using a dual-channel convolutional neural network," *Remote Sensing Letters*, vol. 8, no. 5, p. 10, 2017.
[19] F. Kou, W. Chen, C. Wen, and Z. Li, "Gradient domain guided image filtering," *IEEE Transactions on Image Processing*, vol. 24, no. 11, pp. 4528–4539, 2015.
[20] F. Navarro, F. J. Serón, and D. Gutierrez, "Motion blur rendering: state of the art," *Computer Graphics Forum*, vol. 30, no. 1, pp. 03–26, 2015.

Hindawi
Scientific Programming
Volume 2022, Article ID 8496151, 9 pages
https://doi.org/10.1155/2022/8496151

Research Article

A Sentiment Analysis Method for Teaching Evaluation Texts Using Attention Mechanism Combined with CNN-BLSTM Model

Hong Peng, Zhenwei Zhang, and Hua Liu

School of Computing, Huanggang Normal University, Huanggang, Hubei 438000, China

Correspondence should be addressed to Hua Liu; liuhua_hgnu@126.com

Received 22 December 2021; Revised 28 January 2022; Accepted 4 February 2022; Published 25 February 2022

Academic Editor: Ahmed Farouk

In view of the problems that most existing emotion analysis models ignore the relationship between emotions and are not suitable for students, an emotion analysis model of teaching evaluation text based on deep learning is proposed. Firstly, combining the advantages of CNN extracting phrase features and BLSTM extracting sequence features, the CNN-BLSTM model is constructed to effectively enhance the extraction ability of text information. Then, the attention mechanism is used to adaptively perceive the context information, extract the text features that affect students' emotion, and construct the CNN-BLSTM-AT model. Finally, the CNN-BLSTM-AT model is used to analyze the students' emotion types in the dataset, and the mini-batch gradient descent method is used for model training. The experiment uses the weibo_senti_100k dataset to demonstrate the performance of the proposed model. The results show that adding the attention mechanism can improve the accuracy of the model by about 0.23. Also, its recall rate is not less than 0.57 and the minimum value of F1 is 0.748, which is better than other comparison models, thus demonstrating the effectiveness of the proposed model.

1. Introduction

At present, most of the work of sentiment analysis focuses on the research of sentiment polarity directly presented by the text. It mainly uses statistical machine learning methods to divide the text into positive emotions and negative emotions. There are few studies on the emotions of students that may be triggered by the text [1–4].

The purpose of student sentiment analysis is to study the mechanism by which language and text inspire students to produce emotions such as joy, anger, sorrow, and happiness and to predict the emotions that students may produce after reading the text. Students' online evaluation of teaching is a key link in the development and support system of teachers in various universities. In the practice of online teaching evaluation for many years, universities have accumulated massive amounts of textual data on teaching evaluations. However, due to the non-structural characteristics of the texts of teaching evaluations, routines cannot be carried out. The statistical analysis of the data results in low data utilization. If things go on like this, not only does the teaching evaluation data fail to fully play its role in improving the teaching level of teachers but it also reduces the enthusiasm of students to participate in the evaluation of teaching. Analyzing and studying student emotions through evaluation texts has important practical significance and research value in understanding students' mental state and information retrieval [5]. However, because human emotions are very complex and student emotions are even more diverse, research is relatively difficult, and it is still in its infancy [6]. Existing studies often use hand-designed feature extraction methods to extract text features that affect students' emotions, ignoring the word order and context information of the text and failing to capture the complex language phenomena in the text. Also, most of the current mainstream student sentiment analysis methods adopt a multi-label way to express, and it is difficult to reflect the complexity of a variety of interrelated human emotions [7, 8].

Aiming at the problems that most existing models are not suitable for analyzing complex student emotions and ignoring the relationship between emotions, a teaching evaluation text emotion analysis model using attention mechanism and CNN-BLSTM model is proposed. Compared with other emotion analysis models, the innovations of the proposed model are as follows:

(1) In order to improve the text feature extraction ability of the proposed model, it uses the CNN model to set up convolution windows of different sizes to extract the binary and ternary features of the text. In addition, BLSTM is used for sequence feature extraction, thereby providing highly reliable text features for subsequent classification.

(2) In view of the lack of consideration of the relationship between emotions in traditional analysis models, the proposed model introduces an attention mechanism. It can adaptively combine context information and student emotion information to extract key text features that affect student emotions, effectively improving the accuracy of emotion classification.

2. Related Research

Thanks to the rapid development of computer technology, the research objects of sentiment analysis have also developed from sentence and document level to attribute set data, which have better analysis accuracy and reliability [9]. Sentiment analysis methods have also made considerable progress from the initial sentiment dictionary-based sentiment analysis to machine learning-based sentiment analysis and then to deep learning-based analysis and research [10]. There have been many research studies on sentiment analysis based on sentiment dictionary, such as reference [11] extracting binary relations through word segmentation and dependency analysis. The existing sentiment dictionary is combined with web page information and manual annotations to mark it to form a binary relational knowledge base for sentiment analysis. But it did not take into account the influence of different contexts on emotional orientation. Reference [12] describes a rule-based sentiment analysis method. A sentiment dictionary based on morphological rules and ontological models is used for text sentiment analysis, and the language part that defines the sentiment of the text is determined. A good classification result has been achieved, but the classification accuracy needs to be improved.

Attribute-level sentiment classification based on machine learning mostly uses traditional machine learning classifiers such as support vector machines and Naive Bayes. For example, Samara et al. [13] studied the use of active stimuli to recognize emotional states. A hierarchical machine learning method for emotional state recognition based on facial expressions was proposed. The feature representation based on Euclidean distance is combined with the custom coding of the user's self-reported emotional state. A more accurate emotion recognition is achieved, but the recognition efficiency needs to be improved. Basha et al. [14] proposed a machine learning text emotion recognition method. Using natural language processing technology, emotional information is extracted and recognized when reading or writing. However, the accuracy of emotion recognition for daily non-standard language or behavior expression is poor.

Deep learning produces ideal prediction results in image recognition and other fields by learning multiple representations or features of data. Therefore, it has also been successfully applied to other fields such as sentiment analysis [15]. Jagirdar et al. [16] proposed a deep learning method for emotion analysis, focusing on the understanding of facial expressions of students in the classroom to better implement teaching. However, a large number of high-quality sentiment analysis training sets need to be labeled to improve the accuracy of the model. Lu and Zhang [17] proposed a sentiment analysis model using multi-channel convolutional neural network. It can extract more semantic information from emotional text and learn the emotional information hidden in emotional text. Kottursamy [18] used a new eXnet convolutional neural network for feature extraction to realize facial emotion recognition. Since the eXnet model has fewer parameters, the improved CNN model has higher accuracy. However, large-scale applications cannot be realized in a rich practical environment. At the same time, most of the above-mentioned sentiment analysis research studies are aimed at the recognition of text or facial expressions, and there are few research studies on students' emotion recognition in class. Therefore, a student sentiment analysis model using the attention mechanism and the CNN-BSTM model is proposed.

3. Sentiment Classification Model Based on CNN-BLSTM-AT Model

3.1. CNN-BLSTM Model. Both CNN and BLSTM have their own advantages in sentiment classification tasks. CNN uses multiple convolution kernels to perform convolution operations on the word vectors of the text to more effectively mine the potential semantic information of the text [19]. BLSTM can better predict the semantics of text sequences. Combining the two, the CNN-BLSTM model is formed for students' emotion analysis. The model structure is shown in Figure 1.

In the CNN-BLSTM model, text is input to CNN for emotional feature extraction, and deep-level information of the text is mined. Then, the feature value of CNN is input into BLSTM for further feature extraction, and a vector representation containing the entire sentence information is obtained, so as to realize emotion classification.

3.2. CNN Text Sentiment Analysis Feature Extraction. Based on the relevant characteristics of CNN, a double-layer parallel convolutional neural network is designed to extract and express text features. Its structure mainly includes three layers, embedding layer, convolution layer, and pooling layer.

3.2.1. Embedding Layer: Sentence Representation. The word frequency feature is used to form the word vector, the stuttering word segmentation is called to segment the

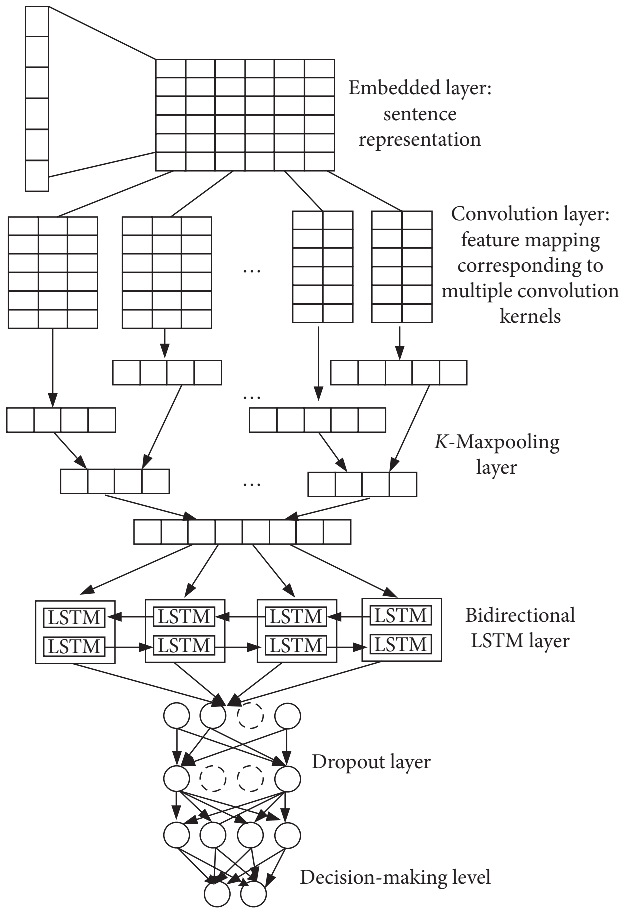


Figure 1: Structure of CNN-BLSTM model.

comment text data, and the word set is obtained and the word frequency is counted. Since the review text is short and concise, the sentence length (the number of words included) is limited to 80. The sentence is input into the embedding layer, each word is converted into a 512-dimensional word vector, and the final embedding layer outputs an 80×512 two-dimensional matrix. Each sentence forms an $n \times m$ two-dimensional matrix $\mathbf{Z} = [\mathbf{c}_1, \cdots, \mathbf{c}_i, \cdots, \mathbf{c}_n]$, where $\mathbf{c}_i = [\mathbf{x}_{i1}, \cdots, \mathbf{x}_{ij}, \cdots, \mathbf{x}_{im}]$ is the word vector of the word $\mathbf{c}_i$.

3.2.2. Convolutional Layer: Feature Extraction. The purpose of the convolutional layer is to extract the semantic features of the sentence, and each convolution kernel correspondingly extracts a certain part of the feature. The number of convolution kernels is set to 256. Convolution operation is performed on each sentence matrix $\mathbf{Z}$ output by the embedding layer:

$$\mathbf{F} = f(\boldsymbol{\omega}\mathbf{Z} + \mathbf{b}), \quad (1)$$

where $\mathbf{F}$ represents the feature matrix extracted by the convolution operation; ω is the weight matrix; and $\mathbf{b}$ is the bias vector. These are the parameters learned by the CNN network.

In order to facilitate the calculation, it is necessary to perform a non-linear mapping on the convolution result of each convolution kernel:

$$f = relu = \max(0, x), \quad (2)$$

where the relu function is one of the commonly used excitation functions for neural network models.

The convolution windows of sizes 2 and 3 are used at the same time to obtain the binary and ternary features of sentences.

3.2.3. K-Max Pooling Layer: Feature Dimensionality Reduction. After the sentence is convolved, the extracted features are passed to the pooling layer. The pooling layer further aggregates these features and simplifies the expression of features. The K-max pooling operation is used in the proposed model, and the Top-K maximum values of each filter are selected to represent the semantic information represented by the filter [20]. The K value expression is

$$K = \left\lfloor \frac{l - \tau_F + 1}{2} \right\rfloor, \quad (3)$$

where l is the length of the sentence vector and τ_F is the size of the convolution window.

Since the number of convolution kernels is set to 256, the sentence representation matrix generated after pooling is $\mathbf{C} \in \mathfrak{R}^{K\times 256}$.

The binary and ternary eigenvectors obtained from convolution layer and pooling layer are spliced together through fusion layer as the input matrix of BLSTM model.

3.3. BLSTM Text Sentiment Analysis Feature Extraction. LSTM memorizes the information of the previous nodes through the gate mechanism, so it is very suitable for processing sequence data [21, 22]. The model consists of multiple repeated modules to form a sequence. The input of each module contains not only the information of the current word but also the output of the hidden state of the previous word. The final model will obtain a vector representation containing the entire sentence information, so as to achieve sentiment classification. In LSTM, each node is more complicated than the traditional RNN, and its model structure is shown in Figure 2.

Each control unit of LSTM contains three gates (input gate $\mathbf{i}_t$, output gate $\mathbf{o}_t$, and forget gate $\mathbf{f}_t$), cell state $\mathbf{e}_t$, and hidden layer state $\mathbf{h}_t$, which are five parts. Among them, the first step of LSTM is to discard part of the information from the cell state. This operation is determined by the forget gate $\mathbf{f}_t$.

The forgetting gate reads the hidden state $\mathbf{h}_{t-1}$ of the previous node and the input word vector $\mathbf{c}_t$ of the current sequence and then outputs a value between 0 and 1 to the cell state $\mathbf{e}_{t-1}$ of the previous node. This indicates how much the current unit retains the cell state information of the previous time node. Among them, 1 means completely reserved, and 0 means completely discarded. The specific implementation is as follows:

$$\mathbf{f}_t = \sigma\left(\boldsymbol{\omega}_f \cdot [\mathbf{h}_{t-1}, \mathbf{c}_t] + \mathbf{b}_f\right), \quad (4)$$

where σ represents the sigmoid function.

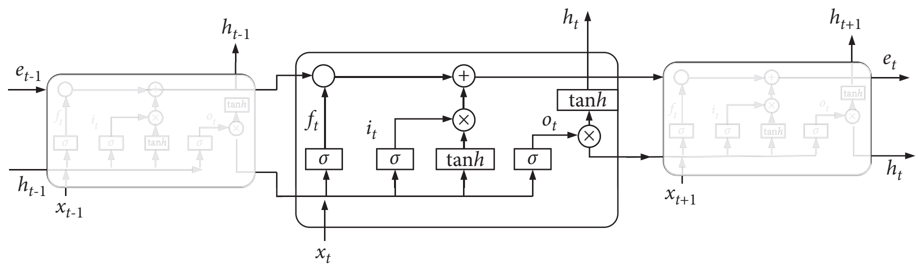


FIGURE 2: Structure of LSTM neural network model.

The second step of LSTM determines the amount of information added to the current cell state. This step requires two operational links to decide. The first link is the sigmoid layer of the input gate, which determines the information that needs to be updated, namely:

$$\mathbf{i}_t = \sigma(\boldsymbol{\omega}_i \cdot [\mathbf{h}_{t-1}, \mathbf{c}_t] + \mathbf{b}_i). \tag{5}$$

The second link is the tanh layer, which generates a vector $\widetilde{\mathbf{E}}_t$, namely:

$$\widetilde{\mathbf{E}}_t = \tanh(\boldsymbol{\omega}_e \cdot [\mathbf{h}_{t-1}, \mathbf{c}_t] + \mathbf{b}_e). \tag{6}$$

After obtaining $\mathbf{i}_t$ and $\widetilde{\mathbf{E}}_t$, the state of the old cell can be updated. Multiplying the old state and $\mathbf{f}_t$ will discard the information that needs to be discarded. Then, add $i_t * \widetilde{\mathbf{E}}_t$ to get the new cell state $\mathbf{E}_t$:

$$\mathbf{E}_t = \mathbf{f}_t * \mathbf{E}_{t-1} + \mathbf{i}_t * \widetilde{\mathbf{E}}_t. \tag{7}$$

The third step of LSTM is to determine the output of the model. This output is calculated from the current cell state $\mathbf{E}_t$, the output $\mathbf{h}_{t-1}$ at the previous moment, and the current input $\mathbf{c}_t$. Among them, $\mathbf{o}_t$ and $\mathbf{h}_t$ are calculated as follows:

$$\begin{aligned} \mathbf{o}_t &= \sigma(\boldsymbol{\omega}_o \cdot [\mathbf{h}_{t-1}, \mathbf{c}_t] + \mathbf{b}_o), \\ \mathbf{h}_t &= \mathbf{o}_t * \tanh \mathbf{E}_t. \end{aligned} \tag{8}$$

Through the output gate, the model finally gets the hidden layer output $\mathbf{h}_t$.

For the text sequence $\mathbf{S} = \{\mathbf{c}_1, \mathbf{c}_2, \cdots, \mathbf{c}_n\}$, after a series of operations, LSTM obtains the output vector $\mathbf{h}_t\,(t = 1, 2, \cdots, n)$ of the model. Finally, the model averages the output vector $\mathbf{h}_t\,(t = 1, 2, \cdots, n)$ of each time series to obtain the vector representation $\mathbf{h}_{LSTM}$ of the entire text.

Since the one-way LSTM can only capture the forward semantic information of the text, it lacks the acquisition of the reverse semantic information. Therefore, the proposed model uses BLSTM to obtain the forward and reverse semantic information of the text. Finally, the text vector representation of BLSTM is $\mathbf{h}_{BLSTM}$ [23, 24].

3.4. CNN-BLSTM Model Incorporating Attention Mechanism. The CNN-BLSTM model not only considers the semantic information within the sentence but also considers the long-distance dependence between sentences. It realizes the effective mining and expression of text semantics [25]. In order to further capture the key text information that affects students' emotions, the attention mechanism (AT) is introduced on the basis of the aforementioned methods to improve it. We propose a CNN-BLSTM model that integrates attention mechanism, namely, CNN-BLSTM-AT model. Its structure is shown in Figure 3.

The model is based on the following assumption: the semantic information of different parts of the text contributes differently to student sentiment classification. For important semantic information, more attention is allocated, and less attention is allocated to other parts. The key issue is how to allocate attention independently without receiving other information.

Observing the corpus, it is found that the importance of words or sentences in the text is highly dependent on the context. That is, the importance of the same word or sentence in different contexts is different. Inspired by this observation, the proposed model introduces a context vector $\mathbf{a}_c$, which can be regarded as a high-level representation containing textual context information, used to perceive important semantic features. The importance is distinguished by assigning an importance score (that is, attention weight) to each hidden node in the sequence layer. The larger the weight is, the more important it is for students' sentiment classification. The attention weight is calculated as follows:

$$\begin{aligned} \mathbf{a}_i &= \tanh(\boldsymbol{\omega}_a \mathbf{h}_i + \mathbf{b}_a), \\ \vartheta_i &= \frac{\exp(\mathbf{a}_c^T \mathbf{a}_i)}{\sum_{i=1}^{L} \exp(\mathbf{a}_c^T \mathbf{a}_i)}, \end{aligned} \tag{9}$$

where $\mathbf{h}_i \in R^{l_h}$ is the implicit vector corresponding to node i in the sequence layer; l_h is the length of the implicit vector; $\mathbf{a}_i \in R^{l_h}$ is the hidden vector in the attention layer; $\vartheta_\mathrm{i} \in R$ represents the attention weight of the node in the sequence layer and satisfies $\sum_{i=1}^{L} \vartheta_\mathrm{i} = 1$; and L Q is the number of sentences in the text. The context vector $\mathbf{a}_c \in R^{l_h}$ can be randomly initialized and then can adaptively learn context information during the training process.

According to the attention weight vector $\alpha \in R^L$, the hidden vectors of all nodes in the sequence layer are weighted to obtain the weighted semantic vector $\mathbf{u} \in R^{l_h}$. The calculation is as follows:

$$\mathbf{u} = \sum_{i=1}^{L} \vartheta_i \mathbf{h}_i. \tag{10}$$

Combining the weighted semantic vector $\mathbf{u}$ and the overall text semantic vector $\mathbf{h}_L$ to obtain the final text feature vector $\mathbf{d}$, which is calculated as follows:

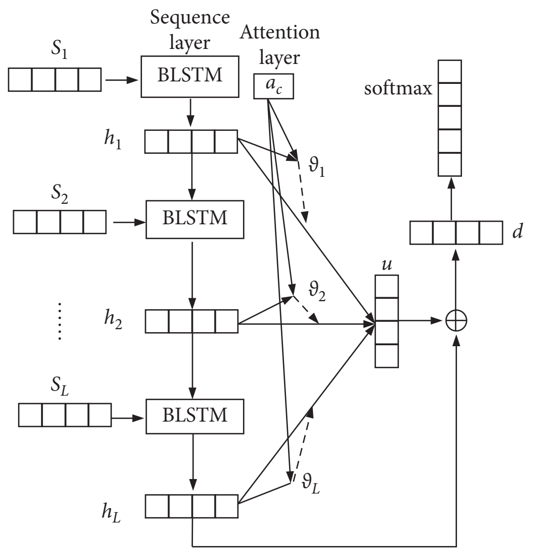


Figure 3: Structure of CNN-BLSTM-AT model.

$$\mathbf{d} = \tanh\left(\boldsymbol{\omega}_p \mathbf{u} + \boldsymbol{\omega}_x \mathbf{h}_L\right), \tag{11}$$

where $\mathbf{d} \in R^{l_h}$, the parameters ω_p and ω_x are learned adaptively during the model training process. The feature vector $\mathbf{d}$ calculated in this way highlights the role of semantic information related to student emotions and reduces the interference of other non-related information.

Finally, the feature vector $\mathbf{d}_s$ representing the text s is used as the input of softmax regression to obtain the probability distribution of student sentiment, which is expressed as follows:

$$p(s;\theta) = \text{softmax}\left(\boldsymbol{\omega}_s \mathbf{d}_s + \mathbf{b}_s\right), \tag{12}$$

where matrix $\omega_s \in R^{K\times l_h}$ and vector $\mathbf{b}_s \in R^K$ are the parameters that the model needs to learn and $p \in R^K$ is a K-dimensional polynomial distribution, which represents the proportion of each sentiment label. The number of sentiment labels is K, and $\sum_{k=1}^{K} p_k = 1$.

3.5. Model Training. The proposed model adopts supervised learning in the training process, taking the cross-entropy error between the true emotion probability distribution q and the predicted emotion probability distribution p of each text in the training set D as the loss function. The calculation is as follows:

$$\varphi(\mathrm{s},\eta;\theta) = -\sum_{k=1}^{K} q_k \ln\, p_k(s;\theta), \tag{13}$$

where parameter set $\theta = [\omega_*, \mathbf{b}_*, \mathbf{a}_c]$ and emotion label collection $T = \{\eta_1, \eta_2, \cdots, \eta_K\}$. Each component p_k in $p(s;\theta)$ corresponds to the predicted probability value of the student's emotion label η_k. q_k represents the true probability value of the student's emotional label as η_k. In order to strengthen the generalization ability of the model, the $L2$ regular term is added, and the loss function is set as follows:

$$J(\theta) = \frac{1}{N}\sum_{(s,\eta)\in D} E(s,\eta;\theta) + \frac{\lambda}{2}\|\theta\|^2. \tag{14}$$

The goal of model training is to obtain the parameter vector θ to minimize the loss function $J(\theta)$. The most used optimization algorithm is based on gradient descent, which only needs to solve the first derivative of the loss function. The computational cost is relatively small and can be applied to large-scale datasets. The proposed model adopts the mini-batch gradient descent method for training. In each iteration process, a small part of the sample is used to replace all the samples to participate in the calculation. Speed up model training while finding the global optimal solution.

4. Experiment and Analysis

The experimental environment configuration is shown in Table 1.

At the same time, the parameters of the proposed model are set for the Chinese dataset. The parameter settings in the experiment are shown in Table 2.

Colleges and universities in Wuhan have implemented online teaching evaluation for more than ten years. Post-90s and post-00s college students are no longer unfamiliar with this feedback mode of teaching evaluation. After the questionnaire survey and document sorting, this article selected nearly 10,000 textual comments for training and testing the sentiment classifier. After manual screening, we obtained about 6010 positive comments, 4770 of which were used for training and 1240 were used for testing. There were about 3950 negative comments, of which 3150 were used for training and 800 were used for testing. At the same time, all comments made by 320 teachers in the same year are selected for the processing output of the whole process.

4.1. Classification Result Statistics. The dataset is divided into training set and verification set by 10 : 1, and the statistical results are shown in Figure 4.

As can be seen from Figure 4, the number of misclassification of anger, surprise, and happiness is relatively small, and the number of misclassified texts does not exceed 20. In addition, there are many misclassifications of sadness and no emotion, accounting for about 65% of the total set of tests in this category. Since there are not many words expressing this kind of emotions and they will not be easily vented in the teaching evaluation texts, there are not many texts and there are many misclassifications. It can also be seen from the results in Figure 4 that students express the most disgusting emotions in the teaching evaluation text, such as hate, dislike, and so on. The teaching evaluation text has become a platform for students to vent their dissatisfaction, and this statistical result can also be useful for the school. Also, the teacher's follow-up student psychological counseling plays a certain supporting role.

4.2. Accuracy and Loss Comparison. In order to demonstrate the role of attention mechanism in student sentiment analysis, experiments were conducted using the experimental dataset. Among them, comparing the CNN-BLSTM model with or without attention mechanism, the results of accuracy and loss are shown in Figure 5.

Table 1: Experimental environment configuration.

Experimental environment	Environmental parameters
Operating system	Ubuntu16.04
CPU	i7-1195G7 5.00 GHz
Internal storage	16 GB
Programing language	Python 3.5
Deep learning framework	TensorFlow

Table 2: Experimental parameter setting of Chinese dataset.

	CNN	BLSTM	CNN-BLSTM	CNN-BLSTM-AT
Word vector dimension	80	80	80	80
Convolution kernel size	[3, 4, 5]	[3, 4, 5]	[3, 4, 5]	[3, 4, 5]
Number of convolution kernels	80		80	80
Pooling layer	Max-pooling	Max-pooling	Max-pooling	Max-pooling
Hidden layer dimension	80	80	80	80
Dropout	0.6	0.6	0.5	0.5
Number of iterations	100	100	100	100
Learning rate	0.001	0.001	0.001	0.001
L2 regularization coefficient	0.005	0.005	0.005	0.005

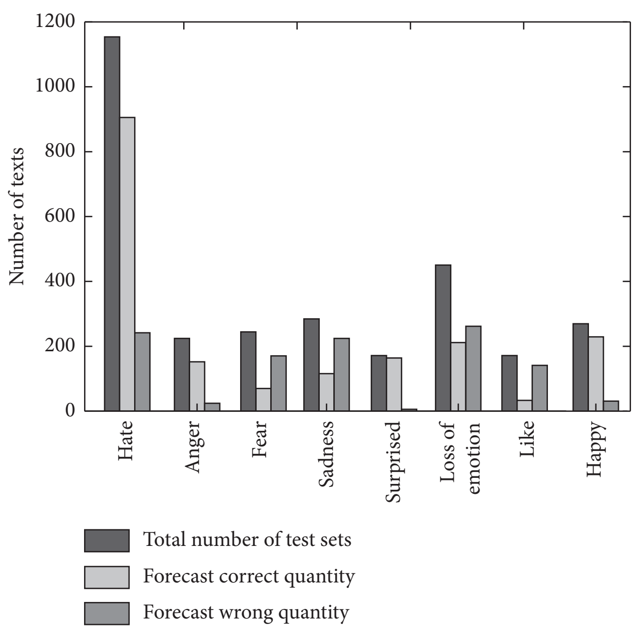


Figure 4: Statistics of text emotion classification results.

It can be seen from Figure 5 that the model with the attention mechanism has a significant improvement in accuracy than the model without the attention mechanism. Especially in the validation set, the accuracy of the model with the attention mechanism is 0.93, while the accuracy of the model without the attention mechanism is only 0.70, a difference of 0.23. Similarly, comparing the loss changes, for the training set, the difference between the two loss values is about 0.15. However, the loss value of the model without the attention mechanism in the verification focus is as high as 1.1. Through the training accuracy and loss value, it can be shown that the sentiment analysis performance of the proposed model has been greatly improved after the attention mechanism is introduced, and the problem that the model is easy to overfit is solved.

4.3. Recall Rate Comparison. In order to verify the performance of the proposed model, a significance test experiment was designed. Using word frequency as a feature, the models in [11, 14, 17] and the proposed CNN-BLSTM-AT model are used for 10-fold cross-validation. The recall rate of the sentiment analysis results is shown in Figure 6.

It can be seen from Figure 6 that compared with other models, the proposed model has the largest analysis recall rate in most arrays, which is greater than 0.57. The proposed model combines CNN and BLSTM and uses the attention mechanism to adaptively perceive the context information and extract the text features that affect students' emotion, which greatly ensures the accuracy of analysis. Reference [11] uses the existing sentiment dictionary combined with web page information and manual annotations to mark it to form a binary relationship knowledge base for sentiment analysis and only considers the binary relationship. Therefore, the analysis effect of the massive dataset of teaching evaluation text is not ideal, and the recall rate is lower than 0.56. But it did not take into account the influence of different contexts on emotional orientation. Similarly, reference [14] uses machine learning for text emotion recognition. The natural language processing technology used therein cannot cope with multiple types of sentiment analysis, such as disgust, so the result of the recall rate is not ideal. Reference [17] combines emotional dictionary and multi-channel CNN for emotional analysis, which can extract more semantic information from emotional text and learn the emotional information hidden in emotional text. Compared with the former two, the analysis ability has been improved to a certain extent, and the recall

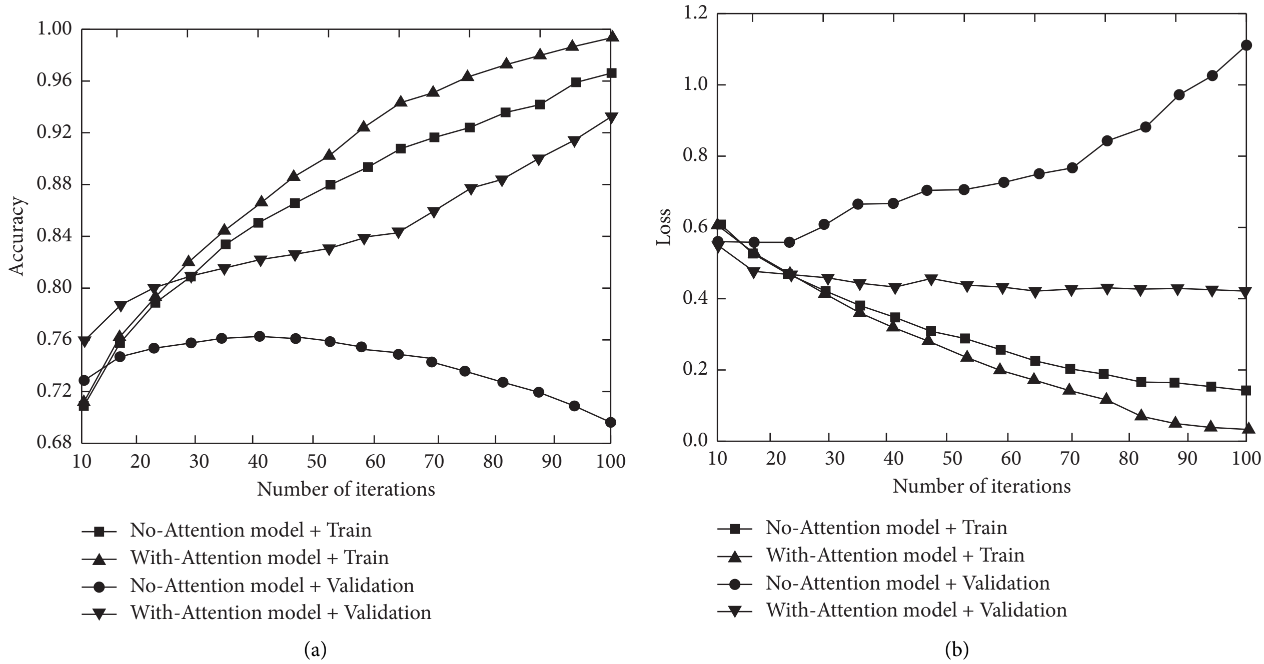


Figure 5: Comparison of accuracy and loss value. (a) Accuracy. (b) Loss.

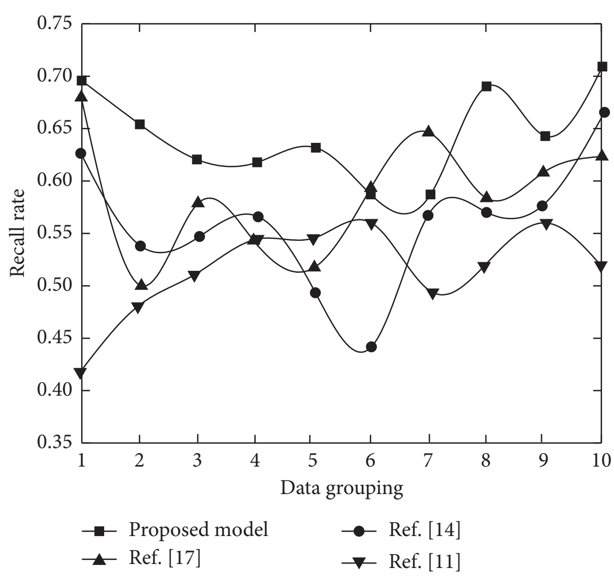


Figure 6: Comparison results of recall rates of different classification models.

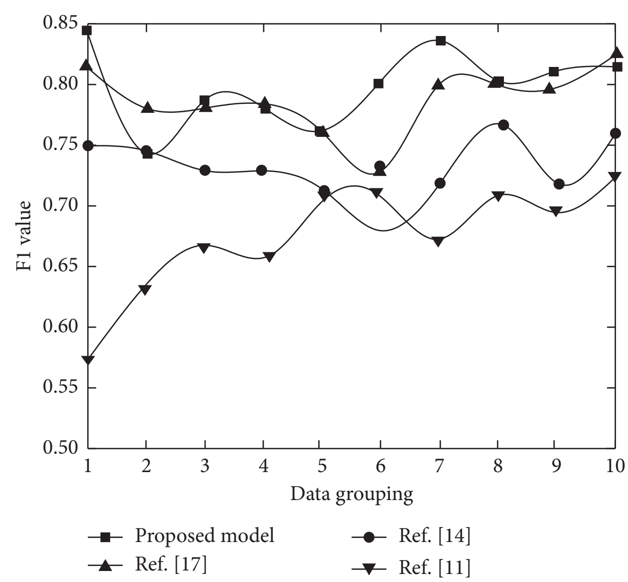


Figure 7: Comparison results of F1 value of different classification models.

rate reached 0.65 at the highest. However, a single deep learning model has certain limitations when dealing with multiple types of emotions, so it needs to be improved.

4.4. F1 Value Comparison. Similarly, the F1 value of the sentiment analysis results obtained by the proposed model and the models in [11, 14, 17] is shown in Figure 7.

It can be seen from Figure 7 that in the 10 sets of data of the proposed model, the maximum F1 value is 0.845, the minimum is 0.748, and the difference is 0.097. The overall performance of student sentiment analysis is better. The main reason is that the attention mechanism is introduced in the CNN-BLSTM model, which can better analyze various emotions that are not easy to recognize, such as disgust, insensitivity, and so on. Reference [11] uses existing sentiment dictionaries to combine web page information and manual annotations to realize sentiment analysis, and reference [14] performs sentiment classification based on machine learning. Neither of them considers the issue of multiple types of emotions in the teaching evaluation text dataset. Therefore, in most cases, the F1 value is lower than

0.75, and the difference between F1 values of different arrays reaches 0.16. Reference [17] combined sentiment dictionary and multi-channel CNN to complete the channel analysis, and the F1 value of some arrays is better than that of the proposed model. It may be that the emotion types in the array are relatively simple and easy to classify. For complex emotion types, the F1 value of the proposed model is higher and more stable.

5. Conclusion

In order to obtain the emotional state of students with high precision, a sentiment analysis model using the attention mechanism and the CNN-BLSTM model is proposed. Among them, the phrase feature and sequence feature of the text are extracted, respectively, through CNN and BLSTM, and the attention mechanism is used to adaptively perceive context information to extract text features that affect students' emotions. We input the fused text features into the softmax classifier to complete sentiment classification. The performance of the proposed model is demonstrated experimentally based on the weibo_senti_100k dataset. The results show that there are more misclassifications of sadness and no emotion, accounting for about 65% of the total set of tests in this category. Also, adding attention mechanism can significantly improve the accuracy of analysis. In addition, the result recall rate of the proposed model in any array is greater than 0.57. In addition, the maximum value of F1 is 0.845, the minimum is 0.748, and the difference is 0.097. For complex emotions, while improving the accuracy of analysis, it also ensures the stability of the model.

However, deep learning methods require large-scale training corpus to improve the learning ability and generalization ability of the model. In practice, the cost of manual labeling is often high, and it is difficult to obtain a large amount of labeling data for specific fields. Therefore, in future work, we will consider combining deep learning methods and transfer learning methods for student teaching evaluation text analysis to alleviate the impact of domain dependence.

Data Availability

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

Conflicts of Interest

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

Acknowledgments

This study was supported by the Huanggang Normal University High-Level Cultivation Projects (no. 37), First-Class Undergraduate Courses Project of Huanggang Normal University (no. 2021CK41), Industry and Science Cooperation and Collaborative Education Project of Ministry of Education of China (no. 202101091023), Hubei Provincial Social Science Fund Prophase Funding Projects (no. 20ZD096), and Research Planning Foundation on Social Sciences of the Ministry of Education (no. 20YJA870017).

References

[1] L.-y. Xue, Q.-r. Mao, X.-h. Huang, and J. Chen, "NLWSNet: a weakly supervised network for visual sentiment analysis in mislabeled web images," *Frontiers of Information Technology & Electronic Engineering*, vol. 21, no. 9, pp. 1321–1333, 2020.

[2] K. Wang and Y. Zhang, "Topic sentiment analysis in online learning community from college students," *Journal of Data and Information Science*, vol. 5, no. 2, pp. 33–61, 2020.

[3] W. F. Dong and Y. F. Qiu, "Transnational sentiment analysis of Social Media for CSA Social Enterprise Innovation-from the Perspective of Sharing Economy and collaborative consumption," *Journal of Information Management*, vol. 26, no. 1, pp. 71–98, 2019.

[4] H. R. Alburo, C. L. C. S. Romana, and L. S. Feliscuzo, "Sentiment analysis of the Academic Services of ESSU Salcedo campus using Plutchik model and Latent Dirichlet allocation algorithm," *International Journal of Recent Technology and Engineering*, vol. 9, no. 6, pp. 176–183, 2021.

[5] W. Muhammad, M. Mushtaq, K. N. Junejo, and M. Y. Khan, "Sentiment analysis of product reviews in the Absence of Labelled data using supervised learning Approaches," *Malaysian Journal of Computer Science*, vol. 32, no. 2, pp. 118–132, 2020.

[6] D. E. Dafaallah and A. S. Hashim, "Sentiment analysis Techniques to analyze Hse Situational Awareness at Oil and Gas platforms using machine learning," *Indian Journal of Computer Science and Engineering*, vol. 11, no. 5, pp. 640–645, 2020.

[7] A.-M. P. Rudzevych, "Machine learning in sentiment-analysis of text information on the example of user attitudes regarding candidates for Ukrainian presidential elections 2019," *System Research and Information Technologies*, vol. 2020, no. 3, pp. 78–88, 2020.

[8] F. M. J. Mehedi Shamrat, S. Chakraborty, M. M. Imran, J. N. Muna, and M. M. Billah, "Sentiment analysis on twitter tweets about COVID-19 vaccines using NLP and supervised KNN classification algorithm," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 23, no. 1, pp. 463–470, 2021.

[9] P. Liu, L. Zhang, and J. A. Gulla, "Multilingual review-aware deep Recommender system via aspect-based sentiment analysis," *ACM Transactions on Information Systems*, vol. 39, no. 2, pp. 1–33, 2021.

[10] K. S. Todd, A. P. Lapointe, and S. P. Broglio, "Sentiment analysis of Journal articles, press Releases, and news articles Pertaining to chronic Traumatic Encephalopathy," *Medicine & Science in Sports & Exercise*, vol. 52, no. 7S, p. 618, 2020.

[11] B. Niu and Y. Huang, "An improved method for web text affective cognition computing based on knowledge Graph," *Computers, Materials and Continua*, vol. 59, no. 1, pp. 1–14, 2019.

[12] B. Yergesh, G. Bekmanova, A. Sharipbay, V. Franzoni, and A. Milani, "Sentiment analysis of Kazakh text and their polarity," *Web Intelligence*, vol. 17, no. 1, pp. 9–15, 2019.

[13] A. Samara, L. Galway, R. Bond, and H. Wang, "Affective state detection via facial expression analysis within a human-computer interaction context," *Journal of Ambient Intelligence and Humanized Computing*, vol. 10, no. 6, pp. 2175–2184, 2019.

[14] S. R. Basha, M. Rao, P. Reddy, and G. R. Kumar, "Emotional tweets analysis on Social Media with short text classification using various machine learning Techniques," *Journal of Computational and Theoretical Nanoscience*, vol. 17, no. 12, pp. 5477–5482, 2020.

[15] Y. Liu, J. Lu, J. Yang, and F. Mao, "Sentiment analysis for e-commerce product reviews by deep learning model of Bert-BiGRU-Softmax," *Mathematical Biosciences and Engineering*, vol. 17, no. 6, pp. 7819–7837, 2020.

[16] M. A. Jagirdar, M. S. Reddy, M. R. Loha, P. Kshirsagar, and A. Yadav, "Deep learning Approach for Identification of students emotion," *Journal of Xi'an University of Architecture and Technology*, vol. 12, no. 5, pp. 1193–1203, 2020.

[17] X. Lu and H. Zhang, "An emotion analysis method using multi-channel convolution neural network in Social networks," *Computer Modeling in Engineering and Sciences*, vol. 125, no. 1, pp. 281–297, 2020.

[18] K. Kottursamy, "A review on finding efficient Approach to Detect customer emotion analysis using deep learning analysis," *Journal of Trends in Computer Science and Smart Technology*, vol. 3, no. 2, pp. 95–113, 2021.

[19] D. F. Sengkey, A. Jacobus, and F. J. Manoppo, "Effects of kernels and the proportion of training data on the accuracy of SVM sentiment analysis in lecturer evaluation," *IAES International Journal of Artificial Intelligence*, vol. 9, no. 4, pp. 734–743, 2020.

[20] K. Kobs, A. Zehe, A. Bernstetter, J. Chibane, and A. Hotho, "Emote-controlled: obtaining implicit viewer feedback through Emote-based sentiment analysis on comments of Popular Twitch.tv channels," *ACM Transactions on Social Computing*, vol. 3, no. 2, pp. 1–34, 2020.

[21] K. Subramonian and G. Sumathi, "Drowsiness detection system with speed Limit Recommendation using sentiment analysis," *International Journal of Recent Technology and Engineering*, vol. 10, no. 1, pp. 184–190, 2021.

[22] X. Ma, J. Zeng, L. Peng, G. Fortino, and Y. Zhang, "Modeling multi-aspects within one opinionated sentence simultaneously for aspect-level sentiment analysis," *Future Generation Computer Systems*, vol. 93, no. 08, pp. 304–311, 2019.

[23] M. Kumar, A. Venkataramaiah, N. Ambuga, N. Achar, and M. K. Av, "Twitter sentiment analysis using aspect-based Bidirectional gated Recurrent Unit with self-attention mechanism," *International Journal of Intelligent Engineering and Systems*, vol. 13, no. 5, pp. 97–110, 2020.

[24] M. Song, H. Park, and K. S. Shin, "Attention-based long short-term memory network using sentiment lexicon embedding for aspect-level sentiment analysis in Korean," *Information Processing & Management*, vol. 56, no. 3, pp. 637–653, 2019.

[25] Y. Z. Zhang, P. Tiwari, D. W. Song et al., "Learning interaction dynamics with an interactive LSTM for conversational sentiment analysis," *Neural Networks*, vol. 133, no. 3, pp. 40–56, 2021.

Hindawi
Scientific Programming
Volume 2022, Article ID 4570550, 10 pages
https://doi.org/10.1155/2022/4570550

Research Article

Financial Self-Service Transaction Method Based on Wireless Communication Network

Wangsong Xie

Business School, Wuxi Taihu University, Wuxi 214064, Jiangsu, China

Correspondence should be addressed to Wangsong Xie; xiewangsong@126.com

Received 5 January 2022; Revised 24 January 2022; Accepted 3 February 2022; Published 24 February 2022

Academic Editor: Ahmed Farouk

With the advent of the new era and the rapid development of the service industry, a self-contained terminal control business with its high-performance operation provides reliable information, saves a lot of manpower and time resources, and maintains flexibility, thus becoming an insignificant and important part of the financial services industry. This article aims to study the financial self-service transaction method based on a wireless communication network. This article starts from three stages such as functional planning, future direction, and final management and makes every effort to help the bank focus on three-dimensional and intelligent development of main business channel services from three levels such as technology, facilities, and channels, so as to realize the banking business from "production and direction" to "the transformation of marketing and experience," providing end users with a brand-new work experience at anytime and anywhere to increase productivity and reduce labor costs. The research results show that more than 80% of the interviewed people have expressed affirmation of the financial self-service transaction service under the wireless communication network, and the interactive design of the operation interface and the information data and security system need to be further improved.

1. Introduction

Although the prospect of "my country's wireless communication network" is bright, its development is far from human expectations [1]. With the rapid development of society, financial services have penetrated each of our worlds. In the past, we had to go to the bank to queue up for business. Now, we can handle business on personal terminals and enjoy 24×365 uninterrupted services. Financial services are closely related to the lives of each of us [2].

With the development of financial information construction and applications, users have more and more needs for financial transaction services [3]. In order to efficiently and promptly respond to user requests for autonomous financial services, it is necessary to develop a set of financial self-service transaction service systems based on wireless communication networks to realize the mobilization of operation and maintenance works, thereby improving the service level of the network center and enhancing users' financial transaction self-service experience. In order to better serve customers, reduce the labor intensity of tellers, and improve the level of financial services, it will become an inevitable trend for transactions to turn to self-service equipment [4, 5]. As a bank's well-functioning and convenient port of call, the role of ATM is obvious. It is the bank's self-service window, providing customers with convenient and fast financial services every day, and is the bank's window image.

At present, there are few researches on financial self-service terminals at home and abroad. From the application point of view, the financial self-service terminal can be regarded as a special self-service financial service terminal [6]. Introducing the Internet of Things into the financial service industry and exploring the driving costs and processes of financial innovation are important milestones in accelerating the promotion of financial innovation. From the perspective of banks and other supply-chain financial institutions, Li takes mainstream trading products in the commodity-trading market as the research object, adopts the LA-VAR model, and fully considers the market-price fluctuations and liquidity factors of supply-chain finance. The theoretical basis for the continuous innovation of rural financial products is analyzed. On the basis of analyzing the basic characteristics and types of rural financial product innovation, the connotation of rural financial product sustainable innovation is explored, evaluation criteria are clarified, and a theoretical foundation for continuous dynamic evaluation is laid [7]. Estrella-Ramon's study extends the diffusion of innovation theories and technology acceptance models that are applicable to describe and model the behaviors observed by individual customers during the preadoption phase of the adoption process. The log-logistic parameter survival model uses panel data to apply from 1,357 new customers randomly selected by the bank. There are significant differences between the survey results and the cycle of bank interaction, the number of products involved in the interaction, and the convenience of interaction and customer behavior related to risks. The results confirm that customers who are more likely to adopt online banking faster show offline-behavior patterns that are more related to higher interaction cycles and convenience [8]. Internet technology has affected the banking system because it can improve the performance of financial services. One of the main problems of the online banking system is the customer's perception of security and trust. Barkhordari conducted an experimental investigation on the important factors affecting the trust of Iran's electronic payment system. A set of potential trust determinants is developed and organized into three main groups: technology and transaction procedures, access to, and availability of security guidelines. In empirical studies, the direct impact of these factors on perceived trust and their indirect impact through perceived security have been evaluated. The data were collected from customers of several Iranian banks. Research has found that perceived security and trust have a positive impact on the use of electronic payment systems. As a result, adherence to technology and transaction procedures, as well as access to security guidelines is the most important factor affecting customer perception of trust [9]. These three researchers all agree that the combination of the Internet and finance can bring huge economic benefits to banks. Although they have conducted experimental studies from different perspectives, how to adjust the banking system with the participation of the Internet, and the effectiveness of the masses have been ignored.

Since the interface interaction design industry of financial transaction self-service terminal service equipment in our country started late, the interface interaction design of self-service terminal equipment used in the market is not yet mature. The user groups served by financial transaction self-service terminal service equipment are extensive and complex. Among them, there are many user groups with insufficient computer operation experience and low cognitive level. These users cannot fully enjoy the convenience and efficiency provided by modern technology self-service terminal service equipment. The main reason for this situation is that the interactive design of the interface in the financial transaction self-service terminal service equipment is not perfect. The self-service terminal page should be designed more simply and have a voice reminder function. It can also set volunteers at fixed points to guide people in business handling. Therefore, the improvement and perfection of the interactive design method of the financial transaction self-service terminal service equipment interface can make information more accurately and efficiently recognized, understood, and used by users, helping users to complete interactive tasks smoothly and improving user experience to the greatest extent. Interaction design is the embodiment of humanization, which represents the interaction between users and devices. If properly designed, users can easily and quickly complete business and have a good user experience. This study uses "user research and analysis-interface interactive innovation design-interface interactive design details redesign-usability testing" as the research process to explore and study the interface interactive design of financial transaction self-service terminal service equipment and find more suitable financial self-service transactions method.

2. Wireless Communication Network and Financial Transaction Algorithm

2.1. Financial Transaction Self-Service Terminal Equipment. With the continuous expansion of banking business, self-service financial equipment was born. Self-service financial equipment is mainly to meet people's daily needs. It is precise because of its practicality [10] that self-service financial equipment is more and more popular with banks and mobile devices. According to the comprehensive statistics of China's major state-owned banks, national joint-stock banks, urban commercial banks, rural commercial banks, rural credit cooperatives, and other financial institutions in 2016, about 103000 ATMs were newly purchased. Favored by institutions, this kind of self-service financial equipment is mostly 24-hour equipment such as ATM, and the number is large [11]. The user groups of self-service terminals are extensive and complex. For users with low technical level and inexperience, difficulty to understand viewpoints and difficulty to interact will affect their performance and enthusiasm. Therefore, it is necessary to improve the self-service terminal. With the improvement of technology and the improvement of the service industry, self-service terminals are widely used in the fields of finance, transportation, catering, government services, medical care, and retail [12]. Self-service terminals can reduce enterprise operating costs, provide value-added services, reduce the pressure of counter banking industry, and make people's life more convenient. It is expected that in the next few years, the self-service terminal market will enter a high-speed growth period. Self-service terminals will be seen everywhere in business halls, streets, and alleys in cities and even villages, and become an indispensable part of public life. Common self-service terminals around us include bank self-service teller machines, mobile phone self-service top-up machines, and campus transfer machines. Under the social background of the rapid development of information technology, the high-quality service economy based on the digital transmission network mechanism and automated management and control functions is strongly impacting the traditional product economy, and the self-service system is precisely this high-quality service economy [13]. The self-service platform that integrates multiple functions and realizes networked management is still in its infancy, and most of them are running on a stand-alone basis. The functions of the self-service platform include bank information query, personal business, corporate business, bank card transfer, agent payment business, etc. The realization of the financial self-service transaction service system under the wireless communication network can provide a comprehensive management service system integrating network management and intelligent self-service.

Wireless network communication technology has the characteristics of high speed, high penetration, and large capacity drive. Applying information technology to traditional enterprises can improve enterprise work efficiency, reduce energy consumption, improve productivity, and promote the upgrading and reorganization of traditional industries. Information technology provides technical support for system redesign [14–16]. In the past, we had to go to the bank counter to queue up for business. Now, we can operate on the financial self-service terminal device through the application of the wireless communication network and can handle our business needs at anytime and in anyplace with a network signal; on the contrary, in the past, financial services must be arranged in accordance with the bank's commuting time and must be operated by bank staff. On self-service financial equipment, consumers can independently complete the payment of various fees, avoiding the trouble caused by consumers needing to go to different places to pay corresponding fees. Self-service financial equipment not only improves the operational efficiency of the bank but also greatly saves people's time for payment and reduces the difficulty of payment [17]. At present, the financial industry is expanding bank outlets, improving the card environment for customers, providing all-weather and all-round financial services, reducing bank costs, and improving bank service quality and comprehensive competitiveness. At present, the business types managed by customers through electronic channels are growing exponentially at a higher growth rate [18].

2.2. Wireless Communication Network. The advantage of financial transaction self-service is to use the convenience and speed of information service embodied by high-tech means to provide a new self-assisted financial service for the financial service field with large liquidity [19]. On the one hand, the service can better improve the performance of self-service terminals; on the other hand, it can promote people's convenient life and improve service efficiency. With the need to improve service levels, the demand for self-service terminals in the wireless communication network and financial service industries has grown rapidly, which has also forced banks to turn to a key acceptance point, electronic self-service terminals [20]. On the wireless communication network, as a very effective service, the personal service terminal can provide person-centered care, attention, and personal service to customers and investigate the influence of the interaction mode between individuals in the system on the overall behavior of the system. Studying the complex network is the ultimate goal to understand the influence of network structure on dynamic energy behavior. When theoretically studying the dynamic characteristics of complex networks, complex networks can be expressed as the structural characteristics of communication networks in the following form [21, 22]. A single node dynamic network connection system can be expressed as follows:

$$R(t) = v(R(t)) + \delta \sum_{i=1}^{m1} a, \quad i = 1, 2, \ldots m1. \tag{1}$$

A single node discrete system [23] can be expressed as follows:

$$R(s+1) = v(R(s)) + \sum_{i=1}^{m1} b, \quad i = 1, 2, \ldots m1. \tag{2}$$

In the above formula, R represents the state vector of the i node. If $R = 0$, it means that the link between network nodes has no directionality. Such a network is called an undirected network [24]. The calculation method of the path length between single nodes is as follows:

$$\begin{aligned} l &= \frac{1}{q(q-1)} \sum_{i,i\neq q} k, \\ l &= k \pm \frac{2a, q}{k_i(k_i - 1)} \sum_{i,i\neq q}^{1} \end{aligned}, \tag{3}$$

where q is the number of nodes in the network, and the average path length describes the degree of separation of segments in the network, that is, how small the network is.

The wireless channel is an important part of the communication system such as the transmission medium between the transmitter and the receiver. In order to facilitate the understanding of the wireless communication network, we must first understand its signal transmission principle [25]. In the process of signal transmission from transmitter to receiver, it has to go through a variety of complex transmission paths. The wireless communication network is essentially a composite signal composed of incoming waves from different paths. During the transmission process, the received energy is affected by many factors such as the ground and constraints that affect signal transmission. In general, the received power of the antenna at a distance of the transmitter can be expressed as follows:

$$D_r(a) = \frac{D_t P_r P_t \gamma^2}{(4 \cdot 3.14)^2 a^2 l}. \tag{4}$$

D_r and D_t are the power of the transmitting end and the receiving end, P_r and P_t are the gains of the transmitting antenna and the receiving antenna, l is the signal transmission distance, and γ is the wavelength. When the relative position between the transmitter and the receiver changes slightly, the signal amplitude of the wireless channel will change. According to the Rice distribution [26], the probability density function in this case is as follows:

$$g_{\text{Rice}}(O) = \frac{O}{\varepsilon^2}\exp\left[-\frac{\left(\lambda^2+\chi^2\right)}{\left(2\varepsilon^2\right)}\right]i_1\left[\frac{o\chi}{\varepsilon^2}\right], \quad o \geq 0,$$
$$g_{\text{Rayleigh}}(o) = \frac{o}{\varepsilon^2}\exp\left[\frac{\lambda^2}{\left(2\varepsilon^2\right)}\right], \quad o \geq 0. \tag{5}$$

In equation (2), χ is the amplitude component of the line-of-sight path, and the ratio of the amplitude component under the line-of-sight path to the sum of the amplitude components under other non-line-of-sight paths is $o\chi/\varepsilon^2$. The larger the ratio, the smaller is the amplitude change. The larger the ratio, the greater is the amplitude change [27].

The power control of signal transmission is a very important link in the cellular system [28, 29]. One of the most important aspects when designing a communication system is how to reduce the transmission capacity of the system. Using power management technology, each user can reduce the antenna power that circulates in the communication quality meeting and at the same time can reduce interference to other users, increase the system capacity, and set the size of the transmission power according to the distance effect and the single user The power regulation in the cellular system is expressed as follows:

$$H_{i,p} = T_{i,p}J_i(i,p)\uparrow\left(\sum_{i=1}^{n}T_{r,t}J_i(r,t) - T_{i,p}J_i(r,t) + \beta_{r,t}\right),$$
$$H_{i,p} = T_{i,p}\left(\sum_{i=1}^{n}T_{r,t}(i,p) - T_{i,p} + \eta_{i,p}\right), \tag{6}$$

where $T_{i,p}$ represents the transmit power of a single user i in the cellular system, and $\beta_{r,t}$ is the thermal noise of the base station side receiver.

With the development of home communication and electronic technology such as the further integration of communication networks, broadcasting networks, and the Internet, providing users with electronic services has become a constant trend. The demand analysis of the equipment investment of the wireless communication network in the financial self-service transaction service terminal technology can be expressed as follows:

$$\sum_{t=1}^{N_t} = \frac{n}{2t} - \sqrt{r_t}\sqrt[i]{t(t+1)+1},$$
$$T = \left(\int(\beta\cdot r_t)\cdot\sum_{i-1}^{i}p\right) - \left(\underset{i=0}{\longleftarrow} i_{p-1}\right). \tag{7}$$

In order to solve the problem of limited or reduced variance model construction in wireless communication networks and personal business services, since the model involves limited reliability variables, the revised model (Tobit) of this survey is selected, which can be expressed as follows [30]:

$$A_i = A_i^* \sum(i-1)\delta + \gamma\cdot X_i,$$
$$X_{i=o} = \sqrt[2]{\left(i\cdot A_\gamma\right)}\delta + \delta - \gamma. \tag{8}$$

Using the least square method will lead to unfair and inconsistent values, so the Tobit model is used to analyze the influencing factors of wireless communication network applications in finance.

3. Application Experiment of Wireless Communication Network in Financial Self-Service Transaction

3.1. Test Subject. (1) 40 business handling people.

(2) ATM machines and other financial self-service transaction service equipment.

(3) Wireless communication network.

3.2. Experimental Process

(1) Research on wireless communication networks and financial self-service transaction services for user experience, a certain postal bank in this city is invited to conduct a questionnaire survey on the business of the day of the survey. The survey content is the experience of commonly used ATM machines and other self-service transaction terminal devices. It senses, understands user needs, and analyzes.

(2) Experimental research is conducted on the internal management of the financial industry, and development prospects of financial self-service transaction equipment combined with wireless communication networks and the areas that need improvement are analyzed and summarized.

(3) Dimensional analysis of the adoption of wireless communication networks and financial self-service transaction methods by the interviewees is carried out.

(4) Interface interaction design analysis of self-service transaction terminal service is carried out.

3.3. Experimental Results. By studying the self-service "man, machine, environment" system, the problems and design goals in the system can be effectively obtained. Through detailed situation investigation of counter services, the integrity of tasks in self-service can be ensured and possible situations can be avoided. Interaction design is dedicated to eliminating the barriers between people and computers, so that people do not feel that computers are high-tech things, but are tools that ordinary people can use as they please. The wireless communication network meets the rapid development of capacity requirements and the development of full services. The optimization of terminal functions to improve the convenience and ease of use of terminal functions is the key to improving customer experience. Wireless communication network plays an extremely important role in financial self-service transaction services.

4. Application of Wireless Communication Network in Financial Self-Service Transaction Service

The self-service channel of bank services has been unanimously recognized by the majority of users, providing customers with a brand-new self-assisted financing method. Banks are taken as an example. In 2012, China's e-banking (including online banking, mobile banking, ATM, self-service terminal, and other forms of self-service e-banking) transactions reached 89.62 billion, and the e-banking replacement rate increased to 72.3%.

However, the requirements for bank self-service terminals are also gradually changing, so the management difficulty is becoming more and more difficult. How to better improve management efficiency and form advanced bank self-service terminals have been paid more and more attention by banks and related industries. In order to meet the information processing needs of bank self-service, technical specifications on the development of bank self-service terminal and related user data standards are formulated, and an integrated structural system and technical system are proposed for bank self-service terminal design. It can better allocate the personal data and business logic processing information of self-service bank users, divide the permissions of business processors, users, and system administrators in detail, and build a high-level bank self-service terminal. A simulation diagram of the application process of a wireless communication network and a self-service transaction service is shown in Figure 1.

The people no longer need to wait for a long time to go to the counter to handle business but directly complete inquiries, deposits, withdrawals, transfers, supplementary bills, payment, and other services through financial self-service terminals, which saves users' time and improves financial payments. The environment has also improved the service level of credit cooperatives, further enhanced the market competitiveness of credit cooperatives, and improved the social image of credit cooperatives. We conducted a questionnaire survey on the use and usability of ATMs of the current common financial self-service transaction equipment. We selected 40 people from a postal bank in this city who came to the bank for business processing that day. Table 1 lists the basics of the interviewed people's information.

The interviewed people have different education levels and can conduct targeted data analysis on ATM self-service teller machines and other financial self-service transaction terminal equipment; according to their different experiences, they can understand the needs of different levels of subjects. The user groups of self-service terminals are extensive and complex. For users with low technical level and inexperience, difficulty to understand viewpoints and difficulty to interact will affect their performance and enthusiasm. Therefore, it is necessary to improve the self-service terminal. Table 2 lists the differences in preferences of different genders for financial self-service transaction services; Figure 2 shows the statistical data of these respondents' understanding of financial self-service transaction equipment.

It can be seen from Table 2 that under the 95% confidence level, the implicit attitudes of different genders towards self-service show different levels of avoidance under different indicators. Among them, the difference is significant under the D-score index, while the average reaction time under this index is not significantly different, and the difference is not significant under the explicit attitude difference index. In addition, we learned about the familiarity of these interviewed people with financial self-service transaction equipment, and the data are recorded as shown in Figure 2.

The 40 interviewed people all have a certain understanding of financial self-service transaction equipment. According to the data, we can understand that ATM machines and bank ticket machines have been widely popularized in our current daily lives. The usage rate is high.

According to the interviewed financial self-service transaction service experiencers (Figure 3), the financial self-service machine must complete a series of complex actions such as card reading, uploading, verification, testing, query, money suction, money dispensing, transfer, and printing. However, the fly in the ointment is that many self-service kiosks do not give full play to their advanced functions (Table 3). Some self-service kiosks often fail and fail to provide services and often make mistakes or swallow cards, and even some personal kiosks cannot be repaired after they fail due to aging. They have become simple decorations that no one cares about. Therefore, in this questionnaire survey, the 40 interviewed people have a further understanding of the experience of self-service transaction terminal service equipment. The data are recorded as shown in Figure 4.

According to the user's proficiency in the interactive design operation of the financial transaction self-service terminal service equipment interface and the frequency of use, users are roughly divided into four categories: novice users, mainstream users, expert users, and casual users. Every user will transform from a novice user to a mainstream user. Through in-depth research on novice users and casual users, the research and analysis are conducive to the solution of usability of nonfunctional problems in interactive design. Each user will have higher new requirements for the interactive design of the man-machine interface such as aesthetic requirements and functional requirements, so listening to the user's requirements for the functionality of the device will help to improve the design of the man-machine interface interaction. Details are redesigned The wireless communication network is combined with the financial self-service transaction service terminal to transform the experimental test results, and the data are recorded as listed in Table 4.

The application of wireless communication network in financial self-service transaction services greatly reduces the time for business processing, simplifies the steps required for transaction business, provides great convenience, and has the characteristics of easy-to-understand wireless operation, so there is a wide range of audience.

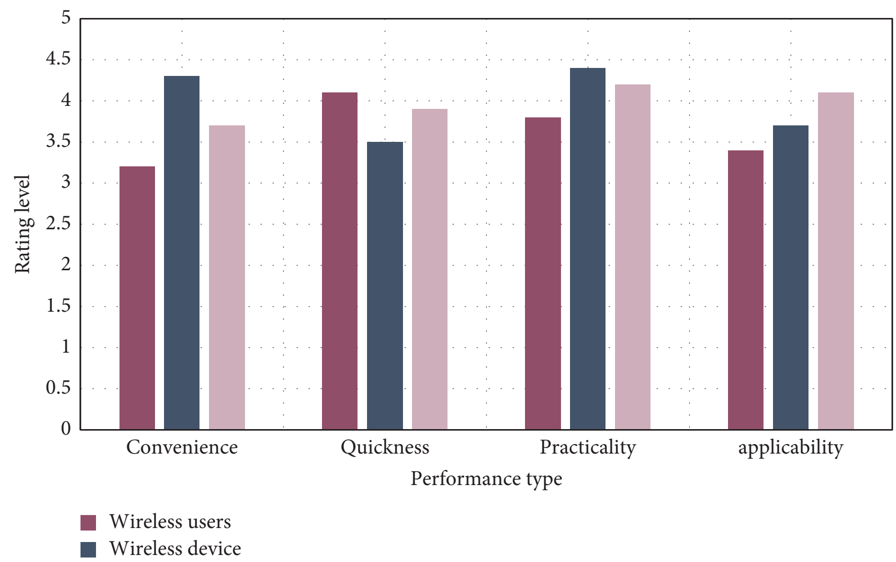


Figure 1: Performance analysis of wireless communication network applications.

Table 1: Basic information of the interviewed people.

Education level	First use	Used a few times	Frequently used
Primary school	3	3	4
Junior high school	2	5	3
High school or technical secondary school	4	4	2
College degree or above	5	1	4

Table 2: Differences in preferences of different genders for financial self-service transactions.

Statistical indicators	Group	Mean	Standard deviation
D score	Female	0.43	0.32
	Male	0,32	0.34
Response time difference	Female	342.9	284.5
	Male	298.5	358.1
Poor explicit attitude score	Female	2.38	1.28
	Male	2.27	0.98

Since the after-sales service problems of self-service transaction service equipment belong to the management of the manufacturer, this makes the management of financial self-service transaction service terminals more difficult. In this regard, some interviewees expressed that there are problems in the combination of wireless communication network and financial self-service transaction services, which are reflected in Figure 5.

Due to the use of information and source division models based on network technology, Internet finance on the one hand reduces the average transaction cost of traditional products and services, and on the other hand, it increases the degree of information asymmetry in our lending process. SME loans combine high efficiency, low cost, and cost-effective management with distributed funds and low default rates. The benefits of this new Internet consumption model are often in line with the concept of business integration. It incorporates disadvantaged groups and remote communities that are mainly involved in eliminating money into the traditional financial service system and uses efficient mobile payment methods and big data processing to give them flexibility and speed in financial services and products, while increasing the size and depth of tolerance.

Financial consumers are also paying more and more attention to user experience, are no longer satisfied with the services provided by traditional financial institutions, and are increasingly pursuing personalized and customized financial services. This demand will become stronger today with the improvement of information technology. We can develop integrated software management functions and distribution and automated upgrades for ATMs of different developers. In order to solve the problems of cross-bank business handling, the four interviewed people adopted the financial self-service transaction dimension summary (Table 5).

According to the data provided in Table 5, the two dimensions of usefulness and ease of use, as well as the social environment that has attracted the attention of the interviewed people, also illustrate the advantages of financial self-service

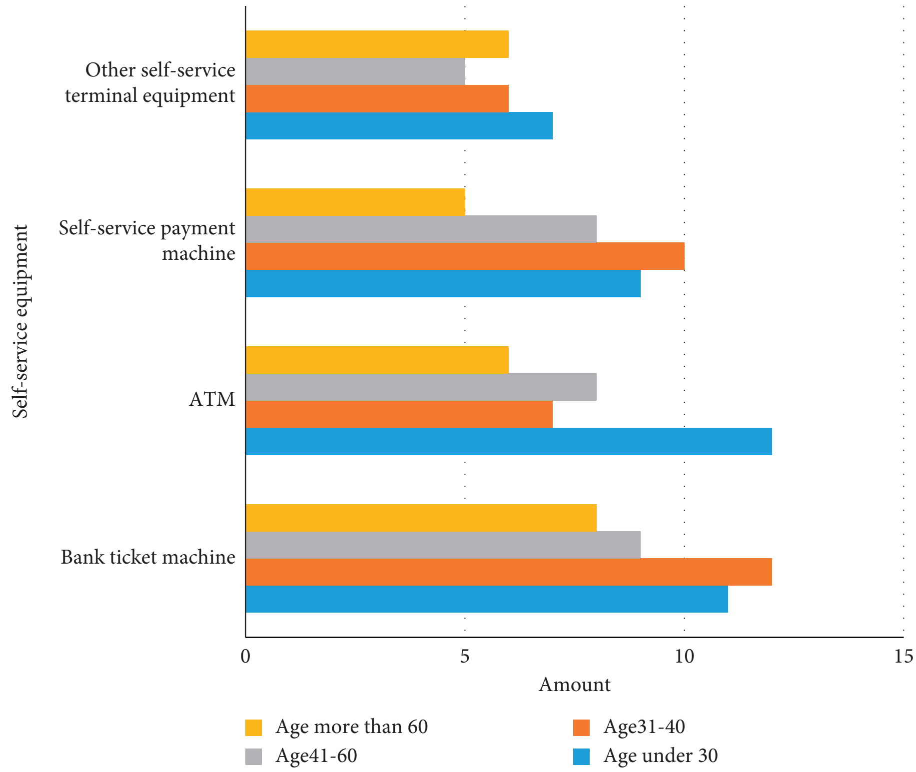


Figure 2: The survey respondents' usage statistics of self-service terminal equipment.

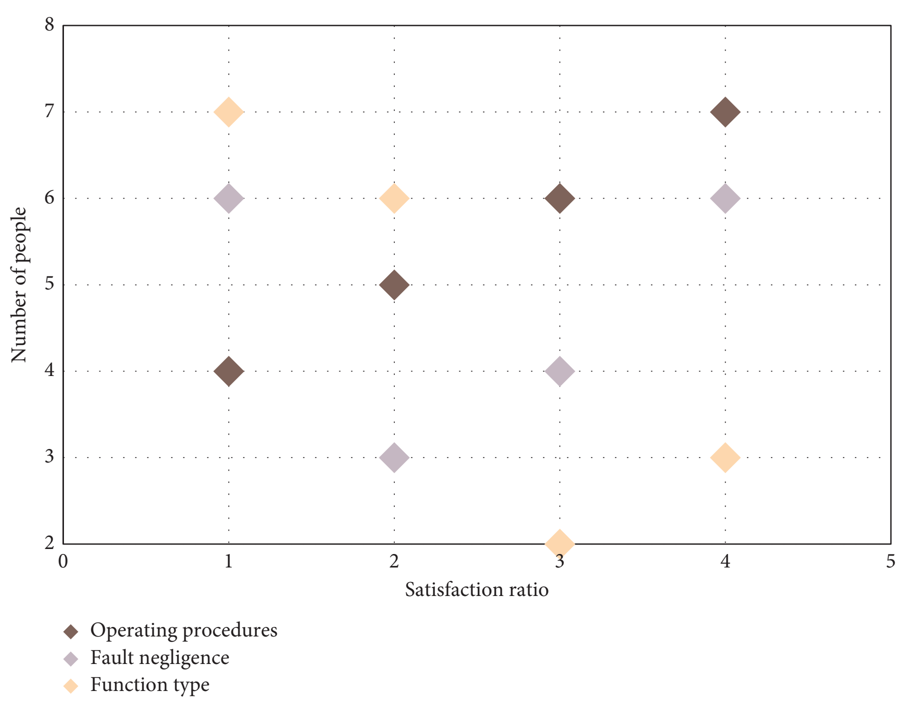


Figure 3: Problems in the current self-service machine business processing process.

transaction services. In the previous article, we mentioned the current problems of information asymmetry, incomplete information, and reputation risks in financial autonomous transaction services. In the face of these problems, wireless communication networks need to be updated and data monitored to enhance system security (Figure 6). With the help of Internet technology, it breaks the limitations of the working time and space of the bank in the past, uses the business data analysis system for risk management, comprehensively enhances the bank's capabilities, simplifies operations, and reduces costs.

Table 3: Self-service transaction server failure statistics table.

<!—Col Count:5 F0E0 Frequency of failure	Machine malfunction	Wrong account	Bank card is stuck	Slow response
Almost none	2	1	2	2
Occasionally	5	4	4	1
Frequently	3	5	4	7

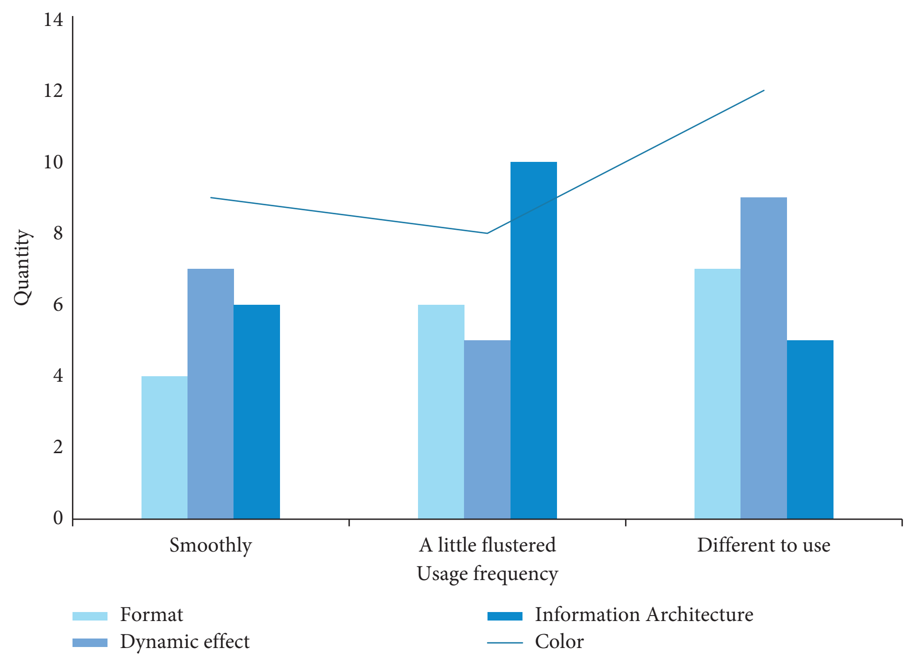


Figure 4: Service evaluation of financial self-service transaction equipment by interviewed mass users.

Table 4: Combination of wireless communication network and financial transaction self-service terminal.

Project type	Withdrawal	Transfer	Pay	Inquire
Wireless communication network interface control (1–10)	8	9	8	9
Total time spent on a task (minutes)	2.5	2.1	2.6	2.4
Success rate	100%	100%	100%	100%
Number of operation steps	4	5	4	3
Comprehension of wireless communication network interface (1–5)	4	5	3	5

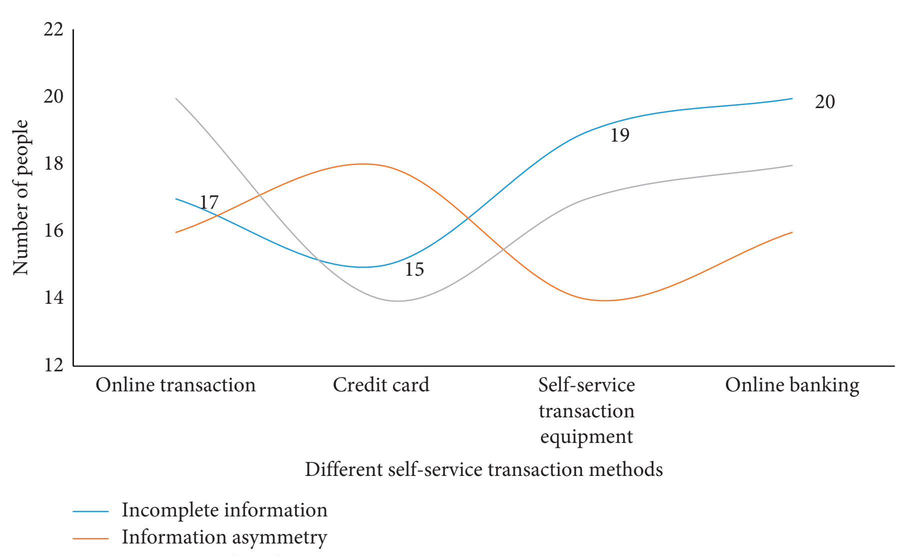


Figure 5: Problem statistics of different self-service transaction devices.

Table 5: Dimensions of adopting financial self-service transaction services.

Classification dimension	1	2	3	4
Usefulness and ease of use	√	√	√	√
Cost perception		√	√	
Self-efficacy	√		√	
Interpersonal environment				√
Social environment	√	√	√	√

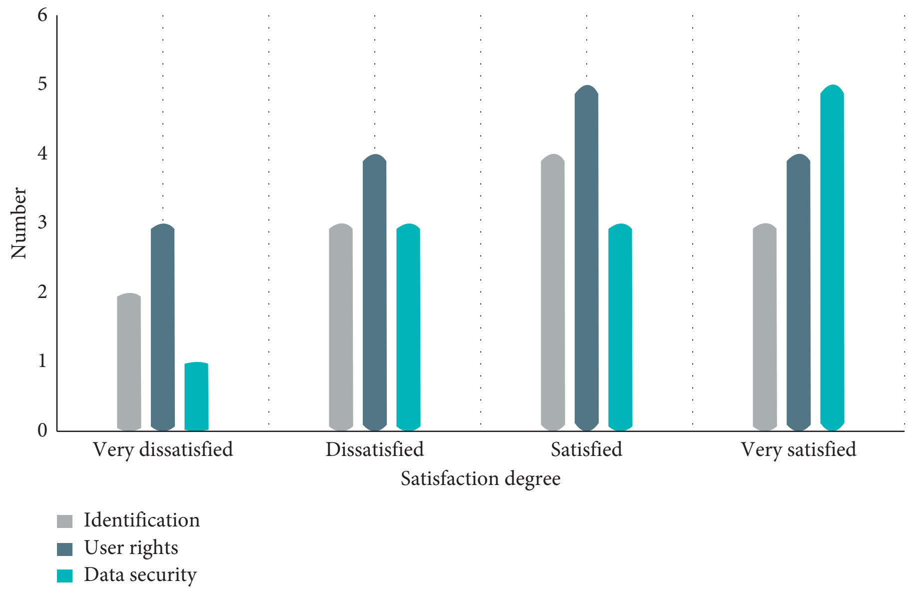


Figure 6: Statistics of people's satisfaction with different factors of system security.

To sum up, financial self-service terminals have been qualitatively improved in terms of technology, facilities, and channels. These changes provide end users with a new work experience, improve work efficiency, and reduce labor costs.

5. Conclusion

The financial self-service transaction service terminal system better realizes the related functions of deposit, withdrawal, transfer, and other requirements, with faster running speed and stable performance. When a user starts a transaction at the personal service terminal, the individual commercial terminal adopts the user's original structure, makes a simple entry decision, and then aggregates the data to the intermediate trading platform. The intermediate trading platform performs more complex authentication and will meet the requirements after the data are compiled again to the back-end error correction system and the back-end core processing system for transaction processing, it is gradually transferred to the self-service terminal of self-service farmer finance in the opposite direction, and finally, a complete transaction is completed. The intermediate business data processing platform processes nonaccounting data, which reduces the burden of the bank's back-end core host, makes the back-end core host mainly process accounting data, reduces the probability of database lock tables, improves host efficiency, and makes the back-end core host version uniform. The transaction is processed through the intermediate business platform and is decomposed into multiple transaction steps, which increases the flexibility of transaction definition and adapts to the changing needs of intermediate business. Self-service terminals can provide people with transaction or inquiry services at anytime and in anyplace. With the continuous improvement of urbanization and informatization, self-service machines will be full of streets and alleys. The research on wireless communication network and financial self-service transaction service market conducted in this study has a certain significance. Through these studies, it is helpful to predict the development trend and prospects of financial transaction self-service terminals and at the same time can summarize the actual implementation steps to guide the construction of financial transaction self-service terminal project. The self-service access service system mainly deals with structured data, but in the information age, there are more and more unstructured data, and the processing of unstructured data can be considered in the later period.

Data Availability

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflicts of Interest

The author declares that there are no conflicts of interest with any financial organizations regarding the material reported in this manuscript.

References

[1] B. Mei, H. Hu, and N. Rouphail, "Simulation model for studying impact of vehicle-to-vehicle wireless communications on traffic network operations," *Transportation Research Record*, vol. 2189, no. 1, pp. 107–115, 2018.

[2] N. Economides and P. Jeziorski, "Mobile money in Tanzania," *Marketing Science*, vol. 36, no. 6, pp. 815–837, 2017.

[3] G. Zanarone, D. H.-F. Lo, and T. L. Madsen, "The double-edged effect of knowledge acquisition: how contracts safeguard pre-existing resources," *Strategic Management Journal*, vol. 37, no. 10, pp. 2104–2120, 2016.

[4] B. Grdoi, E. Skreli, and D. Imami, "Determinants of sustainable relationships in the Albanian apple production sector," *International Journal on Food System Dynamics*, vol. 7, no. 1, pp. 50–65, 2016.

[5] J. Y. Yeh and C. H. Chen, "A machine learning approach to predict the success of crowdfunding fintech project," *Journal of Enterprise Information Management*, 2020.

[6] H. Geun, H.-Y. Kim, and Suh, "A study on the VAT taxation for the financial service and education service - in an aspect of revised tax law practices and education law," *Journal of Tax Studies*, vol. 16, no. 4, pp. 83–116, 2016.

[7] L. Li and H. Li, "Analysis of financing risk and innovation motivation mechanism of financial service industry based on internet of things," *Complexity*, vol. 2021, no. 3, 9 pages, Article ID 5523290, 2021.

[8] A. Estrella-Ramon, M. Sánchez-Pérez, and G. Swinnen, "How customers' offline experience affects the adoption of online banking," *Internet Research*, vol. 26, no. 5, pp. 1072–1092, 2016.

[9] M. Barkhordari, Z. Nourollah, H. Mashayekhi, Y. Mashayekhi, and M. S. Ahangar, "Factors influencing adoption of e-payment systems: an empirical study on Iranian customers," *Information Systems and E-Business Management*, vol. 15, no. 1, pp. 89–116, 2017.

[10] L.-M. Rehnen, S. Bartsch, M. Kull, and A. Meyer, "Exploring the impact of rewarded social media engagement in loyalty programs," *Journal of Service Management*, vol. 28, no. 2, pp. 305–328, 2017.

[11] S. Alaei, F. Alhani, and H. Navipour, "The financial transaction between counseling and nursing care service centers (CNCSCs) and their clients: a qualitative study," *BMC Health Services Research*, vol. 18, no. 1, pp. 282–289, 2018.

[12] E. E. Izogo, "Should relationship quality be measured as a disaggregated or a composite construct?" *Management Research Review*, vol. 39, no. 1, pp. 115–131, 2016.

[13] F. Cuandra, "Pandangan pengguna internet terhadap minat dalam adopsi internet banking pada masyarakat kota batam, provinsi kepulauan riau, Indonesia," *SKETSA BISNIS*, vol. 7, no. 1, pp. 27–36, 2020.

[14] F. Zhu, C. Zhang, Z. Zheng, and A. Farouk, "Practical network coding technologies and softwarization in wireless networks," *IEEE Internet of Things Journal*, vol. 8, no. 7, pp. 5211–5218, 2021.

[15] S. Thangalakshmi and A. M. Ezas, "Congestion management in deregulated power systems using generator rescheduling with particle swarm optimization," *Journal of Computational and Theoretical Nanoscience*, vol. 14, no. 9, pp. 4416–4423, 2017.

[16] M. Adil, M. K. Khan, M. Jamjoom, and A. Farouk, "MHADBOR: ai-enabled administrative distance based opportunistic load balancing scheme for an agriculture internet of things network," *IEEE Micro*, vol. 42, 2021.

[17] L. E. Burman, W. G. Gale, S. Gault, B. Kim, J. Nunns, and S. Rosenthal, "Financial transaction taxes in theory and practice," *National Tax Journal*, vol. 69, no. 1, pp. 171–216, 2016.

[18] Z. Ismail and P. Khembo, "Determinants of energy poverty in South Africa," *Journal of Energy in Southern Africa*, vol. 26, no. 3, pp. 66–78, 2017.

[19] R. Šperka and I. Szarowská, "Financial transaction taxation in agent-based simulation," *M: Ekonomie a Management*, vol. 19, no. 2, pp. 176–187, 2016.

[20] C. k. Ayo, A. A. Oni, O. J. Adewoye, and I. O. Eweoya, "E-banking users' behaviour: e-service quality, attitude, and customer satisfaction," *International Journal of Bank Marketing*, vol. 34, no. 3, pp. 347–367, 2016.

[21] T. Nguyen and S. Pergamenchtchikov, "Approximate hedging with constant proportional transaction costs in financial markets with jumps," *Theory of Probability and Its Applications*, vol. 65, no. 2, pp. 224–248, 2019.

[22] M. Naseri, M. A. Raji, M. R. Hantehzadeh, A. Farouk, A. Boochani, and S. Solaymani, "A scheme for secure quantum communication network with authentication using GHZ-like states and cluster states controlled teleportation," *Quantum Information Processing*, vol. 14, no. 11, pp. 4279–4295, 2015.

[23] E. Lepinette and T. Q. Tran, "Consumption-investment optimization problem in a Lévy financial model with transaction costs and làdlàg strategies," *Mathematics and Financial Economics*, vol. 14, no. 3, pp. 399–431, 2020.

[24] X. Xu, J. Ma, and X. Xie, "Convergence of Markovian price processes in a financial market transaction model," *Operational Research*, vol. 17, no. 1, pp. 239–273, 2017.

[25] A. Amri, H. Zainal, M. Ramadhini, F. Maulana, and M. Firdaus, "Financial transactions flow chart of fish marketing at fish landing center (PPI) lhok pawoh," *Jurnal Inotera*, vol. 5, no. 1, pp. 56–62, 2020.

[26] K. J. Laverierre and M. H. Behrens, "'""The US department of labor""""""," *The Journal of Investment Compliance*, vol. 17, no. 4, pp. 1–22, 2016.

[27] P. Shome and J. G. Stotsky, "Financial transactions taxes," *Social Science Electronic Publishing*, vol. 95, no. 77, pp. 2-3, 2016.

[28] C. Li, P. Liu, C. Zou, F. Sun, J. M. Cioffi, and L. Yang, "Spectral-efficient cellular communications with coexistent one-and two-hop transmissions," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 8, pp. 6765–6772, 2015.

[29] C. Wang, "Analyzing the effects of cross-border e-commerce industry transfer using big data," *Mobile Information Systems*, vol. 2021, no. 8, 12 pages, Article ID 9916304, 2021.

[30] M. Laila, M. Muis, and D. A. S. Parawansa, "The impact of consumer interests, security risks, and financial behavior on new transaction tool (e-money)," *Hasanuddin Journal of Business Strategy*, vol. 2, no. 3, pp. 83–91, 2020.

Hindawi
Scientific Programming
Volume 2023, Article ID 9856029, 1 page
https://doi.org/10.1155/2023/9856029

Retraction

Retracted: The Role of Confucian-Transformational Leadership in Shaping and Influencing Chinese MNEs

Scientific Programming

Received 1 August 2023; Accepted 1 August 2023; Published 2 August 2023

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

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

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

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

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

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

References

[1] Y. Hui, "The Role of Confucian-Transformational Leadership in Shaping and Influencing Chinese MNEs," *Scientific Programming*, vol. 2022, Article ID 5839223, 11 pages, 2022.

Hindawi
Scientific Programming
Volume 2022, Article ID 5839223, 11 pages
https://doi.org/10.1155/2022/5839223

Research Article

The Role of Confucian-Transformational Leadership in Shaping and Influencing Chinese MNEs

Yu Hui

School of Business Administration, College of Arts and Sciences Kunming, Kunming 650222, Yunnan, China

Correspondence should be addressed to Yu Hui; huiyu_0615@163.com

Received 25 December 2021; Revised 15 January 2022; Accepted 21 January 2022; Published 23 February 2022

Academic Editor: Ahmed Farouk

The demand to comprehend leadership across the world is becoming necessary and more urgent since the inevitable trend of globalization. In today's global arena, on the one hand, China has maintained its remarkable economic performance and Chinese culture will have a more powerful influence in the foreseeable future; on the other hand, due to the policy of reform and opening and the economy market, western management theories and practices have flowed into the Chinese market and influencing Chinese companies. Thus Chinese leadership needs to develop more compatible with western leadership, thereby Chinese MNEs become more adaptive and competitive in the current global business environment. Against this background, this paper focuses on Confucian leadership, the most important Chinese leadership shaped by traditional Confucianism for more than 3000 years, and attempts to explore the compatibility of Confucian leadership and transformational leadership. After a thorough case study of Haier Group and its CEO Zhang, Ruimin, the research found that the great success of Haier is due largely to Zhang's Confucian-transformational leadership, which combines both the wisdom of traditional Chinese Confucianism and the essence of western transformational leadership theory. Therefore, it is demonstrated that Confucian leadership plays a vital role in shaping the management style and performance of Chinese companies, and there can be a high level of compatibility between Confucian leadership and transformational leadership.

1. Introduction

As the inevitable trend of globalization, especially in business circles, the demands for mutual penetration and understanding among various nations have been driven. Against this background, the need to understand leadership around the world is becoming necessary and more urgent.

With the implementation of the Belt and Road Initiative from 2013, China has maintained its remarkable strength in the world economy. Thus, it is urgent to develop a deeper understanding of successful Chinese business models and how they differ from those of western [1] through researching Chinese culture and management practices. That is why this research focuses on Confucian leadership.

Meanwhile, with the development of Global Economic Integration, an increasing number of Chinese companies have been influenced by the influx of western management theories and practices. Under this tremendous change, Chinese leadership needs to be developed, thereby Chinese MNEs become more adaptive and competitive in the path of Chinese enterprises going global. In addition, Tsui et al. [2] indicated that interactions between traditional Chinese leadership practices and western leadership views may stimulate new leadership ideas and brew new leadership styles. Thus, this paper creatively attempts to explore the Confucian-transformational leadership, a new leadership that combines both the wisdom of traditional Chinese Confucianism and the essence of western transformational leadership theory. The aim of this paper is to answer the central research question: is Confucian leadership compatible with transformational leadership in Chinese MNEs? Around the research question, this paper will conduct a case study of Haier Group and demonstrate the findings of the relationship between the leadership of Zhang Ruimin and Haier, and use this typical example to further indicate the role of Confucian and transformational leadership in shaping and influencing Chinese MNEs.

2. Literature Review

2.1. Confucian Leadership

2.1.1. Confucianism and Confucian Leadership. As the most orthodox culture in Chinese history, Confucianism, which was consolidated by Confucius (551-479BC), played a vital role in guiding and shaping Chinese thinking and behavior for more than 3000 years. Confucianism is an ideology of scholars, gentlemen, or ritual managers [3]. According to Cheung and Chan [4], the foundation of Confucianism is rituality, which can be expressed in the form of propriety or politeness, and it is regarded as the goal of education which distinguishes *junzi* (gentlemen) from the normal uncultivated person [5]. This rituality forms virtue (morality), which consists of benevolence or humaneness such as love, kindness, forgiving, and generosity to others including subordinates [3, 5] and keeping faith, justice, righteousness, and loyalty, particularly to superiors [4]. The ideal of Confucian is to be a sage to maintain social order through virtuous practice. Thus, Confucianism can be seen as the rule of man, which emphasizes that people should be in the right place to exert the right authority. To achieve order, stability, and harmony under this social hierarchy, five particular interpersonal relationships that Confucius termed as *wulun* are developed: emperor and subject, father and son, elder brother and younger brother, husband and wife, friend and friend. These relationships have mutual and complementary obligations that the junior should respect and obey the senior, and the senior should protect and care for the junior [6] To sum up, Confucian values comprise cultivation of virtual, keeping order of social hierarchy, maintenance of interpersonal relationships, and creation of harmony, etc. [7].

2.1.2. Theoretical Models of Confucian Leadership. McDonald's [8] study examined to what extent the Confucian ideology is evident in practices of modern Chinese business leaders and developed an archetypal model (Table 1) based on Zhang and Alon's [9] biographical dictionary of New Chinese Entrepreneurs and Business Leaders, a comprehensive biographical database of the top 200 business leaders who are identified as influential to Chinese economic growth. In this conceptual framework, Confucian business leadership style, principles, and constants are clearly identified.

In addition, Fernandez [5] established two models of leadership from the perspectives of aims and values of Confucianism. Figure 1 is the Confucian path to leadership. In Confucius's view, to be a true leader is a road to work hard and ceaselessly pursue perfection. In other words, the qualities of leadership can be acquired through a conscious effort of self-cultivation and continuous learning. Along this road, superior leaders should take three things into account at any time: careful thinking, careful speaking, and careful acting. Among these three factors, careful thinking results from leader's attempt to be open-minded, unselfish, and disciplined. In this way, Confucian leaders first perfect themselves through the practice of self-cultivation (the internal aim) and then achieve social harmony through the exemplary conduct of the leader (the external aim).

The Confucian path to leadership (Figure 1) is the result of the leader's values (Figure 2). Fernandez [5] indicated that kindness and justice are two fundamental values in the Confucian system: kindness means loving people; justice means treating things properly. Kindness and justice are developed under two conditions: family and study, as people's character and behavior, are influenced by parents and revealed first in their family, and then studied extensively to self-cultivate. From the practice of kindness and justice, trust and social harmony can be achieved. Trust is what connects one person to another, and Confucius thought that if people trust their government, they will overcome difficulties and ultimately lead to the prosperity of the nation. Harmony means the observance of proper rules of behavior, which ensures social order and stability. Therefore, a leader must aim at bringing trust and harmony to society.

2.1.3. The Impact of Confucian Leadership on Practices of Chinese Managers. The majority of contemporary literature paid attention to the role of Confucianism in shaping the management styles and practices of Chinese managers. Canchu Lin [10] conducted a survey of scholarly literature on the effect of Chinese culture on leadership practices in mainland China and other East Asian countries. He found that leadership attributes such as benevolence, sympathy, forgiveness, friendliness, trust, and fulfillment, harmony, learning, loyalty, righteousness, and humility are all results of Confucianism. Gallagher and Rarick [11] paid attention to Confucian leaders' moral obligation. They highlighted the function of moral obligation that facilitate leader to guide and encourage, enrich, and educate subordinates and indicated that it is virtue and harmony that enable the leader to balance conflicts between different interests of stakeholders.

Many scholars provided valuable evidence to these theories. Cheung and Chan studied and interviewed successful Chinese CEOs twice [12]. Results indicated that their leadership styles are based primarily on relationalism and harmony, virtuous practice, hierarchy, and moderation, and these cultural factors play important roles in facilitating collaboration and coordination, trust and respect, recognition of talent, and other achievements in the relationship between them and subordinates. McDonald's [8] research focused on four excellent Confucian business leaders who have high personal reputations and successful business records in the global business world. Evidence suggested that their practices are well in accord with Confucian culture, and these practices indirectly promote the success of their companies. Wah [13] provided evidence of the influence of Confucian values on Chinese family-owned business management in Singapore, Malaysia, and Indonesia. Ma and Tsui [14] analyzed the leadership behaviors of fifteen highly successful Chinese business leaders and revealed the influence of Confucianism in their leadership practices.

Table 1: The archetypal model of the modern Confucian business leader (source: [8]).

Level one: leadership style	
Benevolent leadership (*junzi*)	*Junzi* (superior person) manifests as *ren* (benevolence), *yi* (righteousness), and *li* (etiquette), and its ultimate goal is to build a harmonious and benevolent world. The Confucian business leader will continually promote these ideals and model them to followers.
Level two: leadership principles	
Virtue (*de*)	The behavior of a leader must be guided and defined by virtue and a set of enduring beliefs and values. The Confucian business leader will attract followers towards positive ideals rather than threaten them with punishments and negative consequences.
Harmony (*he*)	The concept of balance requires Confucian business leaders to be able to listen to different opinions and work together with different people in a harmonious manner
Education (*fuzi*)	Confucian business leaders will manifest themselves as teachers, showing interest in the development of followers
Reciprocity (*shu*)	This "golden rule" means treating others as one would like to be treated. Confucian business leaders should focus more on egalitarian work practices and less on hierarchical organizational structures.
Familial collectivism (*xiao*)	This principle means veneration for ancestors and observance of tradition. Confucian business leaders will pay attention to the culture and traditions of the organization, and relationships with staff.
Level three: leadership constants	
Ren (benevolence/ humanity)	*Ren* is the integration of two concepts: empathy, the ability to put oneself in another person's shoes; excellence, striving to do one's utmost. These two concepts guide leaders to do their very best for the good of all.
Yi (righteousness/ honesty)	*Yi* underlies the moral capacity of Confucian leadership. It focuses on what is right or fitting. The Confucian leader not only needs to distinguish right from wrong but also to do what is right.
Li (etiquette/politeness)	*Li* focuses on ceremonial and ritualistic requirements. This influences the way Confucian leader interacts with others: interpersonal relations need to manifest features such as reverence, listening, and consideration; individual action takes place within the broader context of social order to strengthen the importance of humility.
Zhi (wisdom/knowledge)	*Zhi* means the practical application of knowledge. Confucian business leaders will promote practical learning for their followers; innovation will be emphasized in the organizational culture over rules, policies, and procedures.
Xin (faithfulness/fidelity)	*Xin* addresses the issue of personal integrity with particular emphasis on faithfulness, fidelity, and trustworthiness. It manifests to what extent the leader delivers on what has been promised and keeps to his or her word.

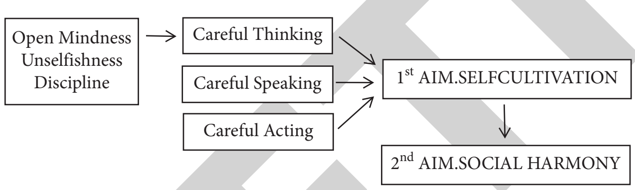


Figure 1: The Confucian path to leadership (source: [5]).

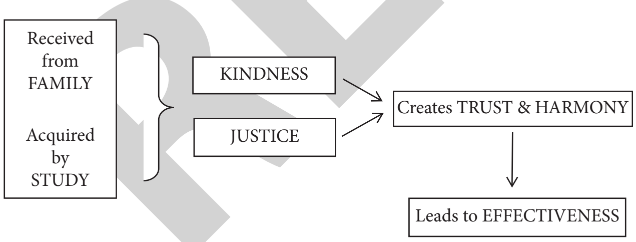


Figure 2: The model of leadership by confucian values (source: [5]).

Even it is acceptable that practices and management styles of Chinese managers are directly shaped by Confucian leadership, which may further promote the development of companies, while there lacks literature or direct evidence on the relationship between Confucian leadership and organizational performance. Specific to this gap, this paper attempts to continue to study the impact of Confucian leadership on organizational success.

2.2. Transformational Leadership

2.2.1. Definition of Transformational Leadership. Transformational leadership has been the dominant focus of contemporary leadership research. It is a leadership style that depends on the long-term development of and rewards in followers. According to Bass [15], transformational leadership comprises factors of charismatic leadership, intellectual stimulation, and individualized consideration. Transformational leader prefers to act as a charismatic role model, an ability of leaders to arouse enthusiasm, faith, loyalty, pride, and trust in themselves and their aims, to exert idealized influence and create a captivating vision for the future to promote inspirational motivation, set high performance expectations to enhance the problem-solving capabilities of followers and encourage them to challenge the status quo, and provide support for followers through maintaining a developmental and individualistic orientation toward them to foster intellectual stimulation [15–17].

2.2.2. The Impact of Transformational Leadership on Organization. The effectiveness of leadership can be measured by examining if it can produce effective managerial outcomes, for instance, acceptance of and satisfaction with leadership [18], organizational commitment and job satisfaction [19], job performance or competence [20], and innovation [21]. Taking all these factors into account, transformational leadership is particularly effective and appears to be a common cause of various favorable outcomes [19].

Bass [15] interviewed 70 senior executives and conducted a survey of 256 business managers to find evidence of transformational leadership's effects. The results demonstrated that transformational leaders can enhance subordinates' awareness of the importance and value of designated outcomes, encourage followers to transcend their self-interests for the good of the whole organization by creating an appealing vision, and improve employees by expanding their portfolios of needs and what they are attempting to accomplish. Moreover, Shin and Zhou [22] conducted a survey of 290 employees and their leaders from 46 Korean companies, and Zhang et al. [23] studied 163 work groups involving 973 employees in 12 Chinese companies. They found that transformational leadership is positively related to creativity potential of individual employees and group creativity.

2.3. Compatibility of Confucian Leadership and Transformational Leadership. Under the trend of globalization, management and leadership styles are developing to a convergent stage contemporarily: on the one hand, Chinese companies have expanded across the world. On the other hand, western values have flowed into China along with a massive influx of foreign investment. With the rise of China as a new key economic partner in the international stage, questions of the compatibility of managerial philosophies between East and West arose [11].

For the aim of exploring the compatibility of Confucian leadership and transformational leadership, research which draws attention to the comparison between Chinese leadership and western leadership from an across-cultural view is valuable for my study. For example, Chen Oi Chin et al. [24] developed a new conceptual model of global leadership competencies and indicated that the compatibility of different leadership can be achieved on the transformational level. Jiang et al. [25] conducted research to explore the mediating role of project leadership, and they found that all Confucian principles had positive effects on transformational leadership styles.

These research outcomes have great reference value, which helps to evaluate leadership from a variety of cultural perspectives. However, their limitations should be noticed. First, they lack focus. Chin's study (2001) just analyzed leadership styles from a general perspective of East and West. This paper concentrates on two specific leadership styles; thus, further research is based on and develops those previous research. Moreover, Cheung and Chan [4] focused on the differences rather than similarities between Confucian leadership and transformational leadership, while in my view, they have many similarities which are not given attention to. Therefore, my research seeks compatible factors that facilitate the collaboration of people from different cultural backgrounds.

3. Context for Study

3.1. Research Objectives. This paper aims to explore if Confucian leadership is compatible with transformational leadership in Chinese MNEs. This central research question will be interpreted by (a) identifying characteristics of Confucian leadership; (b) analyzing the impact of Confucian leadership on companies; (c) exploring the compatibility of Confucian leadership and transformational leadership; (d) investigating the benefits the Confucian-transformational leadership can bring about for enhancing the development of Chinese MNEs.

Since there are no existing models for the two types of leadership, this research had to explore them separately. To achieve research objectives above in a more reliable way, the analysis and measurement of data about Confucian leadership are based on research outcomes of authoritative academic articles: the archetypal model of the modern Confucian business leader [8] and the model of leadership by Confucian values [5]. About the analysis of transformational leadership, Bass's four factors of transformational leadership (1985) have been used to find Zhang's related personalities. Since these models are capable of identifying the characteristics of Confucian leadership and transformational leadership, thus they are suitable for my research purpose.

3.2. Research Approach and Strategy. A qualitative approach is used in this paper since my data is collected in the form of descriptions and will be interpreted and analyzed through nonmathematical procedures, although some relevant information is numerical. The majority of my data is descriptive; "words" and "sentences" are used rather than "numbers" since it is difficult to use quantitative statistics to measure a person's characteristics and leadership style and the impact of leadership style on companies, as well as the convergence of Chinese and western management philosophies, is contemporary phenomena; this paper will be conducted through case study research strategy.

My case is Haier Group and its CEO Zhang, Ruimin. I selected Haier as my case for three reasons. First, Haier is a successful Chinese MNE that owns traditional Chinese cultural features but also needs to confront the impact of western management philosophy on the road of expanding business overseas. Second, the prosperity of Haier is due largely to its CEO, Zhang, Ruimin. McDonald [8] regarded Zhang's leadership as a typical modern-day Confucian leadership that integrates Chinese traditional management philosophies with best business practices from the west. In addition, many scholars have studied Haier Group from various managerial perspectives, and their research can provide valuable data and information for my study.

3.3. Limitations. It should be noticed that this research has three main limitations. First is my research problem is relatively new; thus, it lacks an existing mature theoretical model which combines both Confucian leadership and transformational leadership. Second is secondary data are not generated for the target research question; thus, they may not be perfectly matchable as primary data could do, although they are relevant to the research topic. Last is the problem of lacking comparison and generalization: even focusing on one single case can provide a deep insight into the unique question; the argument for its credibility and contribution exists.

4. Case Study

4.1. History and Development of Haier Group. Haier Group is the global leading brand of white household appliances, which manufactures 15,100 varieties of items in 96 product lines, with headquarters in Qingdao, China. It is widely known in the global business world for its customers spread in more than 100 countries and regions. As shown in Figure 3, from a debt-ridden small factory to a successful giant international company, Haier has experienced six developmental phases.

4.2. Zhang, Ruimin and Haier Group. Zhang, Ruimin is the founder, Chairman of the Board of Directors, and CEO of Haier Group. In 1984, Zhang was appointed as general manager of Qingdao Refrigerator Factory (the former name of Haier) and started the prologue of Haier's development. Thus, the development process of Haier is regarded as one of the ultimate Chinese business success stories, the management exploration of Haier is treated as a world asset, and the leadership of Zhang is known as an illustration of the efficacy of strong Chinese leadership based on Confucian cultural values [8].

4.3. Leadership of Zhang, Ruimin. Zhang, Ruimin is famous for his work in turning an ailing collective factory of refrigerators into the world's largest household appliances manufacture, and his ability to integrate the essence of Chinese traditional culture with the best western modern management concept in Haier's management practice [26, 27]. In Zhang's opinion, a successful entrepreneur should also be a philosopher, and he quite approves of the thinking of the greatest ancient Chinese sage Confucius [28]. Therefore, his leadership accords well against the archetypal model of the modern Confucian business leader [8].

4.3.1. The Impact of Confucian Factors on Zhang's Leadership

Benevolent leadership (junzi) and ren (benevolence/humanity). Zhang Ruimin is first and foremost a benevolent leader with an obvious paternalistic nature [8], which contributed to Haier's 80/20 principle that management is 80% responsible for any subordinate's wrongdoing [29]. When he was appointed as the Director at the Qingdao refrigerator factory, the company was at stake and it seemed hopeless that over 800 workers were waiting for pay anxiously as their salaries were already several months in arrears, and 51 workers intended to leave [30]. He immediately took action to change the terrible situations. Even though there was a huge difficulty, Zhang still did his best to borrow money from a nearby production bridge and arrange all workers' pay. Besides, he cared for subordinates more by taking many detailed things into account. For example, he borrowed money to buy each worker a gift of five catties of fish to celebrate the Chinese Lunar New Year and to replace trucks to buses to make workers more comfortable especially for those who carried children.

Virtue (de) and yi (righteousness/honesty). Identifying with Confucian ideology, Zhang's behaviors were guided and defined by virtue and a set of enduring beliefs and values [8], and he used positive ideals to stimulate his employees and gain support from them rather than "oversupervise" them [30]. A typical expression of virtue is that he puts emphasis on the quality of products, which leads to the quality-centred product standards of Haier and then becomes the company's enduring beliefs and values. For instance, to instill the importance of quality performance, there is a large pair of footprints drawn on the floor of the factory. At the end of every shift, employees who have performed worst that day must stand on the footprints and listen to the criticism of their faults and those who performed best then stand on the footprints and tell how they achieve their outstanding performance in front of every employee [31].

Another expression of virtue in Confucian terms is that a "superior man" should modest and never stop pursuing the right thing no matter how difficult it is. One difficulty Zhang met was that when he put forward a reengineering plan in 1998, there was great opposition and some senior executives were openly against it. At the same time, Zhang insisted as he believed that this change was right.

Harmony (he). The virtue-guided leadership of Zhang is also demonstrated by the corporate social responsibility of Haier. According to Fernandez [5], the Confucian path to leadership is to create social harmony through a leader's own moral cultivation. Zhang's emphasis on virtue leads to Haier's attention to business ethics; thus, Haier "work diligently to serve the country and to pursue excellence" [29], p.2). With this spirit, CSR of Haier fosters a harmonious balance among Haier, different stakeholders, and the environment (Table 2).

Education (fuzi) and zhi (wisdom/knowledge). Education and study are hallmarks of Confucianism. Confucius put emphasis on education and indicated that qualities of leadership can be acquired through a conscious effort of self-cultivation and continuous learning. According to Fernandez [5], individual perfection through self-cultivation is the internal aim of Confucian leadership. Consistently, Zhang never stopped working hard to pursue perfection. As growing up under the widespread upheaval of the Cultural Revolution when most schools and colleges were shut down, Zhang was unable to further his study. Even his former education was sporadic. He had a greedy appetite for learning. He began to study management courses by bicycle between work shifts and was largely self-taught through reading extensively. These efforts led to his Masters' degree after completing a postgraduate MBA Program at China

Figure 3: Development process of Haier group (source: https://www.haier.net).

Table 2: CSR of haier (source: https://www.haier.net).

Examples of public welfare undertakings	
Protect environment	Provides environment-friendly products for the consumer in 160 countries; takes part in the "earth hour" activity
Charities	Delivered needed materials and raised funds to disaster-stricken areas in Cuba, Indonesia, and Malaysia, etc. Funded the association of breast cancer in Sydney.
Education	Participates the project hope from 1995
Sports	In 2006, cooperated with NBA to provide the chance for teenagers to play basketball with NBA players. In 2008, the group became the first official appliance sponsor of the 2008 Beijing Olympic games
Achievements	
Achieved European A $^+$ energy consumption standard in 2002	
Awarded "best international ecological security enterprise" by the United Nations International Ecological Security Academy of Sciences in 2002	
Got Energy Saving, Water Saving, Environmental Protection Contribution Award by China Energy Conservation Product Authentication Centre in 2005	

Technology University in 1995. Due to his profound knowledge, which originated from self-cultivation, he is called "Confucian businessman" and "scholar entrepreneur" [32]. Not just self-cultivation, Zhang also gives priority to the development of employees: in 1999, Haier established its own university to train employees [29].

Reciprocity (shu). This "golden rule" of Confucianism means treating others as one would like to be treated. Guided by this, Confucian business leaders should focus more on egalitarian work practices and less on hierarchical organizational structures [8]. This feature can be demonstrated by three questions which are Zhang thinking carefully every day: "whether he has provided employees with sufficient space to create value and to achieve self-realization? Do employees work just as requested passively? Or they work actively to fulfill their ambitions?" [30], p.145) There is no doubt that Zhang intends to get employees' support and loyalty, while he knows employees should be treated the same way as what he wants to be treated by them since they will be passionate and value their work if the leader is passionate and value them. This reciprocity exists in Haier's corporate culture that Haier should be like the sea to hug all talented people around the world, and every Haier employee should be capable rather than mediocre and redundant since they are the backbone and guarantee of Haier's future development [32].

Familial collectivism (xiao) and li (etiquette/politeness). The concept of *xiao* is not limited to immediate family but also includes key relationships outside the family [8]. It is the foundation of hierarchy and social order. Concerned with business leaders, the relationship between leaders and employees is identified with that of the ruler. Zhang knows how to tackle the problem of troublemaker through acting expeditiously with tough style. In 1998, 4000 employees of Huangshan Television Factory, one of 18 enterprises taken over by Haier, went on strike and hit the secretary assigned by Haier after it belonged to Haier for only six months. When this event was reported to Zhang, on the one hand, he gave the order immediately to stop producing to rectify and improve without the limited time; on the other hand, he endowed the command to the secretary to control the situation. Under this strong attitude, just two days later, the strike was stopped as those unsatisfied workers realized that Haier must do that in order to stand stably in the market, which was also for their benefit. [33].

Familial collectivism then can expand to veneration for ancestors and observance of tradition [8]. Under this principle, the Confucian leader should give priority to the company's culture and rituals and relationship with staff. Hawes and Chew [34] indicated that Haier's success is due largely to Zhang's leader role in insisting on the corporate culture and he exerts influence on employees through corporate culture infiltration: defining the corporate philosophy and values; creating corporate "myths"; establishing rituals to praise the heroes of the company and publicly criticizing ones who fail to hold the corporate values; strengthening the values in place with financial incentives, management systems, and process reengineering; leading by example. For instance, a ritual at Haier is to encourage employees to draw cartoons or calligraphic works to express the firm's cultural values. Prizes are given for the excellent creations which sum up the values in an innovative and entertaining way, and they are posted on the company's website and around factories and offices [34].

Xin (faithfulness/fidelity). *Xin* is the issue of personal integrity with particular emphasis on faithfulness and trustworthiness [8]. In this respect, Zhang is a trustworthy leader, and he is faithful to his company. Zhang was the fourth director who was appointed to Haier in that single year. The former three people had either left or been kicked out as no one was able to shoulder such huge responsibility for a hopeless small factory [30]. However, Zhang did not leave. He stayed and never stopped making Haier better; 28 years' hard work is also the proper illustration of his faithfulness to the company and employees.

4.3.2. The Transformational Leadership-Related Personalities. Zhang, Ruimin is called "Confucian businessman"and "scholar entrepreneur" for his distinctive Confucian leadership features mentioned above. In order to comprehensively understand Zhang's leadership style, it is necessary to explore his personality which makes him such an excellent leader. In the process of Haier's global expansion, Zhang has demonstrated four transformational leadership-related personalities. According to Bass [15], transformational leadership comprises idealized influence and inspirational motivation (two important aspects of charisma), intellectual stimulation, and individualized consideration. These four factors all can be found in Zhang's personalities (Table 3).

Personality1. According to Bass [15]'s study, idealized influence is from leaders' charismatic roles, which means a transformational leader will consciously or unconsciously serve as a role model for employees, which can make every follower enthusiastic about targets and assignments, trust the leaders' capacity, and feel proud to be associated with them. Zhang knows how to establish himself as a role model to create followers and get trust from them.

The most famous incident at Haier was the "refrigerators smashing" in 1985, just after Zhang became the fourth person appointed to run the small refrigerator plant. Aimed at the inferior quality refrigerators which were complained by customers, Zhang lined up 76 defectives of the 400 products on the factory floor and asked his employees about how to deal with them. When he got the answer of selling these defectives at lower price, which is the common practice among other Chinese companies at that time, Zhang said: "If I permit you to sell these today, there will be another 76 such products in the future" [35] and he made an "unreasonable" decision that these inferior products should be destroyed by the workers who made them in public. He even picked up a sledgehammer to participate in the smashing activity. This event made Haier awarded the first National Golden Model of Quality in the refrigerator industry three years later. In order to maintain the influence of this event to highlight the importance of quality for Haier's success, Zhang has constantly repeated it in his speeches, on the company's website, and in the training sessions for new employees even up to the present.

Personality 2. Transformational leaders have a special gift of seeing what is really important and have a sense of mission that excites responses [15]. One of the features is they always create a vision for the future to inspire and motivate followers [17]. Zhang clearly knows what he wants; he is always able to create an inspiring vision for the future, grasp the main issue and opportunity, and then set different goals accordingly to obtain it.

When Zhang came to Qingdao Refrigerator Factory in 1984, the first thing he realized was that workers had no faith in the company and did not care about it. This serious problem resulted in the indifference of quality of products. Against this situation, he attempted to instill the concept of "quality is the first" in his employees' minds through "smashing refrigerators" and began to lead his employees on a rapid development road by establishing the "brand building strategy" for the first coming seven years (from 1984 to 1991). After Haier built its refrigerator brand in the Chinese market, Zhang changed the strategy from single product production to diversified development. From 1992 to 1998, Zhang seized the opportunity of merging and restructuring to implement its second development strategy, the diversification strategy. After that, a famous refrigerator brand was extended to brand groups in the field of household appliances. In the 21th century, Zhang grasped the opportunity for Haier's global expansion through implementing international strategy (1998–2005) and global brand strategy (2005–2012). Therefore, Haier becomes world's largest white household appliances manufacturer. Currently, with the development and utilization of the Internet, under Zhang's leadship, Haier is under its fifth development phase, which concentrates on linking the network market to the networking organization by implementing a networking strategy.

Personality 3. Bass [15] and Judge et al. [17] indicated that transformational leaders are able to stimulate followers through challenging them; he also attends to individual needs by setting assignments on an individual basis to facilitate followers' abilities and motivations. Zhang has the ability to maintain his team effectively, make the team be constantly developed and nurtured, and he also knows how to expand the portfolio of needs of employees to stimulate and improve them.

Dissimilar to other domestic enterprises, Zhang never thought he lacked talents. In his view, the wide gap between Chinese companies and foreign companies is not a technology gap but the high quality of human resources management. What they lack is the mechanism of stimulating their talents [30]. In order to encourage his employees to become talented, OEC management-control system is implemented. This system regards every employee as a strategic business unit with direct responsibility to customers and integrates each employee with company goal, direct selling, and direct delivery of goods and services. Under this system, each employee is stimulated to create value positively and thus becomes the principal part of innovation. As Zhan, Li, Haier's process and IT business department director said, "Only when each individual is responsible for the market can the consistency between speed and accuracy be achieved and only when each

Table 3: Zhang's transformational leadership (source: organized by the author).

	Idealized influence (charisma)	Inspirational motivation (charisma)	Intellectual stimulation	Individualized consideration
Personality 1	√			
Personality 2		√		
Personality 3			√	√
Personality 4				√

Table 4: The compatibility of Confucian leadership and transformational leadership (source: organized by the author).

	Idealised influence (charisma)	Inspirational motivation (charisma)	Intellectual stimulation	Individualised consideration
Benevolent leadership (*junzi*) and *ren* (benevolence/humanity)	√	√		
Zhang's benevolent and humanity behaviors give him an image of "good leader," which serves him as a role model to exert influence, thereby creating followers and making them trust him. For example, after dealing with the main issue of paying salaries in arrear, employees were highly motivated and inspired				
Virtue (*de*) and *yi* (righteousness/honesty)	√		√	
Zhang's strict rule on the quality of products is aimed to raise followers' awareness of the importance and value of company's designated outcomes, and these moral standards also have an idealized influence on the climate of the company. Moreover, highlight of quality fosters innovation and creativity of employees				
Harmony (*he*)	√			
As CSR of Haier results from Zhang's virtue-guided leadership; thus this moral emphasis also has idealized influence, which draws employee's attention to company's overall objective of "to serve the country and to pursue excellence" [29], p. 2) and encourage employees to transcend their self-interests for the good of the group, company, and society [15]				
Education (*fuzi*) and *zhi* (wisdom/knowledge)			√	
Due to the extensive knowledge, Zhang is willing to seek new ways of doing things rather than to accept the status quo. This intellectual component of transformational leadership such as technical expertise and intellectual power, is not simple as making a snap decision but is based on the leader's knowledge, experience, and training [15]				
Reciprocity (*shu*)	√	√		√
Through considering from the perspective of employees and treating employees the same way accordingly, employees are motivated and more value their work; in turn, Zhang wins their support and loyalty. In addition, the OEC management system is operated on an individual basis as it takes each employee's performance into account				
Familial collectivism (*xiao*) and *li* (etiquette/politeness)	√			√
Zhang always focuses on culture and tradition of company; based on that, Zhang exerts influence on employees [34] and created Haier's success. Zhang also pays attention to building a close relationship with employees, which accords with individualized consideration. According to Bass [15], a transformational leader emphasizes individualism. For example, the one-to-one superior-subordinate relationship is of primary importance that the leader is expected to learn the names of all those in the units at least two levels below him. When Zhang first came to Haier, he knew all the names of employees				
Xin (faithfulness/fidelity)	√			
Xin is an expression of "superior man" in Confucianism, and it is an important component of Zhang's virtue role model, which is respected and praised by employees. Thus, this confucian factor demonstrates transformational leadership as idealized influence originates from leaders' charisma [15]				

individual gives full play of his/her potential can the company's goal be achieved or surpassed." [36], p. 48).

Personality 4. According to Keller [37], transformational leaders are creative and innovative as they always question the status quo and their previous cognitive frames, which means they always change the rules according to the situation. Due to Zhang's ability of self-adjustment, he is able to lead the company to advance no matter the situation is favorable to him or not.

Haier's development process experienced the transformation of China from the planned economy to market economy, and the company's success is due largely to its adaptability to different economic systems. As a wise manager, Zhang has a specific strategy with the long-term sight in different periods. For instance, Zhang took over 18 state-owned factories and established Haier Industrial Park when many preferential policies were carried out with the reform of the economic system. Moreover, in order to adapt to the prevalent of e-commerce which brought by China's entry into

Table 5: The effect of Zhang, Ruimin's Confucian leadership on Haier group (source: organized by the author).

Confucian leadership	Zhang's behaviors	The impact on Haier group
Junzi and *ren*	The role of "parent" on the road of Haier's development	80/20 principle: The beginning of Haier
De and *yi*	Never stop pursing right things bring back hope and confidence to the company	Quality-centred product standards and moral standards enduring corporate believes and values strict and high demand on good work of employees reengineering plan
He	Virtual-guided leadership	Green sail public welfare undertakings
Fuzi and *zhi*	Self-cultivation and extensive knowledge	Establishment of the university of Haier
Shu	Consider from the perspective of subordinates	Corporate culture and core values: Haier is the sea OEC compensation system
Xiao and *li*	Tough style to deal with troublemaker insisting corporate culture	The emphasis of corporate culture and rituals which Haier's success relies on a close relationship between managers and employees
Xin	Zhang stayed when the company was hopeless and insisted on hard work	The continuous development of Haier for 28 years

Table 6: Zhang's transformational leadership-related personalities (source: organized by the author).

Zhang's four main personalities	Transformational leadership-related characteristics
Personality 1: establishes himself as a role model to create followers and gets trust from them	Idealized influence (charisma)
Personality 2: always able to create an inspiring vision for the future and grasp the main issue as well as opportunity, then set different goals accordingly to obtain it	Inspirational motivation (charisma)
Personality3: has the ability to maintain his team effective, make the team be constantly developed and nurtured, and knows how to expand the portfolio of needs of employees to stimulate and improve them	Intellectual stimulation individualized consideration
Personality4: has the ability of self-adjustment and can lead the company to advance no matter the situation is favorable to him or not	Individualized consideration

the WTO, Zhang began to carry out a management restructuring program in 1998. During the first 5 years, Haier focused on the organizational restructuring, management decentralizing with the application of advanced information and network systems in order fulfillment, market-chain performance, logistics, capital operation, after-sales service, and product inventory, etc. During the second 5-year period from 2003, Haier carried out the strategic business unit management to stimulate the enthusiasm of every employee and enhance Haier's competitiveness in the global market (https://www.haier.net). From Zhang's constant self-adjustment, Haier can always tackle the challenge and keep up with the pace of economic development.

4.4. A Confucian-Transformational Leader. From Zhang's behaviors and personalities, it can be seen that Zhang's leadership combines both characteristics of Confucian leadership and transformational leadership. Table 4 demonstrates Zhang' Confucian leadership characteristics, which are also expressions of his transformational leadership.

5. Conclusion and Implications

This paper aims to explore the compatibility between Confucian leadership and transformational leadership in Chinese MNEs. The figures show the findings of my case study.

First, as shown in Table 5, Zhang, Ruimin is a typical Confucian leader since his behaviors are well in accordance with traditional Confucianism, and his Confucian leadership is closely associated to Haier's development as the management systems, standards, principles, and values of the company are deeply influenced by his behaviors.

Second, Zhang is also a transformational leader since his four main personalities, which are demonstrated in the process of Haier's development, are all related to transformational leadership (Table 6):

Third, Zhang is a Confucian-transformational leader. This paper found that transformational leadership is well compatible with Zhang's Confucian leadership, particularly in the two charisma factors: idealized influence and inspirational motivation; and this compatibility benefits the development of Haier, that is, due to the combination of Confucian leadership and transformational leadership, the original benefits of Confucian leadership such as virtue cultivation, vision creation, and role model influence are strengthened, and the shortage of less focus on the individual employee is remedied by transformational leadership (Table 7).

In summary, the case study demonstrated that Confucian leadership can be well compatible with transformational leadership in Zhang, Ruimin, and the combination of these two leadership styles are beneficial to the development of Haier Group in the international business environment. The implication of this research for Chinese MNEs is that in order to achieve culture fit, which facilitates the adaptation

Table 7: The compatibility of Confucian leadership and transformational leadership (source: organized by the author).

	Idealized influence (charisma)	Inspirational motivation (charisma)	Intellectual stimulation	Individualized consideration
Junzi and *ren*	√	√		
De and *yi*	√		√	
He	√			
Fuzi and *zhi*			√	
Shu	√	√		√
Xiao and *li*	√			√
Xin	√			

and compatibility of the company in the international business environment, a Confucian-transformational leadership that combines both characteristics of the Chinese Confucian leadership and the western transformational leadership should be developed.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] G. Redding and M. A. Witt, *The Future of Chinese Capitalism*, Oxford University Press, Oxford, UK, 2007.

[2] A. S. Tsui, H. Wang, K. Xin, L. Zhang, and P. P. Fu, "tfb," *Organizational Dynamics*, vol. 33, no. 1, pp. 5–20, 2004.

[3] C. Pan and Z. Yu, *The Modern Applications of Management Thoughts in Ancient China*, Chinese People University, Beijing, China, 2001.

[4] C. k. Cheung and A. F. C. Chan, "Benefits of Hong Kong Chinese CEOs' cd," *The Leadership & Organization Development Journal*, vol. 29, no. 6, pp. 474–503, 2008.

[5] J. A. Fernandez, "The gc," *Organizational Dynamics*, vol. 33, no. 1, pp. 21–31, 2004.

[6] G. Hofstede and M. H. Bond, "The confucius connection: from cultural roots to economic growth," *Organisational Dynamics*, vol. 16, no. 4, 1988.

[7] X. Tian, *Managing International Business in China*, Cambridge University Press, Cambridge, UK, 2007.

[8] P. McDonald, "Confucian foundations to leadership: a study of Chinese business leaders across Greater China and South-East Asia," *Asia Pacific Business Review*, vol. 18, no. 4, pp. 465–487, 2012.

[9] W. Zhang and I. Alon, *Biographical Dictionary of New Chinese Entrepreneurs and Business Leaders*, Edward Elgar Publishing, Cheltenham, UK, 2009.

[10] C. C. Canchu Lin, "Demystifying the chameleonic nature of Chinese leadership," *Journal of Leadership & Organizational Studies*, vol. 14, no. 4, pp. 303–321, 2008.

[11] C. A. Gallagher and C. A. Rarick, "Confucius and total quality management," *Journal of Management Research*, vol. 1, pp. 249–253, 2001.

[12] R. T. Keller, "Transformational leadership, initiating structure, and substitutes for leadership: a longitudinal study of research and development project team performance," *Journal of Applied Psychology*, vol. 91, no. 1, pp. 202–210, 2006.

[13] S. S. Wah, "Chinese cultural values and their implication to Chinese management," *Singapore Management Review*, vol. 23, pp. 75–83, 2001.

[14] L. Ma and A. S. Tsui, "Traditional Chinese philosophies and contemporary leadership," *The Leadership Quarterly*, vol. 26, no. 1, pp. 13–24, 2015.

[15] B. M. Bass, "Leadership: good, better, best," *Organizational Dynamics*, vol. 13, no. 3, pp. 26–40, 1985.

[16] P. M. Podsakoff, S. B. MacKenzie, R. H. Moorman, and R. Fetter, "Transformational leader behaviors and their effects on followers' trust in leader, satisfaction, and organizational citizenship behaviors," *The Leadership Quarterly*, vol. 1, no. 2, pp. 107–142, 1990.

[17] T. A. Judge, E. Fluegge Woolf, C. Hurst, and B. Livingston, "Charismatic and transformational leadership," *Zeitschrift für Arbeits- und Organisationspsychologie A&O*, vol. 50, no. 4, pp. 203–214, 2006.

[18] J. Felfe and B. Schyns, "Personality and the perception of transformational leadership: the impact of extraversion, neuroticism, personal need for structure, and occupational self-e," *Journal of Applied Social Psychology*, vol. 36, no. 3, pp. 708–739, 2006.

[19] F. O. Walumbwa, J. J. Lawler, B. J. Avolio, P. W. Wang, and K. S. Shi, "Transformational leadership and work-related attitudes: the moderating effects of collective and self-efficacy across cultures," *Journal of Leadership & Organizational Studies*, vol. 11, no. 3, pp. 2–16, 2005.

[20] J. I. Menges, F. Walter, B. Vogel, and H. Bruch, "Transformational leadership climate: performance linkages, mechanisms, and boundary conditions at the organizational level," *The Leadership Quarterly*, vol. 22, no. 5, pp. 893–909, 2011.

[21] Y. D. Lee and H. M. Chang, "Leadership style and innovation ability: an empirical study of Taiwanese wire and cable companies," *Journal of American Academy of Business*, vol. 9, no. 2, pp. 218–222, 2006.

[22] S. J. Shin and J. Zhou, "Transformational leadership, conservation, and creativity: evidence from Korea," *Academy of Management Journal*, vol. 46, no. 6, pp. 703–714, 2003.

[23] A. Y. Zhang, A. S. Tsui, and D. X. Wang, "Leadership behaviors and group creativity in Chinese organizations: the role of group processes," *The Leadership Quarterly*, vol. 22, no. 5, pp. 851–862, 2011.

[24] C. Chen Oi Chin, J. Gu, and S. L. Tubbs, "Developing global leadership competencies," *Journal of Leadership Studies*, vol. 7, no. 4, pp. 20–31, 2001.

[25] W. Jiang, X. Zhao, and J. Zuo, "Confucian principles and performance: a contractors' leadership model," *International Journal of Construction Management*, vol. 21, no. 8, pp. 834–844, 2019.

[26] Business week, 2009, http://images.businessweek.com/ss/09/11/1113_business_stars_of_china/38.htm.

Hindawi
Scientific Programming
Volume 2022, Article ID 2576535, 9 pages
https://doi.org/10.1155/2022/2576535

Research Article

Design and Application of an AI-Based Text Content Moderation System

Heng Sun [1,2] and Wan Ni [1]

[1]School of Journalism and Communication, Shandong University, Jinan 250100, China
[2]School of Foreign Languages and Literature, Shandong University, Jinan 250100, China

Correspondence should be addressed to Wan Ni; niwan@sdu.edu.cn

Received 21 November 2021; Revised 6 January 2022; Accepted 26 January 2022; Published 21 February 2022

Academic Editor: Ahmed Farouk

Cloud computing, 5G mobile network, and other new technologies have been applied in higher education in recent years. The education video resource service system with adaptive multiterminals has received widespread attention from the field. From these videos, students can get new knowledge and use the system's built-in text comment function to communicate and interact with others. However, due to the fast increase in the number of such text comments, the traditional text content moderation methods such as the keyword method and the regular expression method can no longer meet the growing business needs. Therefore, to solve this matter, this study designed a text content moderation (TCM) system based on artificial intelligence (AI), which uses artificial intelligence and cloud-based algorithm models to analyse and recognize the text comments submitted from the web-end and app-end of the education video resource service system and completes operations such as automatic detection and manual moderation. The proposed TCM system can significantly improve the efficiency of text content moderation.

1. Introduction

With the expansion of the 5G network coverage and the development of Internet digital media technology, high-quality higher education resources based on mobile Internet spring up continuously, bringing fundamental changes to the knowledge acquisition and digestion mode of learners, and using fragmented learning time to acquire fragmented knowledge has become a common learning method in such a mobile Internet environment [1]. To better serve the teaching practice, our research team designed and developed an education video resource service system based on actual teaching requirements, containing modules such as mobile live broadcast, video on demand (VOD), and video clips. Users use these modules to learn, comment on the resources using texts, and interact and communicate with others; they can express their opinions on these videos; however, malicious posts and junk information would appear in these comments and messages from time to time, exerting negative impact on the online learning environment. Thus, how to quickly and effectively filter the illegal and foul text information in the comments is an urgent problem that needs to be resolved. Currently, the illegal text information in the reviews is generally moderated based on keywords and rules. Specifically, a suspected text is added into a database as a keyword, and the moderation system will look for entries in the database that match the keyword. If a matching entry is found, the text will be determined as containing bad information. However, the keyword-based matching ignores the context and thus releases many false alarms, that is, faces a low accuracy. To solve the problem, the rule-based keyword and regular expression moderation mode come into being. The mode can detect deliberate text confusion, as well as context-related comments. However, the moderation rules and the corresponding corpus must be updated constantly. Otherwise, it is impossible for the mode to adapt to the ever-changing illegal texts.

In terms of the design and development of AI-based TCM system, researcher Chen Jing designed a content management system for bullet screen comments of TV live broadcast, which realized bullet screen comment moderation, edit, and management [2]. The text contents were filtered by comparing the comments and the keywords in the moderation system. But the moderation accuracy depends on whether the keywords cover most illegal texts. Wang et al. [3] proposed a text content safety recognition system based on a recognition model and used deep learning to build moderation model and algorithm; however, each time the algorithm needs to be adjusted or the sample library needs to be updated, it'll take a lot of time and energy. Liu and Huang [4] researched the filtering of illegal and harmful information in the network content and established an information classification system, which can filter information according to the characteristics of each text type; but the classification system, the filter lexicon, and the model features were established based on the researcher's own understanding, so there are a few problems with the system such as the unclear classification, and the system could not update in real time according to the network changes.

In view of the above analysis, this study designed a new TCM system that uses AI, and cloud-end algorithm models to automatically recognize, mark, moderate, and manually recheck the text content of messages and comments submitted from multiple user terminals, and the proposed system could realize intelligent detection and management of text comments.

2. Architecture Design of the AI-Based TCM System

2.1. Technical Architecture. The proposed AI-based TCM system aims at intercepting and filtering the comments, messages, and bullet screen comments that do not meet the moderation standards and rules. The system adopts an intelligent moderation + manual recheck mode to detect the text content [5]. Intelligent moderation is not a complete replacement of manual moderation, it just offers aids and reduces and the workload and intensity of manual operations, for suspected illegal content that cannot be determined by the system, the text will be submitted for manual recheck, and administrators will make judgement on the text. According to the requirement of the moderation task, the system administrator selects the algorithm and text from the existing libraries and configures the moderation by using options and switches in the management control terminal, enabling the automated TCM of the system. When the system encounters a text that cannot be identified or processed, it will push the text to the manual moderation module for manual TCM. At the same time, administrators can conduct spot checks and second moderation on the content that has been automatically moderated; in this way, the moderation accuracy could be improved greatly [6].

The proposed system was developed based on cloud service. Firstly, the cloud server function in cloud service is adopted to complete the basic operation of the TCM system. Secondly, the cloud control platform of cloud service selects the algorithm and text from the existing libraries, configures the moderation, and generates the APIs that can be called by external users. Finally, the APIs are called by the program in the cloud server to detect the text contents and complete the TCM function.

Cloud service can deliver infrastructure, platform, and software resources to users via the network. Users do not have to possess professional knowledge to use the network to access cloud resources through self-service. Our project is based on Tencent Cloud, which provides leading technical products and services to government agencies, corporate organizations, and individual developers, such as cloud computing, big data, and AI. In our project, Tencent Cloud servers are employed to quickly build a system operating environment; Tencent Cloud databases are utilized to realize secure databases with multiple availability zones, preventing malfunctioning of database instances or interruption of availability zones; Tencent Cloud storage is adopted to realize distributed storage of files with high scalability, low cost, good reliability, and strong security; The TI platform of Tencent Cloud is used to achieve one-stop machine learning service platform and other functions. Cloud service providers offer dynamic and scalable resources through the network in a use-on-demand and charge-by-byte mode, and they are also responsible for security management, operation support management, service platform management, resource platform management, etc. [7].

In order to save money, manpower, and material resources, simplify the research and development process, and improve development efficiency, the proposed system was developed under the SaaS cloud service mode. Tencent Cloud service platform provides computing environment services that are directly useable, which meet the complex and diverse calculation needs of our project and satisfy the complex operating environment required by novel computing modes like AI training. The platform offers a dazzling array of computing power combinations, including CPU nodes and GPU nodes. In addition, the software platform adopts a solution different from the job scheduling systems of traditional supercomputing centers. Diverse services can be provided flexibly without sacrificing the computing performance.

On the cloud-end, developers use visual operations to complete the entire development process including data preprocessing, modeling, model training, evaluation, and model release. The project developers can work through visual operations on the cloud end, eliminating the need for laborious pure code operations like building operating environment, model construction, and data processing with command lines. When an algorithm alone cannot complete the development, the algorithm can be replaced swiftly on the cloud console, without suspending the relevant development. During the cloud visual modeling, interactive design can be carried out using the drag-type customizable task flows on the web-end. Both developers and algorithm engineers can quickly build models. The cloud visualization service supports one-stop machine learning. The developers only need to prepare the training data. All the subsequent modeling could be realized on Tencent Cloud service platform. The cloud service platform has many commonly used built-in AI algorithms and models, and developers only need to select the appropriate algorithms and models and

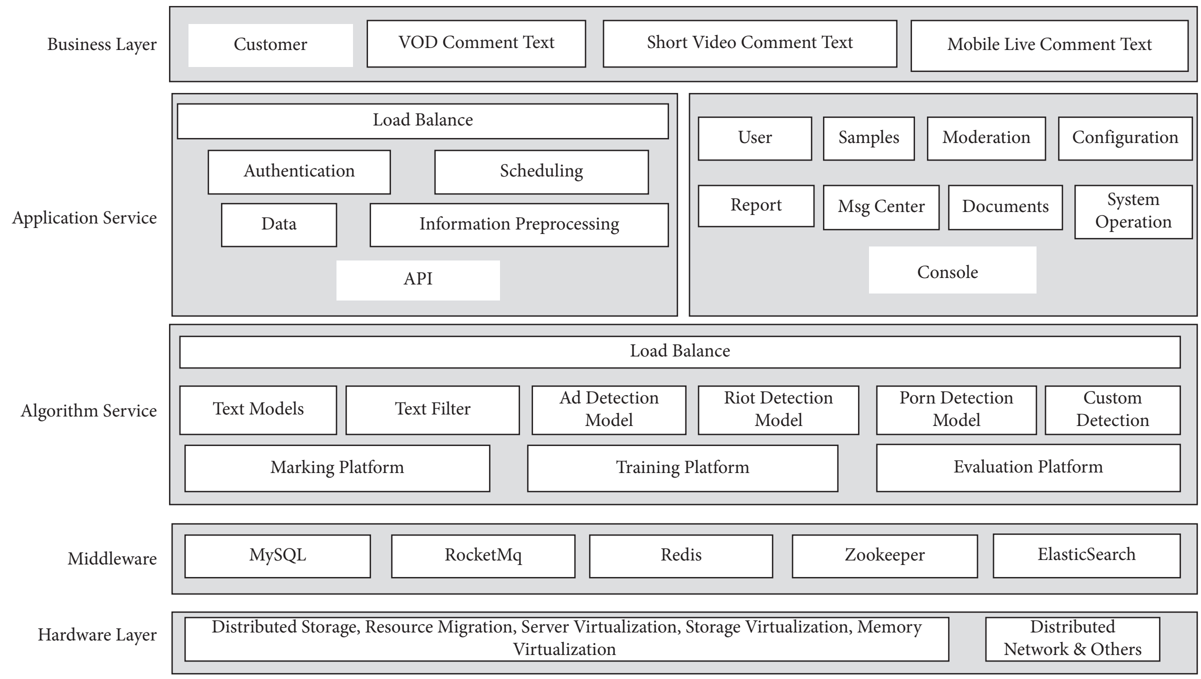


Figure 1: System architecture.

make minor parameter adjustments and local modifications to generate moderation data models according to their actual conditions. The Tencent Cloud's text sample feature library has already accumulated a large number of samples that can cover various Internet social contact scenarios. The feature library mainly contains pornographic contents (texts on severe pornography and vulgar culture), terrorism contents (texts on severe terrorist behaviors and articles), advertising contents (texts on advertising behaviors), illegal contents (texts on contents violating laws and regulations), and abusive contents (texts on severe and light abusive words). The content in the text sample feature library is updated at a regular basis, which can effectively reduce the pressure of developers to collect data and build sample library by themselves.

2.2. System Architecture. The proposed system realizes text content processing, analysis, moderate, and other functions by calling the API (Application Programming Interface) [8]. The system was built with modules, the bottom layer uses various functional components provided by AI, and the top layer adopts self-developed business applications [9]. From bottom up, the system is composed of five modules including a hardware layer, a middleware layer, an algorithm service layer, an application service layer, and a business layer [10], Figure 1 gives a diagram of the system architecture (see Figure 1).

Users can use mobile live broadcast module, VOD module, video clips module, and other modules by logging in to the web-end or app-end of the education video resource service system, and then, they can input text content on the relevant comment page or live broadcast interaction page and submit their comments. The submitted text information performs data communication and transmission with the system through mobile Internet, wireless local area network, and wired network, and the business structure of the system is shown in Figure 2 (see Figure 2) [11]. At first, the text information is preprocessed by the front-end platform, and the security firewall installed in the front-end platform can detect network attacks in a timely manner and prevent the system from being threatened by illegal intrusions; then, the front-end preprocessing server judges the format of the text information and checks for illegal characters and input codes; after security check, the text information enters the AI-based TCM system and the system calls out API to perform text analysis, Lexical analysis, syntax analysis, semantic analysis, sentiment analysis, text classification, and other processing operations on the content. The AI computing platform that provides API has multiple functions such as text tags, model training, machine learning, and AI algorithms, and it can fully cover the various processing of the text content [12]. After security check and content check, the system will detect the text for advertisement, banned content, spams, and other features, and then, the automatic processing results will be pushed to the system administrators who need to confirm or correct the text content processing results. The administrator can adjust the accuracy of intelligence moderation according to the moderation criteria. There are a total of five types of moderation criteria: pornographic contents, terrorism contents, advertising contents, illegal contents, and abusive contents. For example, the common moderation mode could be selected as the moderation criteria for daily use. Then, moderate content moderation will be conducted on the texts that disseminate texts on obscenity, pornography, gambling, violence, murder, and terrorism. For another example, if many terrorism contents pop up in a short term, posing a threat to national

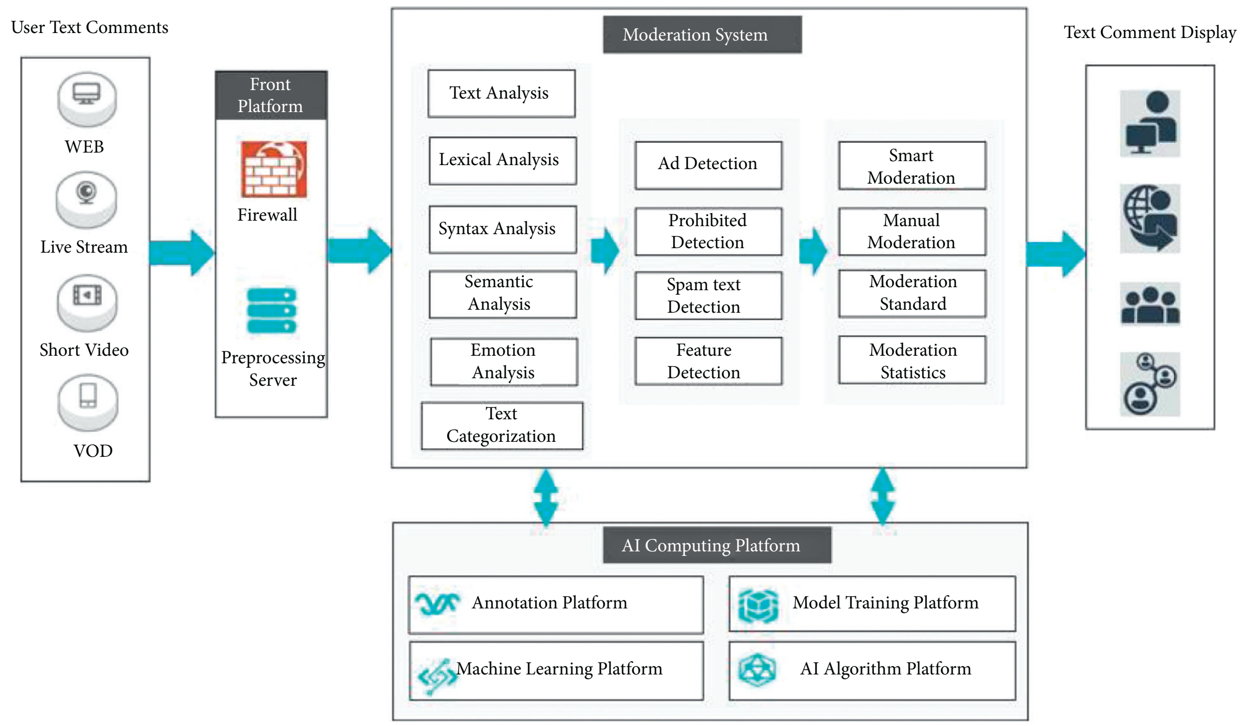


Figure 2: Business structure of the system.

security and race equality, it is necessary to increase the moderation criteria to the strong mode and step up the moderation strength on context, deformed words, and text contents. In this way, the moderation accuracy could be kept within a reasonable range. After that, the system returns the administrators' final moderation results to the AI computing platform and updates text tags and model training, so that the computing platform has the abilities of continuous learning and iterative optimization, later on, when the system comes across the same or similar text content, it can process it according to the moderation method of the administrators. At last, after system moderation, text comments that meet the publishing criteria will be pushed to the web-end and app-end, and displayed in front of all users [13].

2.3. System Operation Process. In the beginning, a user needs to enter the right name and password to log in to the system, and after identity verification is passed, the user can use the web-end or app-end to publish text comments on the mobile live broadcast programs or video clips. The system first checks the format of the input text, and if error has been detected, the system will not process the text anymore, but will prompt that the input format is incorrect, and the user needs to re-enter the text; after format check is passed, the text content will be pushed to the AI-based TCM system, which will call the API to moderate the text content. If the content check is passed, an approval message will be sent to the system administrator, who can conduct random content check and show the moderated text comments on the web-end and app-end [14]. If the text content contains illegal content such as prohibited words, spams, or advertisement and fails to pass the moderation, it will be classified as unapproved type, and then, the AI-based TCM system can clarify the violation type of the text content, prompt alert to the user that the text he/she entered contains illegal content, and point out the violation type, and the relevant information will be recorded in the system log; for the type of the violation that cannot be determined by the system, the text will be pushed to the system administrator for manual moderation.

After manually moderated by the system administrator, text comments that meet the moderation criteria will be published on the web-end and the app-end; at the same time, the system will mark the text content and return it to the database of the AI-based TCM system, so that the text data model can perform update and self-learning; for text content that fails to pass the manual moderation of system administrator, after prompting to the user that the text comment could not be published due to the existence of illegal content, the system will mark the text content, so that the AI-based TCM system can automatically analyse, judge, and moderate similar text content in the future [15]. The operation process of the AI-based TCM system is shown in Figure 3 (see Figure 3).

3. Implementation of the AI-Based TCM System

3.1. System Implementation. According to the settings of different functional modules, the education video resource service system puts a limit on the number of characters in text comments. In the mobile live broadcast module, since the real-time bullet screen comments move fast, comments with many words will be refreshed very quickly; therefore, 50

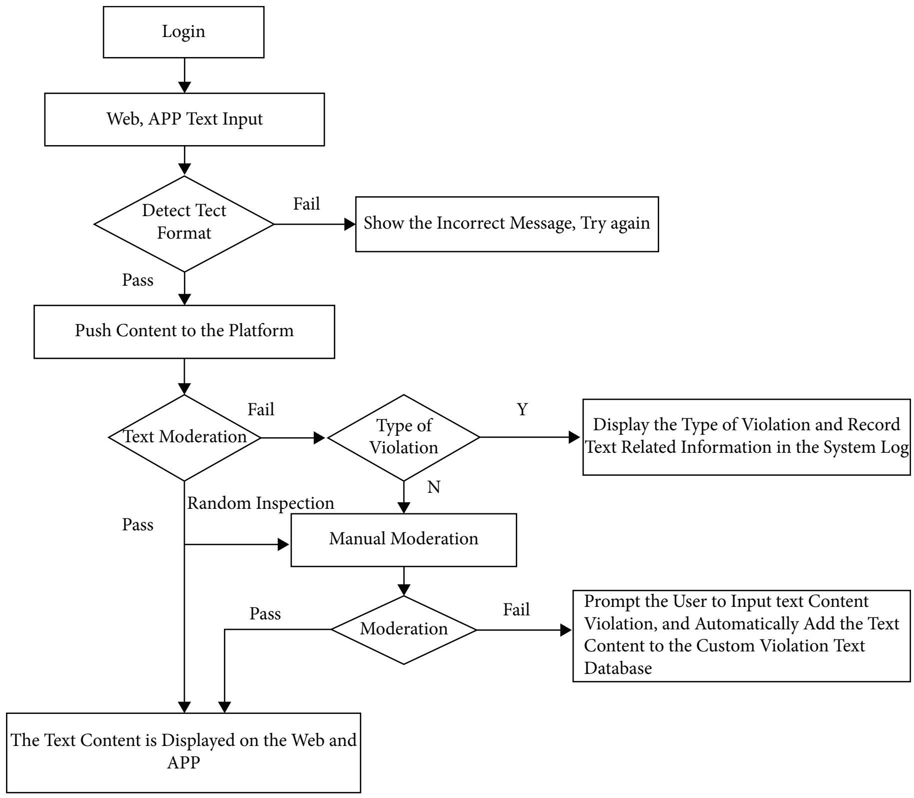


Figure 3: Operation process of the AI-based TCM system.

characters have been set as the limit of each bullet screen comment to facilitate other users' fast understanding of the comment content. In the VOD module, 260 characters have been set as the limit of comments on the videos published by users. In the video clips module, this number has been set to 90 characters. Therefore, the AI-based TCM system was developed based on these character limits of the education video resource service system.

By calling SDK (Software Development Kit), the system encapsulates the moderation API and completes interface docking by passing parameters, and then, it can directly call the interface function provided by the SDK to use the intelligent moderation function [16]. System developers do not have to care about issues such as protocol, encryption, or decryption. The system implementation process is as follows:

(a) The cloud-end management console opens the AI service function and completes works such as user information authentication, system access key authentication, and user ID authentication [17].

(b) The cloud-end management console performs visual modeling. There are many built-in AI algorithms on the cloud platform, such as machine learning and deep learning. In terms of scenarios, it could realize natural language processing and structured data modeling [18]. The cloud-end management console can establish independent models and rules according to different requirements. In this study, the FastText algorithm provided by the cloud server was selected to construct the deep-learning text classification model. The FastText algorithm contains 3 parts: model architecture, hierarchical Softmax, and N-gram features. (1) The model architecture: the FastText model enters a word sequence and outputs the probability of the word sequence belonging to different classes. The words and phrases in the sequence form an eigenvector, which is mapped to the intermediate layer through linear transformation and then mapped to the labels. FastText uses a nonlinear activation function for label prediction. (2) The hierarchical Softmax: some text classification tasks involve many classes, making it complex to compute a linear classifier. To shorten the runtime, the FastText model adopts hierarchical Softmax technique. Based on the Huffman code, the hierarchical Softmax encodes the labels and minimizes the number of model prediction targets. (3) N-gram features: the FastText model adds N-gram to the input word sequence, aiming to prevent the loss of the word order. Specifically, the N-gram is treated as a word and represented by an embedding vector. During the calculation of the hidden layer, the embedding vector of each N-gram is incorporated into the summation and averaging operations. The hash bucket is employed to hash all N-grams into a number of buckets. All the N-grams in the same bucket share the same embedding vector. The process of visual modeling can be divided into

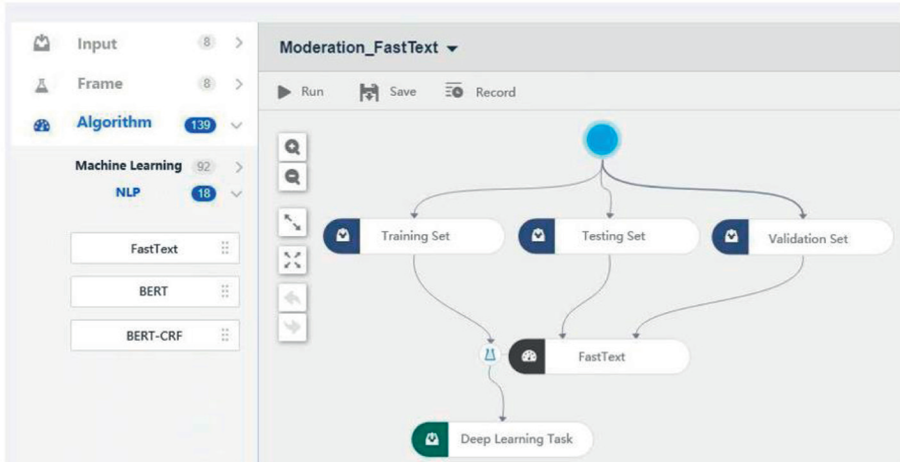


FIGURE 4: Model construction under the cloud management interface.

several steps of project creation, data preparation, model building, and model evaluation.

(i) New project creation: create a new project named "Moderation" in the cloud. In the new project, multiple workflows could be created to perform various processing on the text content according to requirements.

(ii) Data preparation: in this study, a Weibo sentiment analysis dataset containing locally collected and tagged data was adopted. Firstly, deduplication is performed on the repeated samples in the dataset. The samples with a high missing rate and the same value are deleted. Secondly, the data are regularized through case transition and spacing removal. Finally, the missing values are padded, and the abnormal values are processed. After the preprocessing, the dataset contained about 360,000 Weibo posts with sentiment tags, about 200,000 of which were happy, and posts with other sentiments of angry, disgust, and low were about 50,000 each. The dataset was divided into three parts: a training set, a validation set, and a test set, and all of them were uploaded to the AI platform. The training set was used to train the model, the validation set was used to adjust the model parameters, and the test set was used to evaluate the overall performance of the model. The model construction under the cloud management interface is shown in Figure 4 (see Figure 4).

(iii) Use the FastText algorithm to build the text classification model. Configure the FastText model using the cloud console, and complete the setting of algorithm parameters. The paths of training data input, verification data input, and model directory are generated automatically according to the connecting lines. The dimensions of word vector are set to 300, the batch size to 32, the training epochs to 5, and the learning rate to 0.001. Whether to use the pretrained word vector was configured as False and the resource type as on-demand.

(iv) Model performance evaluation: the platform has built-in visual components for model evaluation. In this study, the deep-learning classification task was adopted for evaluation. The prediction effects of this model are evaluated by the deep-learning classification tasks of Tencent Cloud TI platform, and the evaluation indices include Accuracy, Precision, Recall, and F1-score. On the left navigation bar of the console, "Output," "Model Evaluation," and "Depth Learning Classification Task Evaluation" are selected in turn and dragged into the canvas. The output pin is connected to "Deep Learning Classification Task Evaluation." In addition, the tagged sequence number of the evaluation parameter was set to 2, the prediction sequence number was set to 1, and other parameters took the default values, and then, the prediction effect of the established text classification model was evaluated. (c) Set up customized white list and black list vocabulary libraries, and add whitelist keywords and blacklist keywords. (d) Write codes to perform a series of operations such as obtaining system access key authentication, obtaining intelligent moderation SDK software package, environment configuration, and SDK project import, and using SDK for development; then call the moderation model API that had been built on the cloud platform. (e) Sample codes of the calling are as follows:

(i) Configure the user access key authentication in the java file, and generate the corresponding client-end connection object.

```
AisAccess
service = ServiceAccessBuilder.builder()
. ak("######")//User access key
. region("#####")//Set the region where the intelligent moderation function is provided
. connectionTimeout(5000)//Timeout limit for connecting target url
. connectionRequestTimeout(1000)//Timeout limit for connection pool to get available connection
```

```
. socketTimeout(20000)//Timeout limit for obtaining serve response data
        .build();
```

(ii) Enter the text to be reviewed, configure parameters and check.

```
String uri = "/moderation_FastText/text";// The configured text content moderation model module
JSONObject json = new JSONObject();// Create a new JSON object
json.put("categories," new String[] {"porn," "politics," "flood," "ad,"});//Check content type: pornographic, political, spam, or advertisement
JSONObject text = new JSONObject();
text.put("text," "xxxxxxxx");//Text content input position
text.put("type," "content");
JSONArray items = new JSONArray();
items.add(text);
json.put("items," items);
StringEntity stringEntity = new StringEntity(json.toJSONString(), "utf-8");
```

HttpResponse response = service.post(uri, stringEntity);//Pass in the uri parameter corresponding to the text content moderation service and other parameters required by the text content moderation service, the JSON object method is mainly adopted for parameter passing, and the POST method is used to call the service.

ResponseProcessUtils.processResponseStatus(response);//Verify the returned calling status; if it displays correct codes, then the calling is successful; otherwise, it is failed.

3.2. Function Realization of the AI-Based TCM System. The main function of the proposed system is to analyse and detect the text content submitted from multiple terminals to the education video resource service system [19]. The system could realize following functions:

(a) Intelligent moderation: using massive tag data and deep-learning algorithm, the system can perform multidimensional real-time detection on the text information in the comment area or interaction area input from web-end or app-end, and judge whether the text content has violated any regulation or not.

(b) Manual moderation: for text content types that cannot be determined by the intelligent moderation module, the system can submit them for manual moderation. The system administrator uses the system to recheck the published content that has been moderated by the system. After the manual moderation is completed, the system automatically records the processing operations of the system administrator and adds the text content this time into the sample library as a new sample.

(c) Automatic update of text sample library: the system can continuously and quickly upgrade the text sample library; the system administrator can merge the local sample library with the cloud sample library and identify new types of illegal content in a timely manner.

(d) System management console: the system can perform content safety management, user management, system configuration, and other operations; it also can conduct content safety detection configuration, such as define the detection intensity level and manage the vocabulary database.

(e) Algorithm model configuration: if the detection effect of the algorithm model does not meet requirements, the system administrator can adjust the parameters of the original algorithm model or use a different algorithm model for testing [20]. The following models of the model can be adjusted: (1) separator—the separator for separating sentences and labels; (2) word vector dimensions—the dimensions of the word vector in the network; (3) batch size—the size of the batch of training samples; (3) training epochs—the number of trainings for the training data; (4) learning rate—the rate of learning (learning_rate); (5) whether to use the pretrained word vector—if it is set to True, the path of the word vector file can be filled in; the file format is the same as the official format of glove word vector.

Table 1: Moderation accuracy of the proposed system in the test.

	Normal text	Advertising	Spam
Sample size	60	30	30
AI confirm	60	29	29
AI suspicion	0	1	1

4. Test of the AI-Based TCM System

To test the accuracy of the proposed system, our research team had compiled and collected 120 text posts from the Internet, each text contained 20–150 characters, and the text samples included 60 normal comments, 30 advertisements, and 30 spams. Taking the web-end VOD comments as an example, text samples were input to the proposed system for testing. The proposed system completed the moderation within 1 millisecond and returned the results. According to final statistics, 118 texts had been directly identified by the system, 2 texts were identified as suspected illegal texts by the system and submitted for manual moderation; the moderation accuracy was 98.3%, a very high value. The moderation accuracy of the proposed system in the test (see Table 1).

Using the back-end content moderation list, the system administrator browses and moderates all comments that had passed the detection. The system records the new manual moderation operations, and returns the moderation results and text content to the back-end, and then, it performs sample analysis, tagging, and training, modifies the cloud-end moderation model, expands the feature sample library, and personalizes the moderation strategies, keeping the moderation criteria being in an optimal state. Using the

Content Moderation List							
Content	User	Moderation	Type	Admin	Dimension	Confidence	Time
!!@@##$$^^^^^********	xs2005	Fail	AI	Auto	Invalid Text	0.998	2020-12-10 10:50:22
This party is really great	yjs1955	Pass	AI	Auto			2020-12-10 10:52:01

Figure 5: The back-end content moderation list.

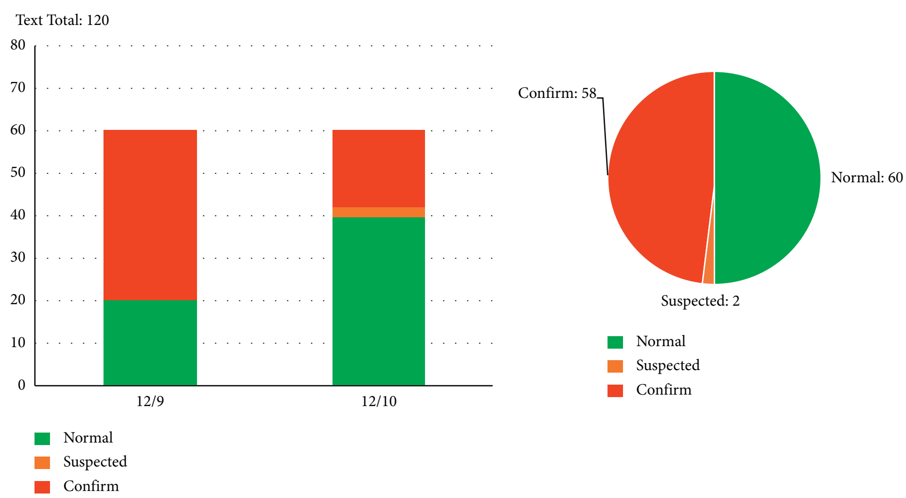


Figure 6: Statistics of text content moderation.

query function, the system administrator can count and analyse the numbers of normal texts, suspected illegal texts, and confirmed illegal texts in the comments, and plot the statistical results in the form of histogram or pie chart. Figure 5 shows the back-end content moderation list (see Figure 5); Figure 6 shows the statistics of the text content moderation (see Figure 6).

5. Conclusion

This article proposed an AI-based TCM system, which was developed on an AI cloud service platform, and the system could automatically and intelligently analyse and detect the text content input by users from the web-end and app-end by calling built-in algorithm models on the cloud-end. With the help of the proposed system, the workload of manual moderation had been greatly reduced, and fast and efficient text moderation had been realized. The computation workload of cloud-end text content moderation can be controlled flexibly according to the use scenarios, and if the computation workload is heavy, the concurrent moderation capacity will be expanded; if the computation workload is small, idle resources will be quickly released. In this way, the system can ensure moderation efficiency under frequent computation workload changes and effectively reduce the moderation costs.

As higher education is heading towards a digitized and networked development direction, the proposed system can effectively detect and manage the ever-increasing real-time interactive text comments, and it could play a positive role in creating a healthy, safe, and civilized network environment, and ensuring the safety and stability of the campus and the society.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported in part by the Research and Development Planning Project of Shandong Province, China (year: 2019; Grant no. 2019GGX105019); Education and Teaching Reform Research Project of Shandong University (Year: 2020; Grant no. 2020Y288); and Construction and Management Research for Laboratory Major Project of Shandong University (year: 2020; Grant no. SY20201101).

References

[1] S. Q. Guo, J. J. Huang, and Q. F. Yuan, "A review of the development of mobile learning applications abroad," *E-Education Research*, vol. 5, pp. 105–109, 2011.

[2] J. Chen, "Design and realization of the content management system of TV," *Broadcasting and Television Technology*, vol. 4, pp. 4–10, 2015.

[3] S. Wang, Z. Wang, and H. Ren, “Research on fusion model based on deep learning for text content security enhancement,” *Telecommunications Science*, vol. 36, no. 5, pp. 25–30, 2020.

[4] M. Liu and G. Huang, “Research on harmful text filtering model based on semantic analysis,” *Journal of Chinese Information Processing*, vol. 32, no. 2, pp. 126–131, 2017.

[5] S. Myers West, “Censored, suspended, shadowbanned: user interpretations of content moderation on social media platforms,” *New Media & Society*, vol. 20, no. 11, pp. 4366–4383, 2018.

[6] A. Heldt and S. Dreyer, “Competent third parties and content moderation on platforms: potentials of independent decision-making bodies from A governance structure perspective,” *Journal of Information Policy*, vol. 11, no. s1, pp. 266–300, 2021.

[7] Q. Chen, X. Hu, and H. Yuan, “A large-scaled platform of education resources based on cloud services,” *Modern Educational Technology*, vol. 21, no. 12, pp. 112–115, 2011.

[8] E. A. Ahmed and H. Ali Ahmed, “A proposed model for education system using cloud computing,” in *Proceedings of the 2018 3rd International Conference on Emerging Trends in Engineering, Sciences and Technology*, December 2018.

[9] J. Seering, “Reconsidering community self-moderation: the role of research in supporting community-based models for online content moderation,” *Proceedings of the ACM on Human-Computer Interaction*, CSCW2, vol. 4, , p. 107, 2020.

[10] B. Cameron, E. Crawley, and D. Selva, *Systems Architecture. Strategy and Product Development for Complex Systems*, Pearson Education, 2016, https://www.google.com/search?rlz=1C1GCEB_enIN990IN990&q=London&stick=H4sIAAAAAAAAAOPgE-LUz9U3MC8wrSpW4gAxTbIKcrS0spOt9POL0hPzMqsSSzLz81A4VhmpiSmFpYlFJalFxYtY2Xzy81Ly83awMgIA61Psi08AAAA&sa=X&ved=2ahUKEwjr976Lyd71AhXZ8XMBHbFNCGwQmxMoAXoECDgQAw.

[11] W. Zhu, H. Gong, R. Bansal et al., “Self-supervised euphemism detection and identification for content moderation,” in *Proceedings of the IEEE Symposium on Security and Privacy*, pp. 229–246, Francisco, CA, USA, May 2021.

[12] G. Uddin, F. Khomh, and C. K. Roy, “Mining API usage scenarios from stack overflow,” *Information and Software Technology*, vol. 122, Article ID 106277, 2020.

[13] P. Coutinho and J. Rui, “Moderation techniques for user-generated content in place-based communication,” in *Proceedings of the 2017 12th Iberian Conference on Information Systems and Technologies*, June 2017.

[14] A. Veglis, “Moderation techniques for social media content,” *Social Computing and Social Media*, in *Proceedings of the International Conference on Social Computing & Social Media*, pp. 137–148, Heraklion, Crete, Greece, June 2014.

[15] M. J. Kavis, *Architecting the Cloud: Design Decisions for Cloud Computing Service Models*, Wiley, 2021, https://www.google.com/search?rlz=1C1GCEB_enIN990IN990&q=Hoboken&stick=H4sIAAAAAAAAAOPgE-LUz9U3MMotLypT4gAxK_LMk7S0spOt9POL0hPzMqsSSzLz81A4VhmpiSmFpYlFJalFxYtY2T3yk_KzU_N2sDICAC-vG35QAAAA&sa=X&ved=2ahUKEwiZpKvvzN71AhVt7HMBHY68D08QmxMoAXoECCYQAw.

[16] D. M. Riehle, M. Niemann, J. Brunk, D. Assenmacher, H. Trautmann, and J. Becker, “Building an integrated comment moderation system - towards a semi-automatic moderation tool,” *Lecture Notes in Computer Science*, in *Proceedings of the International Conference on Human-Computer Interaction*, pp. 71–86, Heraklion, Crete, Greece, June 2020.

[17] J. A. Panattoni, R. McAlpine, K. B. Bobade, M. J. Wilson, and C. Willy, “Escalation of machine-learning inputs for content moderation,” *U.S. Patent Application*, vol. 331, 2018.

[18] J. Pavlopoulos, P. Malakasiotis, and I. Androutsopoulos, “Deeper attention to abusive user content moderation,” in *Proceedings of the EMNLP 2017 - Conference on Empirical Methods in Natural Language Processing*, pp. 1125–1135, Copenhagen, Denmark, September 2017.

[19] V. Maddumala and R. Arunkumar, “Big data-driven feature extraction and clustering based on statistical methods,” *Traitement du Signal*, vol. 37, no. 3, pp. 387–394, 2020.

[20] S. Jhaver, S. Ghoshal, A. Bruckman, and E. Gilbert, “Online harassment and content moderation: the case of blocklists,” *ACM Transactions on Computer-Human Interaction*, vol. 25, no. 2, Article ID 3185593, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 8479423, 15 pages
https://doi.org/10.1155/2022/8479423

Research Article

A Novel Precise Personalized Learning Recommendation Model Regularized with Trust and Influence

Xuefeng Zhang, Mengfan Li, Dewen Seng, Xiuli Chen, and Xiyuan Chen

Key Laboratory of Complex Systems Modeling and Simulation, Hangzhou Dianzi University, Hangzhou 310018, China

Correspondence should be addressed to Dewen Seng; sengdw@hdu.edu.cn

Received 23 November 2021; Revised 1 January 2022; Accepted 17 January 2022; Published 19 February 2022

Academic Editor: Ahmed Farouk

Many precise personalized learning recommendations in massive open online courses (MOOCs) have emerged in the intelligence education field. Up to now, most researches simply put the dual learner-resources relations into consideration and are short of studies looking deep into its intrinsic social relation, thus rarely introducing the influential factors such as social trust, which means to apply the mutual trust relation between learners in the precise personalized learning recommendation. Therefore, we propose a personalized learning recommendation method based on learners' trust and conduct a quantitative analysis on two aspects: social trust and influence, so as to realize a precise personalized learning recommendation service. First, we establish a new module on social trust scale which integrates the interactive information and preference degree to reveal the implicit trust relation between learners in social networks and construct social trust networks. Next, we adopt improved structural hole (ISH) algorithm by integrating the topological structure of social trust network with learners' interactive information and identify the most influential learners cluster by the ISH algorithm. For the final stage, we predict the score of target learners based on explicit and implicit feedback information and realize the personalized learning recommendation for new learners. Since the score is predicted, we compare MAE and RMSE in two real-world datasets which are Canvas Network and Wanke website, respectively. The result of experiment validates the accuracy and effectiveness of our recommendation model.

1. Introduction

Nowadays, massive open online courses, or MOOCs, are attracting widespread interest as an alternative education model. Many MOOCs platforms such as Coursera, edX, and Udacity have been built and provide low cost opportunities for anyone to access a massive number of courses from the worldwide top universities [1]. With the 2.0 action projects for education informatization being carried out quickly and the construction of MOOC platforms, the supply of excellent courses resources will increase year by year, which will inevitably lead to resources overloading. How to help learners quickly locate the target interesting course is also a question that needs to be considered in the process of building an intelligent MOOC platform. Due to the low threshold for registration, open resources, and asynchronous and unconstrained presentation in MOOCs, it can be predicted that the number of courses covered on the website will explode as the size of the online course learning website expands and becomes more influential throughout the world. Information overload has become a crucial challenge that users are overwhelmed, and to help learners locate their interested course or appropriate learning resources, learning partners and domain experts are becoming an unprecedentedly important task, attracting attention from both research and application domains [2, 3]. How to let the user find the most suitable course in massive course information will become one of the most important problems that need to be solved to promote the user experience. In MOOC platforms, recommender systems learn users' learning needs and preferences and direct them towards possible resources of interest [4]. With the recent pandemics, the subscription to MOOC platforms has increased by 25–30%, which makes the research on recommender systems in these platforms more and more relevant. Therefore, how to provide learners with targeted learning resources and improve the learning efficiency of online courses is a major challenge for online education. The diversified courses in MOOCs platforms demand an effective way of precise personalized learning course recommendation for their learners.

From the national education policy level, both the Preparation for Future Learning: Reshaping the Role of Technology in Education issued by US National Education Technology Plan 2016 and Educational Informatization 2.0 Action Plan proposed by China Ministry of Education emphasize education should rely on big data and artificial intelligence technology to innovate and improve educational data system and thus promote personalized learning and educational governance. Appropriate courses can be recommended to learners by embedding personalized recommendation technology into MOOC platforms. On the one hand, it can save a lot of time for the learners to locate the target courses and provide personalized learning services. On the other hand, it can greatly improve the utilization rate of the courses resources. By embedding personalized course recommendation technology, the platform can provide more intelligent service, thus realizing the innovative supply of educational resources services.

These years scholars have attempted to apply the techniques of recommendation systems to solve the problems of educational recommendation [5], whose main goal is to identify learners' interested items or possible interested items in the future and provide them with the corresponding resources, peer and expert recommendation services, through analyzing learners' historical interests and preferences, which is, therefore, called personalized learning recommendation system [6]. According to Social Relation Theory (SRT) [7], users with strong social relation always share similar preference and mutual influence in some aspects, which benefits to construct the personalized recommendation system. With the popularity of social platforms, trust information is very common in most social media; it can describe the relationship between users, which means that users have common interests in some aspects [8]. Therefore, research on personalized recommendation method based on social trust has become a hot issue and attracted extensive attention from both the academic and educational fields.

Social trust relation, which reveals one's comprehensive evaluation of another user's behavior and ability, often is regarded as a decision support tool to deconstruct relevant reliable information sources, especially seek advice from those sources, and then make the final decision [7]. However, the uncertainty of trust relationship becomes the biggest challenge to the trust prediction due to the different trust relationship between different users and the difference of trust relationship intensity in different domains. Besides, influence, another important aspect influencing user's behaviors in social networks, extends the description of social trust from another dimension. Influence plays an increasingly prominent role in behavior influence. For example, early politicians used their influence to win elections, and businessmen used influence to sell goods. Microblog celebrities used their influence to lead the opinions, and their influence can be witnessed in many hot topics and unexpected events. Therefore, this paper conducts a quantitative analysis on two dimensions of social trust measurement: trust relationship and influence, to calculate the trust degree of trust relation between individual users and cluster influence and then improve the efficiency and accuracy of personalized learning recommendation.

This paper treats students in MOOC learning as users in electronic commerce, the test questions as items, and the scores on the test questions as rating to the items. Moreover, since most researches on personalized learning recommendation systems simply put the dual learner-resources relations into consideration and often ignore the impacts of social trust on precise recommendation, this paper proposes a precise personalized learning resource recommendation method based on social trust, constructs a "learner-resources-social trust" triangle recommendation model, which depicts the social trust relation between individual learners and between learners clusters through quantitative analysis of social trust and influence dimensions, and thus provides precise recommendation for personalized learning recourses and improves learner's self-inquiry learning ability. The architecture of our recommendation algorithm is shown in Figure 1, which shows using social network to dig the trust users and influential users and then apply it to recommending. The main contribution of this research is as follows:

(1) A new model of social trust measurement is proposed and social trust networks are constructed, which integrates learners' interactive information and preference degree, to excavate the implicit trust relationship among learners in social network.

(2) Based on the topological structure of social trust networks and the interactive information among learners, the improved structural hole algorithm is applied to identify the most influential cluster of learners in the networks.

(3) Perform quantitative analysis on social trust and influence degree, together with implicit and explicit learner's feedbacks, to predict learner's test scores.

(4) Comparison experiments in two real-world datasets, Canvas Network and Wanke website, validate the accuracy and effectiveness of our recommendation model.

The remainder of this paper is organized as follows. Section 2 gives an overview of the related work. Section 3 demonstrates details of our proposed model. Section 4 illustrates experiment datasets and evaluation metrics. Section 5 shows experiment analysis. Section 6 concludes the paper.

2. Related Work

In brief, there are three kinds of efforts involved in our work: personalized learning recommendation, trust-aware recommendation, and social influence analysis. We review previous works on these topics in this section.

Present researches on personalized learning recommendation system mainly focus on three different

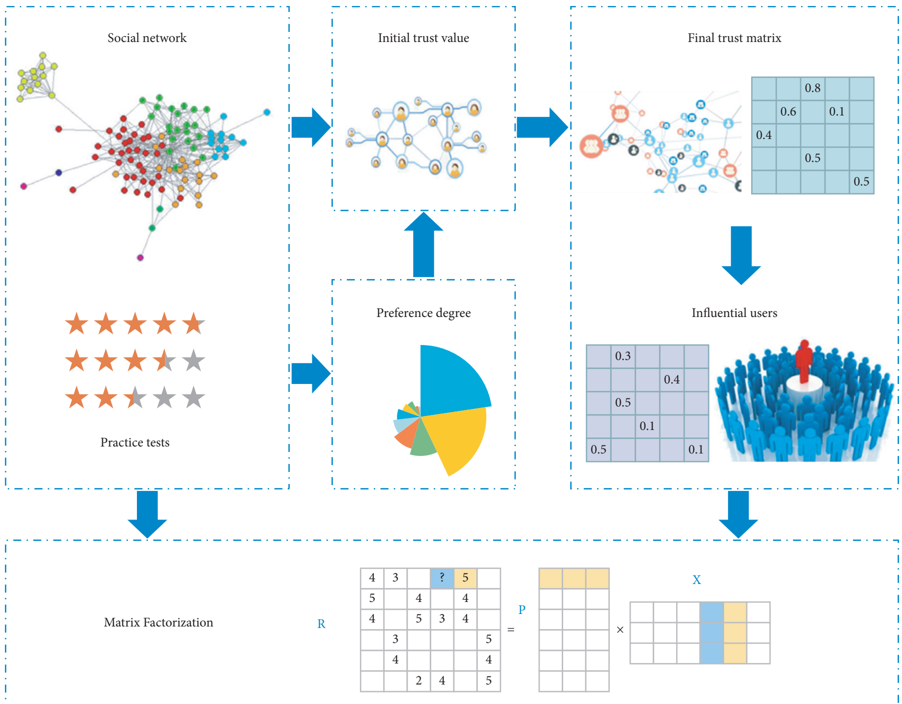


FIGURE 1: The architecture of our recommendation algorithm.

recommendation objects, which are resource, peer, and learning routes. Relevant researches reveal that personalized learning recommendation system could exert certain positive influence on learning interest and efficiency, which could drive a more in-depth application of online learning. Bao et al. [2] proposed the basic elements and the model in social recommendation system from four perspectives, such as learners' features, the characteristics of recommendation objects, social relation, and the context. Based on the element model, Bao designed a social recommendation system model and method based on interested topics. Thus, proper education resources could be recommended in accordance with learners' actual demands in different contexts, and meanwhile by recommending resources to proper learners, the model could well realize the connection between Learner-to-Resource and Resources-to-Learner and offer more precise education service based on multidimensional correlation analysis of global data. Jiang and Zhao [9] illustrated how to apply the AprioriAll algorithm to dig up learning route among the same learning group cluster and conducted precise personal push in accordance with learners' characteristics, such as learning style and knowledge background. Eugenijus [10] applied artificial intelligence technology, such as ant colony optimization, to realize the push of static and dynamic personalized learning primitives in line with learning style. Its experiment reveals that research outcomes applied in e-learning could cut short the learning time and improve learning efficiency and quality. Seng et al. [11] proposed a powerful Item-based Collaborative Memory Network (ICMN) for ICF, which is based on the architecture of End-to-End Memory Networks. Ding and Zhang [12] came up with the idea to integrate learners' social network information with traditional collaborative filtering, so as to calculate the trust degree between new learners and friends. Through their friends' rating data to learning resources, the new learners' rating could be predicated. This way could fill the missing data of new learners in the learner-resources rating matrix and realize the personalized recommendation to new learners.

The research on social recommendation system can be traced back to Referral Web System (RWS) proposed by Kautz et al. [13] in 1997, which integrates social networks on the traditional collaborative filtering model to provide users with more precise and efficient recommendation results. This proves that the integration of social relationships provides reliable data support for the recommendation system. While improving the recommendation accuracy, it also provides new ideas for solving the cold-start problem. The matrix decomposition recommendation model has the characteristics of high recommendation accuracy, good scalability, and high flexibility. For this reason, researchers have proposed a series of matrix decomposition models that integrate social information. Trust-based social recommendation system is the most common social recommendation system. The basic method is to use social trust as an indicator to measure the social relationship between users and to calculate the trust value between users by calculating the mutual trust relationship between users. Generally, two users with higher trust values have more similarities. A large number of researchers have conducted research on recommendation systems based on user trust. Yang et al. [14] proposed TrustMF, a social recommendation model based on the relationship between trust and being trusted. According to the directivity of trust relationship, TrustMF maps each user into two different K-dimensional feature vectors, which are called trustor feature vector and trusted feature vector, respectively. Jamali and Ester [15] introduced the method of trust transition into the recommendation algorithm (SocialMF), spreading the trust relationship by constraining the similarity of the average preferences of users and their friends, thereby obtaining more precise results. SoReg is a social regularization recommendation model proposed by Ma et al. [16] on WSDM in 2011. The idea of this model is similar to that of SocialMF; that is, it is assumed that the user feature vector should be similar to the friend's feature vector. For this reason, it is proposed to use social information to regularize the user feature vector, so as to use the preference information of friends to influence the final prediction score of the user. In order to deal with the sparsity of rating and trust relationship, Guo et al. [17] introduced social information on the basis of the SVD++ model [18] and proposed a trust-based matrix decomposition model TrustSVD that takes into account both scores and trust information, taking into account the explicit and implicit effects of score and trust information when predicting the score of unknown items. Zhang et al. [19, 20] proposed a novel trust value measurement model that combines user interaction information, preferences, and trust which is brought up to explore the implicit trust relationship between users in social networks and reconstruct the social trust network. Wu et al. [21] proposed TrustEV and took the view of multitask learning to unite collaborative filtering for recommendation and network embedding for user trust. Yu et al. [22] introduced an adaptive trust-aware recommendation model based on a new trust measurement developed using a user-item bipartite network. Ardissono and Mauro [23] extended trust-based recommender systems with additional evidence about trust, based on public anonymous information, and proposed the Multifaceted Trust Model (MTM) to define trust among users in a compositional way, possibly including or excluding the types of information it contains. Bao et al. [24] decomposed trust information into four dimensions to measure: Goodwill, Integrity, Ability, and Predictability. The above algorithms study the trust intensity between users from the perspective of scoring or trust data and have made a significant improvement compared with the algorithm which regards the influence of each friend on the user as the same.

Social influence refers to the case when individuals change their behaviors under the influence of others. Various fields including viral marketing, online advertising, and personalized recommendation have expressed their interests in understanding diffusion. Domingos and Richardson [25] investigated social influence in the customer network. They proposed a model to identify customer's influence between each other in the customer network and built a probabilistic model to mine the spread of influence for viral marketing. Aris et al. [26] exploited a statistical analysis method to identify and measure whether social influence is a source of correlation between the actions of individuals with social ties. These works prove that analyzing social influence can help us to understand peoples' social behaviors, provide theoretical support for making public decisions and influencing public opinion, and promote exchanges and dissemination of various activities [27]. In light of the significant increasing of social networks in both scale and volume, how to measure a user's social influence to other users becomes increasingly important.

The key node measurement methods based on node attributes and network location can be divided into two types: network local attributes and network global attributes. The node important ranking index based on the network local attributes considers node information and the neighbor node information, which is simple calculation with low time complexity. However, the network global attributes consider network global information, the index of which is high accuracy and time complexity. The global calculation of evaluating the nodes importance methods usually includes betweenness centrality (BC), closeness centrality (CC), and so on. BC measures the times a node acts as a bridge along the shortest path of two other nodes [28]. It requires that information should spread through the shortest way, but sometimes the information does not spread through the shortest way in most real networks. CC is defined as the average distance from one vertex to the other vertices in a network [28], which is used to measure the ability of nodes in the network to influence other nodes through the network. The closer the node is, the more important the node is in the center of the network. However, these algorithms' time complexity is very high as they require knowing the whole network structure in advance and also need traversing the graph. Local evaluation of nodes importance measures includes the degree, Structural Holes, etc.; the easiest one is based on the degree of a node. Albert et al. [29] used the Degree Centrality (DC) to find the most influential nodes in the social network. They pointed out that, in heterogeneous scale-free networks, nodes with high degree (also called Hub nodes) have a higher influence. However, the DC measurement method only considers the number of neighbors but ignores the topological relationship between the neighbors and does not consider the location of the node in the network. Therefore, it does not reflect the interaction between neighboring nodes, resulting in inaccurate results. In order to consider the topological relationship between neighbor nodes in the evaluation index, Chen et al. [30] proposed using the two parameters of clustering coefficient and degree to jointly evaluate the propagation ability of the node. Seng et al. [31] put forward a hybrid top-N recommendation algorithm that combines mutual trust and influence. Burt [32] proposed another effective method using local information to evaluate the nodes importance, which is to find the "structural holes" in complex networks. Yu et al. [33] proposed an algorithm that can identify important nodes in a complex network, since this algorithm only considers the neighbor nodes and the nearest neighbor node of target node regardless of the overall structure of the network, the nodes' importance can be calculated based on the local information of the complex network, and it is verified on the ARPA network that the algorithm is better than DC, BC, and CC in terms of node importance measurement. Moreover, Rezvani et al. [34] devised two fast yet scalable algorithms for the top-k structural hole spanner problem, by developing innovative filtering techniques that can filter out unlikely solutions as early as possible. The invented techniques are built up on fast estimations on the upper and lower bounds on the cost of an optimal solution and an observation of that the Articulation Points (AP) in a real social network usually are the structural hole spanners of the network. Inspired by the above research, we analyze how structural holes influence the procedure of information diffusion and study a novel problem of mining structural hole spanners in social networks; moreover, we propose an ISH algorithm which makes it possible to efficiently excavate key nodes in directed graphs.

3. The Proposed Model

This section introduces the overall framework of the ITSVD and details the three key stages of the method in five steps. The overall framework of the ITSVD is illustrated in Figure 2. To facilitate discussion, some symbols are introduced with specific definition as shown in Table 1. It functions as follows: first construct a "learner-resource" rating matrix based on learners' learning record or practice tests, then apply the explicit and implicit feedback information together with preference degree to measure the trust relation between learners, and then discover the learners' clusters sharing mutual trust with the target learners; after that, identify the learners' cluster with the biggest influence in the trust network through improved structural hole algorithm, which points that one with higher trust degree has greater influence over others, and finally predict the resource rating values of the target learners through the social trust recommendation model. Afterwards, precise personalized top-N recommendation could be offered to the target learners based on the predicted rating values, which means that the resources within the top-N rankings could be recommended to target learners.

The model mainly includes three stages and five steps. The three stages refer to the calculation of learners' trust value (trust relation), identification of the influential learners' clusters (influence), and model training. The three stages are implemented in five steps:

(1) Calculation of trust degree

Step 1. We firstly use the interaction information between learners to calculate their initialization of trust value. We put forward a hypothesis: while learners have a common ranking score on the same test i, record is an interaction.

Step 2. Trust value could be changed along with interactions; thus the interactions on different tests could change the trust value as well. Moreover, users tend to trust more those who have successful interaction over their favorite tests. Therefore, we introduce preference degree to measure learners' preference over different tests.

Step 3. At final step, assign different weight over tests in each interaction based on learners' preference over test i, then generate the final trust value, and the trust network is formed after filtering out the weak trust relationship.

(2) Identification of influential learners

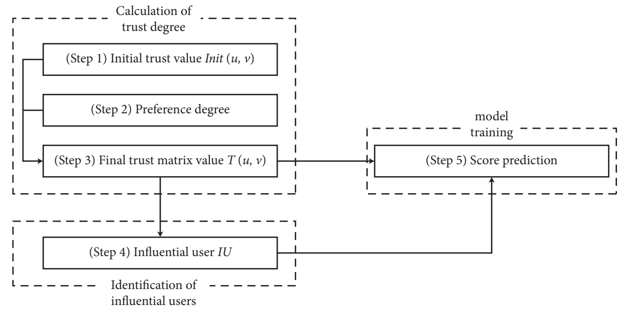


Figure 2: The overall framework of FSTID.

Step 4. Based on the directed trust network achieved in Step 3, apply nodes and their neighboring topological structures to calculate the constraint value of nodes. Utilize the constraint values as an indicator to evaluate the importance of node, which is called "Influence." Finally, screen out the cluster of the most influential learners.

(3) Model training

Step 5. Combining explicit and implicit feedback information, we introduce the trust relation between learners to reveal their influence over each other, so as to improve the accuracy of simulation test. To avoid overfitting, the loss function adopts the regularization strategy of TrustSVD [18] algorithm, that is, to adopt less punishment to learners and tests with higher scores, but to adopt more punishment to the cold-start learners (new learners) and new tests.

3.1. Calculation of Learners' Trust Value (Step 1, Step 2, and Step 3).

Calculation of learners' trust value is an important step in social recommendation process. Trust originates in the experience of the subjective individual [6]. The more the learner u trusts learner v, the more the interaction that will occur. In reality, trust degree between people gets influenced by interaction relation, as well as by the interaction result. Successful interaction could increase their trust degree and vice versa. Besides, the trust influence resulting from interaction varies along with the preference difference caused by learners' different interest over tests.

Therefore, in this section, we propose a new measurement model of trust relation in consideration of learners' interaction information and preference, so as to take comprehensive account of learners' scoring and preference degree over different tests.

First, we make the following two hypotheses:

(1) If two learners score the same value over one test, they are assumed to have one interaction.

(2) If the score of test i achieved by learners u and v is higher or lower than average score of each learner, this interaction is considered to be a success, or otherwise that is a failure, where $r_{u,i}$, $r_{v,i}$ are the evaluation of item i by user u and user v, respectively, and $\overline{u}$, $\overline{v}$ are the average scoring of user u and user v, respectively.

Table 1: Symbol definition.

Symbol	Definition
U, I	$\{u_1, u_2, \ldots, u_m\}$ refer to the learners' clusters and $\{i_1, i_2, \ldots, i_n\}$ refer to the test clusters
R	Test score $[r_{u,i}]_{m\times n}$
$\mathrm{I_u}$	Test cluster learner u has already rated i
U_i	Learners' cluster who has already scored in test
P, Q, Y, W	Refer to learners' eigen matrix, test eigen matrix, implicit eigen matrix, and trust eigen matrix
B_u, B_i	Indicate learner's bias vector and test's bias vector
T	Trust matrix
T_i	All trust clusters of learner i, including truster cluster T_i^+ and trustee cluster T_i^-
$G = (V, E)$	Social network
$<i, J>$	An edge from node i pointing to node j
IU	Cluster of influential learners

$$\begin{cases} \text{success}, & \left(r_{v,i} - \overline{u}\right) * \left(r_{v,i} - \overline{v}\right) \geq 0, \\ \text{failture}, & \left(r_{v,i} - \overline{u}\right) * \left(r_{v,i} - \overline{v}\right) < 0. \end{cases} \tag{1}$$

Under the condition when learner u and learner v share one iteration shown as $Iu \cap Iv \neq \varphi$, the trust measurement of learner u over learner v is as below:

$$T(u, v) = \mathrm{Init}(u, v) * \frac{\sum_{i\in\text{success}} \mathrm{Pre}(u, i) - \sum_{i\in\text{failure}} \mathrm{Pre}(u, i)}{\sum_{i\in\text{success}} \mathrm{Pre}(u, i) + \sum_{i\in\text{failure}} \mathrm{Pre}(u, i)}. \tag{2}$$

Init(u, v) refers to the initial trust value, calculated as

$$\mathrm{Init}(u, v) = \frac{\min\left(\left|\mathbf{I}_u\right|\left|\mathbf{I}_v\right|, \mathbf{D}_u\right)}{\mathbf{D}_u}. \tag{3}$$

Threshold value $Du = \sqrt{|I_u|}$ indicates the minimum interaction times when two learners fully trust each other. $\mathrm{Pre}(u, i)$ points to the preference degree of learner u over test i:

$$\mathrm{Pre}(u, i) = \frac{\sum_{o\in U_i} \mathrm{sim}(u, o)}{U_i}, \tag{4}$$

U_i represents the cluster of learners who have already scored on test i. The more the similarities the learner u shares with others in the cluster, the more he prefers test i. $\mathrm{sim}(u, o)$ refers to the similarities between learner u and learner o. Users who are similar to user u would like item i, scored by user u. To solve the problem that the number of common tests shared by learners is limited, we introduce the classic measurement of two variables' relevance by Pearson Correlation Coefficient (PCC) formula to estimate the similarities, which is proposed to calculate two variables' relevance by Karl Pearson in 1880s. By introducing the weight parameters of common tests' number and adjusting the PCC between 0 and 1, the similarity formula is modified as

$$\mathrm{sim}(u, o) = \left(\frac{1}{2} + \frac{\sum_{i\in I_U \cap I_O}\left(r_{u,i} - \overline{u}\right)\left(r_{o,i} - \overline{o}\right)}{2 * \sqrt{\sum_{i\in I_U \cap I_O}\left(r_{u,i} - \overline{u}\right)\sum_{i\in I_u \cap I_O}\left(r_{o,i} - \overline{o}\right)^2}}\right) * \frac{I_u \cap I_O}{I_u}. \tag{5}$$

The different weights are assigned to different tests based on the learner's preference in successful or unsuccessful interactions. Therefore, the final trust value $T(u, v)$ is achieved by

$$T(u, v) = \mathrm{Init}(u, v) * \frac{\sum_{i\in\text{success}} \mathrm{Pre}(u, i) - \sum_{i\in\text{failure}} \mathrm{Pre}(u, i)}{\sum_{i\in\text{success}} \mathrm{Pre}(u, i) + \sum_{i\in\text{failure}} \mathrm{Pre}(u, i)}. \tag{6}$$

3.2. Identification of Influential Learners (Step 4). Traditional structure hole (SH) theory enjoys a wide application and serves well to identify the influential nodes in social network. SH is an effective method which only uses local information to identify key nodes of networks. SH is originally developed by Burt [32] who introduced this concept in an attempt to explain the origin of differences in social capital. Burt's theory suggests that structural holes are gaps in information flows between individuals linked to the same ego but not linked to each other. It indicates that the people on either side of the hole have access to different flows of information. The calculation of SH is relatively complicated. Generally, there are two evaluation indices: the index given by Burt [32] himself and the betweenness centrality index. The former involves four aspects: Effective Size, Efficiency, Constraint, and Hierarchy, where the degree of constraint is the most important. The latter mainly refers to Freeman's betweenness centrality [35] for the overall network and its promotion form, where the basic idea is that if a node is on the shortest path of many other node pairs, the node has a higher betweenness centrality, and it is more likely to occupy the structural hole location. The constraint refers to the node's ability to use SH in its own network, setting the evaluation criteria as the node's reliance value to other nodes. The formula is as follows:

$$C(i) = \sum_{j \in \Gamma(i)} \left(p(j,i) + \sum_{q \in \Gamma(i)} p(j,q) * p(q,i) \right)^2, \quad i \neq q \neq j, \tag{7}$$

where $\Gamma(i)$ refers to the nodes which have direct connection with node i in undirected graph. Since the trust network is directed network, to avoid confusion in later process, T_i^- is used to replace $\Gamma(i)$. $p(j,i)$ stands for the percentage of energy which node i spends to maintain the relationship with node j in its total energy.

$$p(j,i) = \frac{Z_{ji}}{\sum_{j \in T_i^-} Z_{ji}}, \tag{8}$$

where <j,i> is the connection between node j and node i; if connected, it is 1; otherwise it is 0.

$$Z_{ji} = \begin{cases} 1, & \langle j,i \rangle \neq \text{null}, \\ 0, & \langle j,i \rangle = \text{null}. \end{cases} \tag{9}$$

$\sum_{q \in Ti^-} (j,q) * p(q,i)$ is determined by the number of bridging node q between nodes i and j. The closed triangles are formed more and more due to the close ties between nodes i, j, q, which is not conducive to the widespread dissemination of information. In (10), C(i) can comprehensively evaluate the number of neighbors and the tightness of connections between nodes. Higher values of $C(i)$ indicate that the in-degree (number of incoming nodes) of one node is smaller and has a high closed degree with these users. Such nodes are less likely to acquire new information. On the contrary, nodes with smaller constraint coefficients have greater influence on information spreading.

However, its limit lies in that it only measures the relation between a node and its close neighboring nodes but ignores the topological relationship between a node and its two-step neighboring nodes. Therefore, some important nodes could be neglected. As shown in Figure 3, from the one-step neighbor perspective of nodes A and E, nodes A and E have the same structure. According to the calculation formula of constraint degree proposed by Burt, the constraint degree of node A and node E is

$$\begin{aligned} C(A) &= C(E) \\ &= 3 * \left(\frac{1}{3}\right)^2 \\ &= 0.333333. \end{aligned} \tag{10}$$

However, it can be seen from Figure 3 that the trusted node C of node A and the neighbor node G of node E have different topological structures, and node G has better relationship than node C. Therefore, Burt's constraint degree calculation method cannot effectively quantify the node differences in the digraph. It is necessary to improve the calculation method of network constraint degree to measure the importance of nodes in the network more accurately.

The Information Flow Theory (IFT) indicates that information spreading on Internet always reaches to the leading nodes first, and then from the leading nodes it reaches out to a broader network. From this view, if a node has connection with many leading nodes, the node has more possibilities to become a structure hole. On the other hand, when observing the influence of node E on node A and node G, respectively, it can be found that there is another trust node L in node G, which weakens the influence of node E on G and to some extent weakens the influence of node E on the trusted nodes H, i, and J of G. Thus, we propose two assumptions:

(1) If the node j trusted by node i is a leading node or Hub node with many in-degree nodes, then node j could greatly enhance the influence of node i.

(2) If the node j trusted by node i has multiple truster nodes, the influence of node i will be weakened.

An improved structural hole algorithm (ISH) is put forward by integrating the in-degree and out-degree influence of neighboring nodes on target nodes with the classic structural hole algorithm:

$$C(i) = \sum_{j \in T_i^-} \left(p(j,i) + \sum_{q \in T_i^-} p(j,p) * p(q,i) \right)^2 * \frac{\left|T_j^+\right|}{\left|T_j^+\right| + \left|T_j^-\right|}, \quad i \neq q \neq j. \tag{11}$$

With the above formula, the constraint coefficient of all nodes could be calculated. Afterwards, the top-k% learners with the smallest constraint coefficient are marked as IU, as the learners cluster with global influence, where $\Gamma(i)$ represents the nodes with direct connection with node i in the undirected graph; and T_i^- stands for $\Gamma(i)$; p(j, i) refers to energy ratio that node i spends in maintaining the relation with node j.

According to the calculation formula of constraint degree proposed by ISH, the constraint degree of node A and node E in Figure 3 is

$$\begin{aligned} C(A) &= 3 * \left(\frac{1}{3}\right)^2 = 0.333333, \\ C(E) &= \left(\frac{1}{3}\right)^2 + \left(\frac{1}{3}\right)^2 * \frac{1}{4} + \left(\frac{1}{3}\right)^2 * \frac{2}{5} = 0.183333. \end{aligned} \tag{12}$$

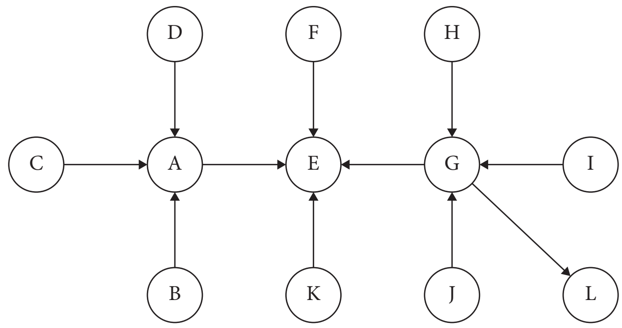


FIGURE 3: The architecture of our recommendation algorithm.

It is found that node E has smaller constraint degree than node A, which means that node E has better ability of information transmission, i.e., influence. The improved formula has changed from considering only one-step topology neighbor to introducing two-step topology information, so as to more accurately excavate the structural hole nodes in the network.

3.3. Model Training. There is a problem that learners' explicit information is difficultly obtained, which has data sparsity in social Internet. And except the relationship of one-to-one trust, the reliability of learners is also important which is influence in social Internet. The influence of different learners is great difference, where a few learners not only switch public opinion, but also have long term sustainability effect on other learners. Thus, trust learners and influential learners have effect on other learners in sense. The rationale behind SVD++ is to take into consideration user/item biases and the influence of rated items other than user/item specific vectors on rating prediction. The TrustSVD model is built on top of a state-of-the-art model known as SVD++, which combines implicit influence of trusted users and implicit influence of trusting users. The proposed algorithm based on SVD++ [17] and TrustSVD [18] introduces the trust relation between learners to reveal their influence over each other, so as to improve the accuracy of simulation test:

$$\hat{r}_{u,i} = b_u + b_j + u + q_j^T\left(p_u + |I_u|^{-1/2} \sum_{i\in I_u} y_i + |T_u|^{-1/2} \sum_{v \in T_u} W_v + |IU|^{-1/2} \sum_{f\in IU} p_f \right), \tag{13}$$

where b_u, b_j are the bias of user u and item j; u is the global mean score; I_u is the cluster of items that u has rated; y_i is the implicit feedback on item i; $qj^T yi$ is the influence of all other items I on u's rating prediction. Then let w_v be the vector in the trust eigen matrix W and $qj^T wv$ be the influence of user v trusted by over u's rating prediction on item j. For each influential learner $f \in IU$, inner product $pf^T yi$ refers to the impact of influential learners f over target test i.

To avoid overfitting, the loss function adopts the regularization strategy of TrustSVD algorithm, that is, to adopt less punishment to learners and tests with higher scores, but to adopt more punishment to the cold-start learners (new learners) and new tests; the loss function can be expressed as

$$\begin{aligned}
J &= \frac{1}{2}\sum_{u\in U}\sum_{i\in I_u^-}\left\|\left(r_{u,i} - r_{u,j}\right) - \left(\hat{r}_{u,i} - \hat{r}_{u,j}\right)\right\|_F^2 + \frac{\lambda}{2}\left(\|P\|_F^2 + \|Q\|_F^2 + \|X\|_F^2 + \|Y\|_F^2 + \|b\|_F^2\right),\\
L &= \frac{1}{2}\sum_{u}\sum_{j\in I_u}\left(\hat{r}_{u,i} - \hat{r}_{u,j}\right)^2 + \frac{\lambda_t}{2}\sum_{u}\sum_{v\in T_u^+} W_v\left(\hat{t}_{u,v} - t_{u,v}\right)^2 + \frac{\lambda}{2}\sum_{u}|I_u|^{-1/2} b_u^2 + \frac{\lambda}{2}\sum_{j}|U_j|^{-1/2} b_j^2\\
&\quad + \sum_{u}\left(\frac{\lambda}{2}\left(|I_u|^{-1/2} + |IU|^{-1/2}\right) + \frac{\lambda_t}{2}|T_u|^{-1/2}\right)\|P_u\|_F^2 + \frac{\lambda}{2}\sum_{j}|U_i|^{-1/2}\|q_j\|_F^2 + \frac{\lambda}{2}\sum_{i}|U_i|^{-1/2}\|y_i\|_F^2,\\
&\quad + \frac{\lambda}{2}|T_v^+|^{-1/2}\|W_v\|_F^2 + \frac{\lambda}{2}\sum_{f}|IU|^{-1/2}\|P_{uf}\|.
\end{aligned} \tag{14}$$

U_{j}, U_{i} represent the cluster of learners who have scored, respectively, on items j and i, and T^{+} represents the trustors' cluster of learner v. To reduce the complexity of the model, the same parameter λ for all the regularized terms is applied, except the regularized trust term λ_t.

To obtain the local optimal value of the objective function of equation (10), the following gradient descent for all learners and items is performed on b_{u}, b_{j}, p_{u}, q_{j}, y_{i}, p_{f}, and w_v in the train dataset:

$$
\begin{aligned}
\frac{\partial L}{\partial b_u} &= \sum_{j\in I_u} e_{u,j} + \lambda \left|I_u\right|^{-1/2} b_u,\\
\frac{\partial L}{\partial b_j} &= \sum_{u\in U_j} e_{u,j} + \lambda \left|U_j\right|^{-1/2} b_j,\\
\frac{\partial L}{\partial P_u} &= \sum_{j\in I_u} e_{u,j} q_j + \lambda_t \sum_{v\in T_u} e_{u,v} W_v + \left(\lambda\left(\left|I_u\right|^{-1/2} + \left|U_j\right|^{-1/2} + \lambda_t \left|T_u\right|^{-1/2}\right)\right) p_u\\
\frac{\partial L}{\partial q_j} &= \sum_{u\in U_j} e_{u,j}\left(p_u + \left|I_u\right|^{-1/2}\sum_{i\in I_u} y_i + \left|T_u\right|^{-1/2}\sum_{v\in T_u} W_v + |IU|^{-1/2}\sum_{f\in IU} p_f\right) + \lambda \left|U_j\right|^{-1/2} q_i\\
\forall i \in I_u, \frac{\partial L}{\partial y_i} &= \sum_{j\in I_u} e_{u,j}\left|I_u\right|^{-1/2} q_j + \lambda \left|U_j\right|^{-1/2} y_i\\
\forall v \in T_u, \frac{\partial L}{\partial w_{v_i}} &= \sum_{j\in I_u} e_{u,j}\left|T_u\right|^{-1/2} q_j + \lambda_t e_{u,v} p_u + \lambda \left|T_v^{+}\right|^{-1/2} W_v\\
\forall f \in IU, \frac{\partial L}{\partial p_f} &= \sum_{j\in I_u} e_{u,j} |IU|^{-1/2} q_j + \lambda |IU|^{-1/2} p_f.
\end{aligned}
\tag{15}
$$

The pseudocode for the ITSVD is shown in Algorithm 1, where the input is regularization parameters $\lambda, \lambda t$ and learning ratio η. First, randomly initialize the eigen matrix and the bias vector (Line 1), then calculate the loss function, and update the variants with stochastic gradient descent method (Lines 10–16) until the function recesses (Line 2). Finally, return to the bias vector eigen matrix and the bias vector as output (Line 19).

4. Datasets and Evaluation Metrics

The emphasis of social recommendation is to collect learners' social data in online learning platforms. In order to highlight the attributes of social relations and avoid bias, this paper selects data from two real-world online learning platforms: Canvas Network (http://www.canvas.net) and Wanke (http://www.wanke001.com/index).

Canvas Network is an open online course learning platform owned by Instructure, an American educational technology company. It offers open online courses, including massive open online courses (MOOC), which are free of charge to learners around the world. The chosen set is a public data set from January 2014 to September 2015 released by Canvas Network in March 2016. The data set includes 238 courses in 10 disciplines on Canvas Network platform, among which 130 courses are related to vocation and education, whereas relatively few courses are related to medical, mathematics, physics, and computer science. Majority of the courses last from 1 to 2 quarters, and only 26 courses expand to 3 quarters or longer. Most courses span from 35 to 65 days. The data include 325199 aggregate records, each representing individual learner's behavior in a course. The variables can be generated from three sources: course management, interactions between learners and courses, and learners' questionnaire. The structure of Canvas Network is based on the 2014 edX dataset. Due to deidentification process, Canvas removes two fields of learner's gender and nationality, which is worth analyzing, but adds the field about learners' questionnaire, compared to the 2014 edX data. Canvas offers 26 lists, including 4 types of information, regarding courses, learners' basic information, learning intention, and learning behaviors. The specific attributes include course IDs, user IDs, registration, browse history, course discussion, completion, score, motivation, country, learner's type, study time per week, education background, age, gender, registration time, course start time and end time, recent interaction, number of interactions with the course, interaction dates, number of viewed chapters, numbers of discussion posts, and course duration dates or dates with learner's participation in the course. Our experiment conducts data preprocessing to the Canvas data and deletes the data with no score.

Wanke (http://www.wanke001.com), a commercial online learning platform launched in 2013, is an interactive flipped classroom teaching platform for Chinese universities, similar to MOOC. Wanke combines the online MOOC teaching with offline classroom interaction, brings online learning into evaluation mechanism, and realizes the one-window classroom service, including teacher-learner real-time interaction, course tests, score evaluation, and personalized learning experience, etc. To verify the validity, the C Programming Language course learning data from 2016 to 2018 and 161 learners from 4 classes enrolled in 2015, 2016, and 2017 are selected as experiment subjects. The attributes of Wanke include user name, name, student ID, major, knowledge point, study times, etc., among which study times represent the number of times a learner spends in completing the test. Meanwhile, the tests' score of all 56 knowledge points in the C Language Programming course is chosen for the research. Considering that some tests have no score, the maximum study times are set at 10, and the scores that exceed the maximum study times default to 0. For rest data, take the ratio of learners' study times to their maximum study times on a test as the learner's score on the test. After the processing, the value range of score is [0, 1].

Table 2 illustrates the specifications of two data sets, which finds out that Canvas Network data is very sparse, whereas Wanke data is less sparse. The choice of these two datasets benefits to observe how our model performs in different sparse conditions. Table 3 illustrates the attribute comparison of two data sets.

Ultimate goal of learning resources recommendation system is to fulfill the personalized learning demands. Learner's satisfaction rate over the recommendation result is a key index to evaluate the system. However, the satisfaction rate is very subjective and it is hard to quantitatively measure how much they are satisfied. Thus, certain quantitative evaluation indexes are applied, such as precision rate, recall rate, coverage rate, F value, Root Mean Squared Error (RMSE), and Mean Absolute Error (MAE), etc. In this section, we adopt two widely applied precision indices: MAE and RMSE to evaluate the experiments:

$$
\begin{aligned}
MAE &= \frac{\sum_{u,j}\left|\hat{r}_{u,j} - r_{u,j}\right|}{\mathrm{N}}, \\
RMSE &= \sqrt{\frac{\sum_{u,j}\left(\hat{r}_{u,j} - r_{u,j}\right)^2}{\mathrm{N}}},
\end{aligned}
\tag{16}
$$

where N is the rating times in the experimental test. Lower MAE and RMSE represent better recommendation performance.

5. Experiment Analysis

In this section, a series of experiments are conducted in two real-world data sets: Canvas Network and Wanke001.com to compare the proposed methods with other mainstream recommendation methods.

5.1. Comparative Experimental Methods and Parameters Setting. ITSVD and other selected main recommendation methods are compared, excluding the impact of trust and influence:

(1) UAvg, IAvg: baseline approach. Avg applies the rating average of each user to predict the unknown rating, whereas IAvg applies the rating average of each item to predict the unknown rating.
(2) basicMF: the basic matrix decomposition algorithm.
(3) SVD++ proposed by Koren [18], a recommendation algorithm based on latent (hidden) factor. It applies user's historic evaluation data as implicit feedback and deducts the preference information of users and items which is evaluated in recommendation process.

The optimal parameters are selected for final comparison, and then its performance is verified when the eigenvector dimension is at 5 and 10.

The optimal parameters are set in the experiment as below:

(1) Biased MF: set $\lambda_u = \lambda_i = \lambda_b = 0.01$ at Canvas Network data cluster; set $\lambda_u = \lambda_i = \lambda_b = 0.2$ at Wanke data cluster.
(2) SVD++: let $\lambda = 0.01$ at Canvas Network data cluster; let $\lambda = 0.1$ at Wanke data cluster.
(3) ITSVD: set $\lambda = 0.1, \lambda_t = 0.9$ at Canvas Network data cluster; set $\lambda = 0.1, \lambda_t = 1.2$ at Wanke data cluster.

5.2. Experiments and Results Analysis. This section conducts experiments and analyzes results from 3 perspectives:

(1) Comparison analysis of personalized learning resources recommendation models. Compare the proposed model, trust-based ITSVD, with other recommendation models (such as UAvg, IAvg, basicMF, and SVD++) which neglect the trust and influence effects in account of the accuracy and efficiency in predicting the test scores of target learners.
(2) Discuss the setting of k, quantity of influential learners to the global recommendation performance.
(3) Simulation tests on influential nodes show the proposed model has better capacity in identification of influential learners.

5.2.1. Comparison Analysis of Personalized Learning Resources Recommendation Models. To keep the experiment unbiased, tests are carried out on Canvas Network and Wanke data sets, and the accuracy of the models is verified at the dimension of 5 and 10. Table 4 illustrates the results and analysis of all models' performance at two data sets, where the optimal results are in bold, and the numbers with asterisk are the best results except the optimal results. The table reveals that the MAE and RMSE from ITSVD model are smaller than from other models, which means the

$U \leftarrow$ users set:$R \leftarrow$ scoring matrix:$T \leftarrow$ trust matrix:$IU \leftarrow$ influential user set
Input: λ, λ_1, η and the Iteration maximum L
Output: B_u, B_j, P, Q, W, Y
(1) Initialize bias vector b_u, b_i and feature matrix P, Q, W, Y with random in (0,0,1);
(2) While Loss function j not converged or the number of iteration < L do
(3) for each $u \varepsilon U$ do
(4) for each $j \varepsilon I_u$ do
(5) The score of item j by user u is predicted according to formula (11);
(6) end
(7) end
(8) The loss functions is calculated according to formula (12)
(9) Use the stochastic gradient descent method to update the parameters;
(10) $b_u \longrightarrow b_u - \eta(\partial L/\partial b_u), u = 1, \ldots, m$
(11) $b_j \longrightarrow b_j - \eta(\partial L/\partial b_j), j = 1, \ldots, n$
(12) $p_u \longrightarrow p_u - \eta(\partial L/\partial p_u), u = 1, \ldots, m$
(13) $q_j \longrightarrow q_j - \eta(\partial L/\partial q_j), j = 1, \ldots, n$
(14) $\forall i \varepsilon I_u, y_i \longrightarrow y_i - \eta(\partial L/\partial y_i), u = 1, \ldots, m$
(15) $\forall i \varepsilon T_u, W_v \longrightarrow W_v - \eta(\partial L/\partial W_v), u = 1, \ldots, m$
(16) $\forall i \varepsilon T_u, p_f \longrightarrow p_f - \eta(\partial L/\partial p_f)$
(17) Iteration number ++;
(18) end
(19) return P, Q, W, Y, B_u, B_j

Algorithm 1: The learning Algorithm of ITSVD.

Table 2: Dataset statistics.

Database	Users no.	Item no.	Score record	Score sparsity (%)
Canvas network	49863	194	57852	0.6
Wanke	161	56	3149	34.9

Table 3: Dataset attributes.

Database	Users no.	Item no.	Score record	Country	Age	Education background	Major
Canvas network	√	√	√	√	√	√	×
Wanke	√	√	√	×	√	×	√

Table 4: Comparison analysis of different models.

Datasets	Metrics	UAvg	IAvg	bisedMF	SVD++-	ITSVD
Canvas network ($d = 5$)	MAE	0.32506	0.241933	0.241576	0.240272*	0.238157
	RMSE	0.374268	0.293496	0.291701	0.290887*	0.288134
Canvas network ($d = 10$)	MAE	0.32506	0.241933	0.241843	0.24017*	0.238375
	RMSE	0.374628	0.293496	0.292356	0.290768*	0.288123
Wanke ($d = 5$)	MAE	0.078015	0.080324	0.074327*	0.074379	0.074111
	RMSE	0.112521	0.113965	0.106839	0.106764*	0.106619
Wanke ($d = 10$)	MAE	0.078015	0.080324	0.074475*	0.074513	0.074143
	RMSE	0.112521	0.113965	0.10697	0.106897*	0.106738

personalized learning resources recommendation model based on social trust can significantly improve the global performance and quantity of resources recommendations.

Besides, one noticeable point of ITSVD is that its recommendation accuracy in Wanke data set is lower than in Canvas Network, which is due to the sufficient score data in Wanke. Under this case, other models could perform well; for example, the MAE and RMSE from AVeg reach, respectively, 0.078 and 0.112 and thus show no much differences between those models.

5.2.2. Analysis of Number of Influential Learners k. Parameter k controls the cluster number of influential learners. Select the most influential top-k % learners as the cluster of global influential learners. Since it is considered to be only a small number of influential learners in the social network, the experiment selects the top 10% users as subject. In order to testify the influence of parameter k on the recommendation performance, k value is modified from 0 to 10 in step 1. Figure 4 shows that when $k = 0$, excluding the effect of influential learners, the experiments in two data sets

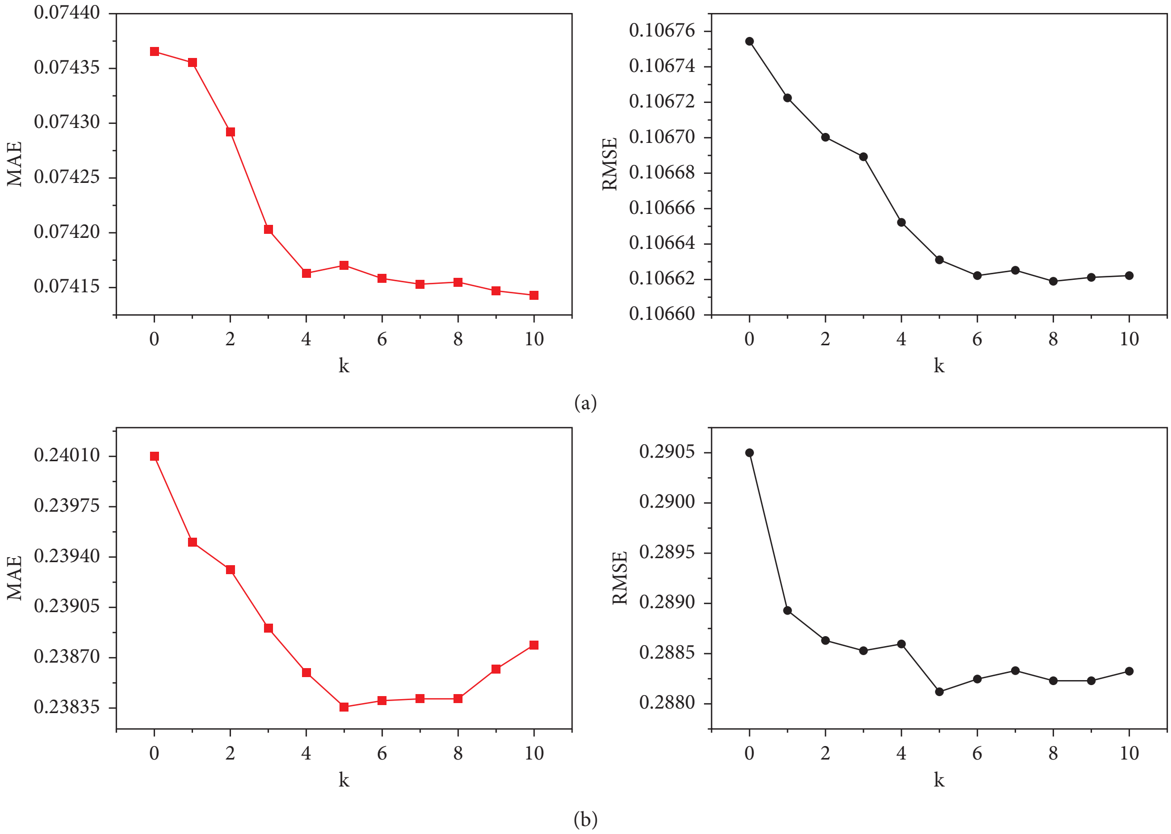


Figure 4: The effect of MAE and RMSE value of parameter K ($d = 10$). (a) Represents the results of an experiment on the Wanke Dataset. (b) Represents the result of an experiment on the Canvas Network Dataset.

show the worst results, which suggests the cluster of influential learners will improve the recommendation performance. Meanwhile the descanting rate of error value in Wanke data set is slower than that in the Canvas Network, which is because the excessive trust relation among learners in Wanke results in the overlap of influential learners' cluster with trust learners' cluster and thus could not unveil well learners' interest.

Another interesting finding lies in that the error value in the Canvas Network does not gradually decrease along with the increasing number of influential learners. The reason behind is the serious polarization of influence due to the sparse data, which indicates only few learners enjoy high influence, whereas the majority enjoy little or no influence. When k exceeds certain threshold value, the low-influence learners will be included. These learners take no benefits in scoring predication but misguide target learners.

5.2.3. Analysis of Influential Learners' Identification. Simulation tests on influential nodes are carried out under the classic SI model of epidemic diseases to effectively identify influential learners. The model effectively simulates the transmission of simulated information and virus.

Under the SI model, nodes in the network obtain two possible states at any time: susceptible (S) and infected (I).

The S node can at each time period transmit virus to neighboring nodes at a transmission probability of $\gamma \in (0, 1)$. If the S node once is infected to I status, the process is irreversible.

Two experiments are designed to evaluate the dynamic performance of different influential nodes measurements in scale-free network model. Experiment 1 carries out the influence identification to top-10 learners, so as to compare the accuracy of algorithms in ranking the nodes' transmission capacity. Experiment 2 aims to identify the influence of global learners, so as to comprehensively compare the identification capacity of different algorithms in low-influence and high-influence nodes' identification and then improve the experiment's reliability.

Experiment 1 sets top-10 learners ranked by different influence measurement models as initial transmission source, compare the changes of nodes' status along with time t, and then apply as the evaluation index the ratio of infected nodes I during the transmission process. Set social network data in Canvas Network as sample, $\gamma = 0.01$, the maximum time step, $t_{\max} = 50$, and S_{i} is sum of infected nodes after the time as the actual transmission influence. Meanwhile in order to get reliable results, experiments are conducted several times to get the mean value:

$$\overline{S}_t = \frac{1}{M} \sum_{m=1}^{M} S_i, \tag{17}$$

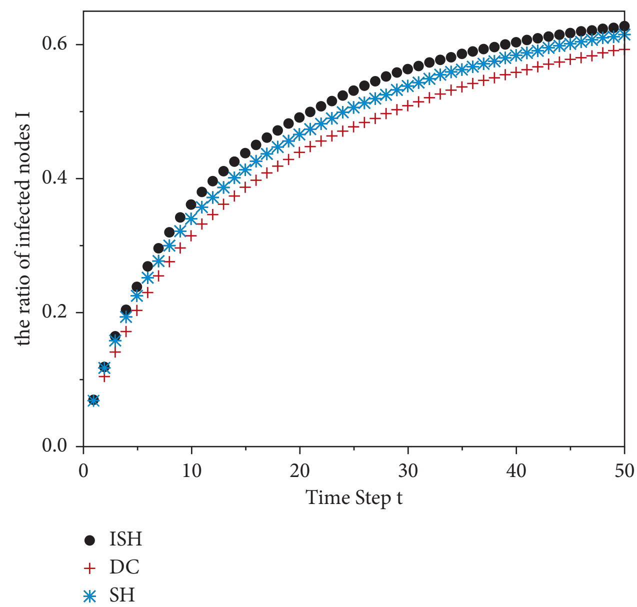


FIGURE 5: Changes of I ration under different influence measurement models in Canvas Network data.

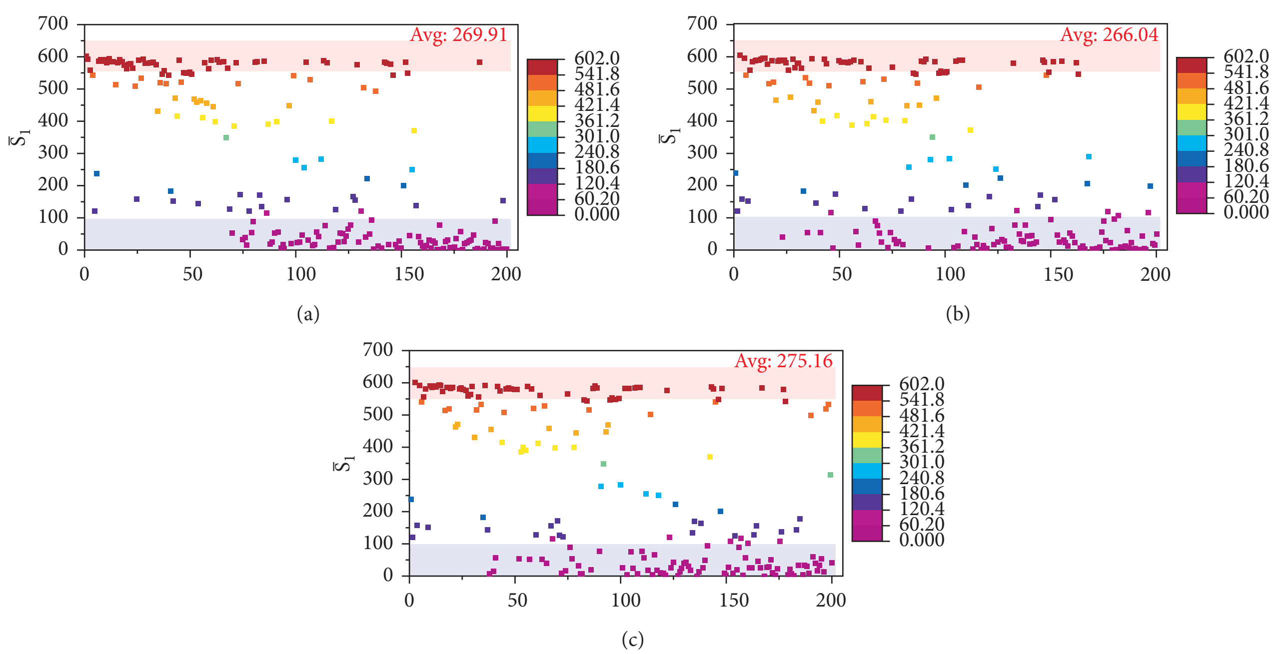


FIGURE 6: Results of correlation analysis of learners' influence in Canvas Network.

where M is the repeated times of experiment on node i. As above mentioned, set $M = 100$, and get its mean value $\overline{S}i$ as the infected nodes at time t. Figure 5 compares the changes of I ratio in Canvas Network of DC, SH, and ISH models and reveals the results from ISH model show stronger and quicker transmission capacity than that from SH and DC models, which verifies ISH model's advantage at node's influence ranking.

Experiment 2 conducts node's influence analysis over global learners under the Simulation Investigation (SI) model but expands the subjects to the global learners. The design is as follows: Set real social network data at Canvas Network as sample; keep the relevant parameters setting of Experiment 1 unchanged. The initial transmission sources could be any learners in the network, and the transmission time is $t = 10$. Same as Experiment 1, conduct the experiments several times to get the mean value of relevant nodes' transmission capacity, as illustrated in Figure 6. Due to limited space, here only display the top-200 real influential nodes of each algorithm. The segmented information of influence is clearly marked in purple (low-influence nodes) and red (high-influence nodes). The specific results are as follows:

(1) Low-influence nodes (among the purple area): comparing SH and DC models, their results are quite similar; however SH model ranks the nodes more advanced than DC model, which suggests the DC model is better than SH model. Moreover, the low-influence node ratio is apparently lower in ISH than that of SH and DC models, and its low-influence nodes aggregate at the second half section.

(2) High-influence nodes (among the red area): Analyze the top-200 nodes, and find out that the numbers of high-influence nodes out of DC, SH, and ISH models are close to each other with little difference, which suggests the principle is valid: the node with more in-degree is of more importance. The improved SH model is availed of utilizing the neighboring nodes' degree information, which proves its advantage of high-influence nodes identification.

(3) Mean value: Higher mean value indicates better identification performance. Thus among the three models, mean value of ISH is the highest, which shows its best identification capacity.

The above experiment indicates the global identification capacity of influence models. ISH model enjoys better performance in identifying low-influence and high-influence nodes over the other models, as well as its global identification performance.

To conclude, ITSVD model, the proposed precise personalized learning resources recommendation model based on trust and influence, shows better performance over its function, predication accuracy, and influential learners' identification. The reason behind is that ITSVD model takes into consideration the mutual trust relation between learners, that is, learners with stronger trust relation enjoy more similarities, and impact of influential learners, that is, stronger trust indicates stronger influence capacity, as well as more impact over other learners. Thus, ITSVD could improve the accuracy and efficiency of recommendation system.

6. Conclusion

The future of online learning lies in massive online learning. Its priority depends on whether massive online learning could offer more precise personalized learning resources recommendation service. Along with the popular social networks, learner would more and more likely rely on social networks for learning and communication, which offers more clues to understand learners' cognitive features, learning styles, and personal interest.

What we propose here is a precise personalized learning resources recommendation model based on trust and influence. Through looking into the inner social connection between learners, the paper unveils the implicit connection among learners, learning resources, and social relation. Experiments' results on two real-world data sets, Canvas Network and Wanke, prove the accuracy and efficiency of ITSVD model's application in education recommendation field. The paper opens new perspectives for precise personalized learning resources recommendation in massive online learning.

Future research will explore the quantitative analysis of social trust, multimode learning, and trust mechanism and include offline real interactive behavior data into trust analysis.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was supported by the Fundamental Public Welfare Research Program of Zhejiang Province (no. LGF22F020036), the Educational Science Planning Project of Zhejiang Province (no. GH2021562), and the National Experimental Teaching Demonstration Center of Computer Science in China.

References

[1] Y. Q. Yang and J. L. Jiao, "A framework for personalized learning ecological design for MOOC learners," *E-Education Research*, vol. 8, pp. 32–37, 2014.

[2] H. G. Bao, Y. F. Zheng, and Y. Y. Li, "Social recommendation model and method for mass online learning," *Modern Distance Education Research*, vol. 3, pp. 94–103, 2018.

[3] W. Feng, J. Tang, and T. X. Liu, "Understanding d," *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 33, no. 1, pp. 517–524, 2019.

[4] L. Boratto, G. Fenu, and M. Marras, "The effect of algorithmic bias on recommender systems for massive open online courses,"vol. 11437, pp. 457–472, in *Proceedings of the Advances in Information Retrieval - 41st European Conference on IR Research*, vol. 11437, ECIR, Cologne, Germany, April 2019.

[5] F. Wang, Q. Liu, E. Chen et al., "Neural cognitive diagnosis for intelligent education systems," in *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 34, no. 4, pp. 6153–6161, New York, NY, USA, February 2020.

[6] D. Jannach, M. Zanker, A. Felfernig, and G. Friedrich, *Recommender Systems: An Introduction*, Cambridge University Press, Cambridge, MA, USA, 2011.

[7] P. V. Marsden, "Friedkin Network studies of social influence," *Sociological Methods & Research*, vol. 22, no. 1, pp. 127–151, 1993.

[8] D. W. Seng, B. Q. Li, and C. X. Lai, "Adaptive learning user implicit trust behavior based on graph convolution network," *IEEE ACCESS*, vol. 9, pp. 108363–108372, 2021.

[9] Q. Jiang and W. Zhao, "Research on accurate personalized learning path mining in the context of big data - group behavior analysis based on aprioriall," *E-Education Research*, no. 2, pp. 45–52, 2018.

[10] K. Eugenijus, "Recommending suitable learning paths according to learners' preferences experimental research results," *Computers in Human Behavior*, vol. 51, pp. 945–951, 2015.
[11] D. W. Seng, G. S. Chen, and Q. Y. Zhang, "Item-based collaborative memory networks for recommendation," *IEEE Access*, vol. 8, pp. 213027–213037, 2021.
[12] Y. G. Ding and X. Zhang, "Collaborative filtering of learning resource recommendation by integrating learners' social network," *Modern Educational Technology*, vol. 26, no. 2, pp. 108–114, 2016.
[13] H. Kautz, M. Shah, and B. Selman, "Referral web: combining social networks and collaborative filtering," *Communications of the ACM*, vol. 40, no. 3, pp. 63–65, 1997.
[14] B. Yang, Y. Lei, and J. Liu, "Social collaborative filtering by trust," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 39, no. 8, pp. 1633–1647, 2017.
[15] M. Jamali and M. Ester, "A matrix factorization technique with trust propagation for recommendation in social networks," in *Proceedings of the Fourth ACM Conference on Recommender Systems*, pp. 135–142, New York, NY, USA, September 2010.
[16] H. Ma, D. Zhou, and C. Liu, "Recommender systems with social regularization," in *Proceedings of the Fourth ACM International Conference on Web Search and Data Mining, WSDM '11*, Hong Kong, China, 2011.
[17] G. Guo, J. Zhang, and N. Yorke-Smith, "A novel recommendation model regularized with user trust and item ratings," *IEEE Transactions on Knowledge and Data Engineering*, vol. 28, no. 7, pp. 1607–1620, 2016.
[18] Y. Koren, "Factorization meets the neighborhood: a multifaceted collaborative filtering model," in *Proceedings of the 14th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, pp. 426–434, New York, NY, USA, August 2008.
[19] X. F. Zhang, X. L. Chen, and D. W. Seng, "Top-n recommendation algorithm combining user trust and influence," *Journal of Zhejiang University*, vol. 54, no. 2, pp. 311–319, 2020.
[20] X. F. Zhang, X. L. Chen, and D. W. Seng, "A factored similarity model with trust and social influence for top-n recommendation," *International Journal of Computers, Communications & Control*, vol. 14, no. 4, pp. 590–607, 2019.
[21] Q. T. Wu, L. Jiang, X. F. Gao, X. C. Yang, and G. H. Chen, "Feature evolution based multi-task learning for collaborative filtering with social trust," in *Proceedings of the Twenty-Eighth International Joint Conference on Artificial Intelligence IJCAI-19*, pp. 3877–3883, Macao, China, July 2019.
[22] T. Yu, J. Guo, W. Li, H. J. Wang, and L. Fan, "Recommendation with diversity: an adaptive trust-aware model," *Decision Support Systems*, vol. 23, p. 113073, 2019.
[23] L. Ardissono and N. Mauro, "A compositional model of multi-faceted trust for personalized item recommendation," *Expert Systems with Applications*, vol. 140, no. 112880, pp. 1–15, 2020.
[24] Y. Bao, J. Zhang, and H. Fang, "Leveraging decomposed trust in probabilistic matrix factorization for effective recommendation," in *Proceedings of the Twenty-Eighth AAAI Conference on Artificial Intelligence*, pp. 30–36, Quebec, Canada, July 2014.
[25] P. Domingos and M. Richardson, "Mining the network value of customers," in *Proceedings of the Seventh ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, pp. 57–66, New York, NY, USA, August 2001.
[26] A. Aris, K. Ravi, and M. Mohammad, "Influence and correlation in social networks," ", in *Proceedings of the 14th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, pp. 7–15, Las Vegas NV, USA, August 2008.
[27] S. C. Peng, A. M. Yang, L. H. Cao, S. Yu, and D. Q. Xie, "Social influence modeling using information theory in mobile social networks," *Information Sciences*, vol. 379, pp. 146–159, 2016.
[28] S. Peng, Y. Zhou, and L. Cao, "Influence analysis in social networks: a survey," *Journal of Network and Computer Applications*, vol. 106, pp. 17–32, 2018.
[29] R. Albert, A. L. Barabási, and H. Jeong, "Error and attack tolerance of complex networks," *Nature*, vol. 406, no. 6794, pp. 378–382, 2000.
[30] D. Chen, L. Liu, and M. S. Shang, "Identifying influential nodes in complex networks," *Physica A: Statistical Mechanics and its Applications*, vol. 391, no. 4, pp. 1777–1787, 2012.
[31] D. W. Seng, J. X. Liu, and X. F. Zhang, "Top-n recommendation based on mutual trust and influence," *International Journal of Computers, Communications & Control*, vol. 14, no. 4, pp. 540–556, 2019.
[32] R. S. Burt, "Structural holes: the social structure of competition," *The Economic Journal*, vol. 104, no. 424, pp. 685-686, 1994.
[33] H. Yu, Z. Liu, and Y. J. Li, "Using local improved structural holes method to identify key nodes in complex networks," in *Proceedings of the 2013 Fifth International Conference on IEEE Measuring Technology and Mechatronics Automation (ICMTMA)*, pp. 1292–1295, Hong Kong, China, January 2013.
[34] M. Rezvani, W. Z. Xu, and W. F. Liang, "Efficient algorithms for the identification of top-k structural hole spanners in large social networks," *IEEE Transactions on Knowledge and Data Engineering*, vol. 29, no. 5, pp. 1017–1030, 2017.
[35] L. C. Freeman, "A set of measures of centrality based on betweenness," *Sociometry*, vol. 40, no. 1, pp. 35–41, 1977.

Hindawi
Scientific Programming
Volume 2022, Article ID 1990951, 9 pages
https://doi.org/10.1155/2022/1990951

Research Article

Crowd Density Estimation Method Using Deep Learning for Passenger Flow Detection System in Exhibition Center

Jun Xiang [1] **and Na Liu** [2]

[1] *School of Economics and Trade, Chognqing College of Finance and Economic, Yongchuan, Chongqing 402160, China*
[2] *Organization United Front Work Department, Chognqing College of Finance and Economic, Yongchuan, Chongqing 402160, China*

Correspondence should be addressed to Jun Xiang; jun_xiangevent@126.com

Received 10 December 2021; Accepted 20 January 2022; Published 18 February 2022

Academic Editor: Ahmed Farouk

Aiming at the problems of crowd distribution, scale feature, and crowd feature extraction difficulties in exhibition centers, this paper proposes a crowd density estimation method using deep learning for passenger flow detection systems in exhibition centers. Firstly, based on the pixel difference symbol feature, the difference amplitude feature and gray feature of the central pixel are extracted to form the CLBP feature to obtain more crowd group description information. Secondly, use the LR activation function to add nonlinear factors to the convolution neural network (CNN) and use dense blocks derived from crowd density estimation to train the LR-CNN crowd density estimation model. Finally, experimental results show that the mean absolute error (MAE) and mean square error (MSE) of the proposed method in the UCF_CC_50 dataset are 325.6 and 369.4, respectively. Besides, MAE and MSE in part_A of the Shanghai Tech dataset are 213.5 and 247.1, respectively, and they in part_B are 85.3 and 99.7, respectively. The proposed method effectively improves the accuracy of crowd density estimation in exhibition centers.

1. Introduction

The foreign exhibition service industry has developed into a relatively mature industry, and the domestic exhibition service industry is also developing rapidly. At present, most exhibition service companies still focus on whether the exhibition can be successfully held and provide postshow analysis reports for exhibition organizers. However, there is a lack of research on realtime exhibition hall analysis services, especially in terms of passenger flow detection [1]. The exhibition service industry based on location services has gradually emerged, and various crowd density estimation solutions have emerged [2–4].

Population counting and density estimation have great practical significance [5–7], which can be extended to the following three applications:

(1) Public safety supervision: in places with dense crowds in the real scene, the staff monitors the crowd's dynamic information in realtime through electronic camera equipment, analyzes potential safety hazards, and tries to avoid them [8, 9].
(2) Intelligence collection and analysis: as far as China is concerned, residents' travel and tourism have become normal during the annual holidays. Statistics and analysis of crowd flow of major tourist venues in China are beneficial to road traffic management and arrangements. At the same time, the overall tourism policy can be adjusted according to the travel preferences and interests of the crowd in each time period obtained in the past [10, 11].
(3) Virtual model construction: it provides a reliable mathematical model for the transformation between virtual reality and reality [12].

Crowd counting and density estimation research cannot only provide important guarantees for the safety of people's lives and property but also aid in promoting the maximization of social and economic benefits. It has a wide range of application prospects and important practical significance [13–15]. Therefore, crowd counting and density estimation have gradually become a common research hotspot in academia and industry.

In the early research, scholars used the Haar wavelet transform, shape feature, directional gradient histogram, and texture feature to manually extract the detection. Counting was completed by detecting head, body, or wholebody features in crowd images [16–18]. With the improvement of hardware technology and the advancement of deep learning technology, the performance of many computer vision tasks has been greatly improved, and CNN has played an important role in tasks such as target detection, image classification, and semantic segmentation. Therefore, CNN was widely used in counting tasks, and the related performance was greatly improved [19, 20]. Reference [21] designed a multitask framework based on CNN to simultaneously estimate the density level and the number of target crowds. It used the former to provide additional information to assist the latter to improve the counting performance of the model. Reference [22] established a multicolumn CNN, using different sizes of receptive fields to obtain target features of different scales. The crowd density map was generated by fusion with a 1×1 size convolution kernel. Reference [23] used the same network to process and generate crowd density maps for input images at different resolutions, and at the same time, output attention maps to supervise the generation of crowd scale predictions. However, this method needed to reason about multiple pictures of different scales at the same time, which greatly increases the number of network calculations. Reference [24] introduced an attention mechanism to fuse features based on detection and regression, but this method did not perform well in high-density areas and could not achieve realtime prediction. In order to enhance the perception of crowd density areas, reference [25] established a series of attention modules and regression modules. It used deformable convolution to establish an attention module to detect crowd areas and improve the perception of density maps for crowds of different densities. Reference [26] proposed a self-supervised counting algorithm that uses the rule that there are always more people in large image blocks than in small image blocks in unlabeled data to establish a self-supervised learning task to improve the counting performance of the algorithm. Reference [5] proposed an end-to-end population density estimation network to generate a high-quality population density map, which can obtain high-quality map estimation. Reference [27] proposed a crowd counting method based on crossconfrontation loss and global features for high-density scenes of different scales. The cross-countermeasure loss was used to generate the residual map, and the uniformity problem of the fusion density map was solved through the consistency between different scales, extracted a wide range of contextual information and focused on the key information in the global spatial features to generate a residual map. In reference [28], a multilevel neural network is constructed to estimate population density, and good results are achieved. Reference [29] proposed a multiscale context learning module called the multiscale context aggregation module. The module first extracted information on different scales, and then adaptively aggregated it to capture the fullscale of the crowd. However, most research is still focused on traditional shallow models. The fitting ability of shallow models is limited, and the effect is better in simple image processing of crowd scenes. But when the background is more complex, crowd density estimation is more difficult, and the extraction of scale features and crowd features is not sufficient.

Based on the above analysis, this paper proposes a crowd density estimation method using deep learning for passenger flow detection systems in exhibition centers in order to solve the problems of crowd distribution, scale feature and crowd feature extraction difficulty in the exhibition center scene. Firstly, extract the difference between the amplitude feature and gray feature of the center pixel to form the CLBP feature together to obtain more descriptive information about the crowd density. Then use the LR activation function to add nonlinear factors to CNN and use the dense blocks obtained by crowd density estimation to train the LR-CNN crowd density estimation model.

2. Proposed Model Framework

The primary problem of crowd behavior analysis is to detect an area where a large crowd gathers and perform corresponding crowd behavior analysis in this area. Based on the traditional algorithm, this paper uses the complete local binary pattern (CLBP) to extract the characteristics of crowd aggregation. On this basis, the deep learning model is used to construct the detection of crowd gathering. CNN is applied to crowd group detection, and the CLBP feature is trained by operations such as convolution and pooling. After extracting the fundamental features, the prediction result of crowd gathering is obtained. Comparing with the prediction results given by actual experts, five density results are obtained: sparse, normal, low-density, medium-density, and high-density. The steps of the crowd density estimation algorithm are shown in Figure 1.

3. Image Preprocessing and CLBP Feature Extraction

The local binary patterns (LBP) feature is one of the most commonly used texture feature detection methods. However, the LBP feature is not compatible with the density detection of any level of the crowd. The real-time performance and accuracy in complex scenes are not enough. Thus, this paper proposes a CLBP feature extraction method. Traditional LBP features use rectangular neighborhoods, which are not rotation invariant. In order to realize the texture feature of rotation invariance, a circular neighborhood is added. The schematic diagram of the circular neighborhood is shown in Figure 2.

In the circular neighborhood, the neighborhood of the center pixel has a larger selection range. When certain values cannot be read directly from the pixel, the bilinear interpolation method is used to give the calculation result and the pixel is read. For the same radius, when there is a rotation,

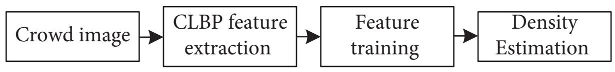


Figure 1: Crowd density estimation algorithm.

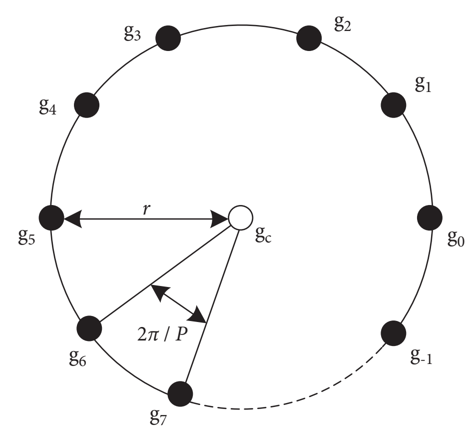


Figure 2: Circular neighborhood diagram.

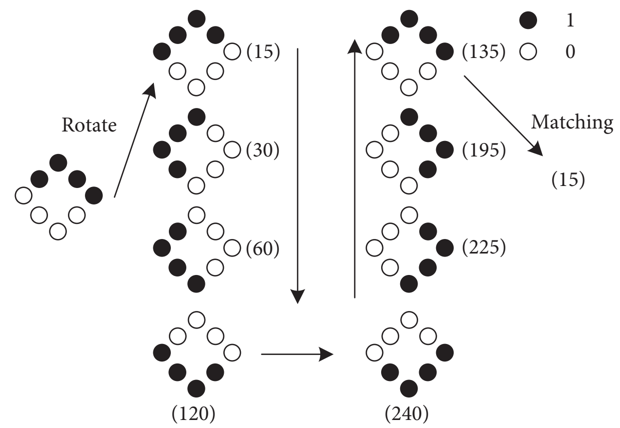


Figure 3: Calculation process of rotation invariant LBP in the circular 8 neighborhood.

the LBP value is different. In order to obtain the same LBP value, the smallest LBP value should be selected from all the results after rotation as the LBP value of the neighborhood. That is, a result that satisfies all the rotations should be selected. Figure 3 below shows the rotation result, where black represents "1" and white represents "0." The calculated LBP value results are given in parentheses.

The introduction of the circle makes the calculation object more complicated, and the "uniform mode" calculation method should be adopted at this time. This method only performs two change calculations of 0–1 or 1–0, and the following formula is given to calculate the rotation-invariant LBP of the circular neighborhood:

$$U\left(\mathrm{LBP}_{P,R}\right) = \sum_{i=0,j=0}^{P-1} \left|s\left(g_i - g_c\right) - s\left(g_j - g_c\right)\right|,$$
$$s(x) = \begin{cases} 0, x \geq 0, \\ 1, x < 0. \end{cases} \tag{1}$$

Figure 4 shows the circular neighborhood rotation-invariant LBP method for uniform mode calculation.where the number in the center of the neighborhood represents the uniform mode LBP value of LBP, and the neighborhood value is the number of "1." The LBP value of the neighborhood of nonuniform mode ($U > 2$) is $P + 1$, and the calculation formula is as follows:

$$U\left(\mathrm{LBP}_{P,R}^{r2}\right) = \begin{cases} \sum_{i=0}^{P-1} s\left(g_i - g_c\right) \\ P+1 \end{cases}, s(x) = \begin{cases} 0, & x \geq 0, \\ 1, & x < 0. \end{cases} \tag{2}$$

Traditional LBP only extracts the difference between the pixel value of the neighborhood and the pixel value of the center point, and the characteristics that can describe the crowd are limited. In order to better express the local features of the crowd, this paper also extracts the amplitude feature of difference and the gray feature of the center pixel on top of the symbol feature of pixel difference, forming a CLBP feature. This feature can give more descriptive information about the group of people. The extraction process of CLBP is shown in Figure 5.

The matrix (a) gives the center pixel and its 8 neighboring pixels. First, calculate the difference between the neighboring pixels and the center pixel to get matrix (b). Then generate the sign of each difference to get matrix (c). Finally, take the absolute value of all the differences of the matrix (b), obtain the magnitude of the difference, and get matrix (d). After the preprocessing is complete, the following steps are taken:

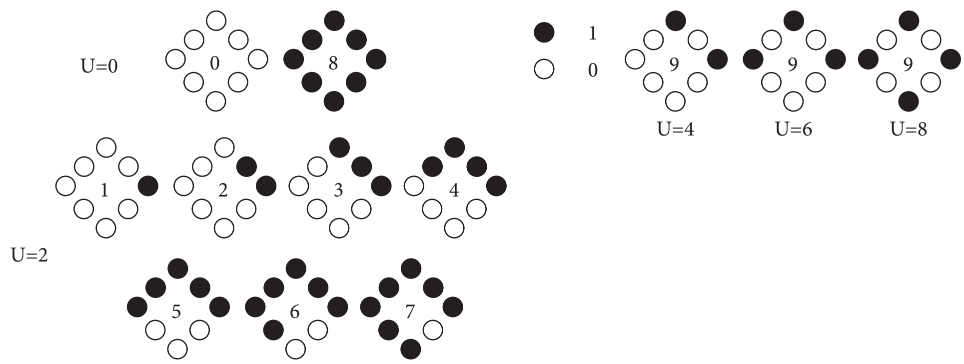
(1) The symbol matrix (c) is binarized to obtain a matrix composed of "0" and "1." Then use the above formula (2) to calculate the characteristic S of symbols describing the difference;

(2) The global average of elements of the difference magnitude matrix (d), denoted as m_p is calculated. All elements in the matrix (d) are used to make the difference with the global average value. If the result is negative, it is recorded as "0," and if it is nonnegative, it is recorded as "1" to generate a binary matrix. Equation (2) is used again to calculate the characteristic M that describes the magnitude of the difference;

(3) The average gray value of the center pixel is calculated, denoted as c_p. In the same way, c_p used to binarize the central pixel, and then equation (2) is used to calculate and describe the grayscale characteristics of the central pixel.

4. CNN Framework Construction of Crowd Density Estimation

4.1. Network Training Framework. After extracting the stable CLBP feature from the original crowd video sequence, it is necessary to predict the crowd group through a classifier, find the crowd group that exceeds the threshold range, and define it as a large crowd gathering situation. In this link,



(a) (b)

Figure 4: Calculation process of uniform mode circular neighborhood rotation invariant LBP; (a) uniform mode $P = 8$ and (b) nonuniform mode $P = 8$.

12	15	54
2	34	21
67	22	14

-4	-8	25
-6		50
46	75	37

-1	-1	1
-1		1
1	1	1

1	7	75
45		40
66	85	14

Figure 5: LBP calculation process of the uniform mode circular neighborhood rotation invariant.

traditional methods use shallow learning models for prediction and tracking, including common BP neural networks and SVM classifiers. The shallow model has achieved good results in learning and predicting a small number of samples. However, when the scene of crowd group detection is more complicated, and there are occlusions and overlaps, the limited learning ability of shallow models will gradually reduce the effect of crowd group detection, and gradually lose a certain degree of robustness. In recent years, there have been relatively few studies on the detection of crowd groups in deep learning. But deep learning has made good progress in the fields of image processing and pattern recognition. Therefore, this paper intends to use the deep learning model to predict and track the CLBP feature to obtain the clustering of a crowd.

CNN is a feedforward neural network. CNN is based on the biological vision system. It simplifies the fully connected neural network into CNN, and the connections of neurons between the upper and lower layers of adjacent layers are no longer all related. From a mathematical point of view, the weight between the two fully connected network layers is overwhelmingly zero. For example, in image processing, each pixel is only related to the local area around it. By simplifying the number of connections of neurons, the neural network can be simplified without affecting the characteristics of the image itself, reducing network complexity and reducing calculation time.

When the input $x_t\,(t = 1, 2, \ldots, n)$ and the filter $f_t\,(t = 1, 2, \ldots, m)$ are given, the input signal length n is much greater than the filter length m, and the output of one-dimensional convolution is

$$y_t = \sum_{k=1}^{n} f_k \cdot x_{t-k+1}. \tag{3}$$

One-dimensional convolution can be used in signal processing. When the filter is $f_t = 1/n$, the convolution is equivalent to the moving average of the signal sequence. Two-dimensional convolution is often used in image processing. Given an image $x_{ij}, 1 \le i \le M, 1 \le j \le N$ and filter $f_{ij}, 1 \le i \le m, 1 \le j \le n$, generally $m \ll M, n \ll N$. The output of a convolution is

$$y_{i,j} = \sum_{u=1}^{m} \sum_{v=1}^{n} f_{uv} \cdot x_{i-u+1, j-v+1}. \tag{4}$$

Figure 6(a) is the fully connected layer of the network. If there are $n^{(l-1)}$ neurons in the l layer, there are n^l neurons in the $l-1$ layer, and there are $n^{(l)} \times n^{(l-1)}$ connected edges. That is, the weight matrix has $n^{(l)} \times n^{(l-1)}$ parameters. When the number of neurons increases, the parameters increase, and the time complexity of calculation increases, which greatly reduces the efficiency of training. As shown in Figure 6(b), the fully connected layer is replaced with a convolutional connection. At this time, each neuron in the l layer is only connected to a neuron in a local area window of the $l-1$ layer, forming a local connection network. The input of i neuron of l layer is defined as

$$\begin{aligned} a_i^l &= f\left(\sum_{j=1}^{m} w_j^{(l)} \cdot a_{i-j+m}^{(l-1)} + b^{(l)}\right) \\ &= f\left(w^{(l)} \cdot a_{(i-j+m)i}^{(l-1)} + b_i\right), \end{aligned} \tag{5}$$

where $w^{(l)} \in R^m$ is an M-dimensional filter.

The above formula can be simplified to:

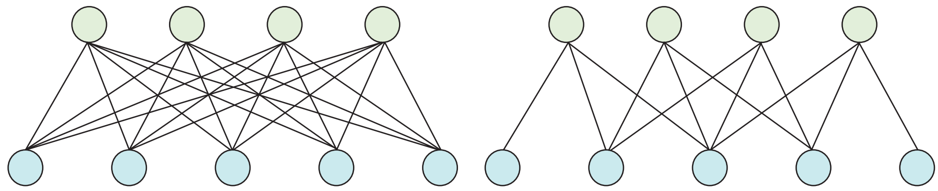


Figure 6: Full connection layer and convolution layer. (a) Full connection layer. (b) Convolution layer.

$$a^l = f\left(w^l \otimes a^{(l-1)} + b^{(l)}\right). \tag{6}$$

It can be seen from formula (6) that w^l is the same for all neurons. This reveals another extremely important feature of CNN: weight sharing. That is, for two adjacent layers of networks, the weight matrix w^l is the same. Only a few parameters are needed to describe the output from the l network to the $l+1$ layer, and the number of neurons in the $l+1$ layer is determined, which is $n^{(l+1)} = n^{(l)} - m + 1$.

When processing images, the computer cannot directly recognize the surface features of an image, like a human brain, and the computer can only accept and process the data. Therefore, a digital image can be converted into a two-dimensional matrix, and the position of each pixel is used to describe the entire image. The two-dimensional matrix of image conversion is used as the input of the neural network, and two-dimensional convolution is required at this time. Assume that $x^{(l)} \in R^{(w_1 \times h_1)}$ and $x^{(l-1)} \in R^{(w_{l-1} \times h_{l-1})}$ are the neuronal activity of l and $l+1$ layers, respectively. Each element of $X^{(l)}$ is

$$X_{s,t}^{(l)} = f\left(\sum_{i=1}^{u}\sum_{j=1}^{v} W_{i,j}^{(l)} \cdot X_{s-i+u,t-j+v}^{(l-1)} + b^{(l)}\right). \tag{7}$$

After a filter is processed, the characteristics of an image can be obtained. By increasing the number of filters used, a number of different features can be obtained, thus enhancing the ability of the convolutional layer to represent images. The filter is essentially a feature extractor. Due to the weight sharing, each set of output uses the same filter, which is the feature extractor. The output of the image processed by the filter is a feature of the image. This process can also be called feature mapping. Assume that the number of filters used in the $l-1$ layer is n_{l-1}, and the size of each group of feature maps is $m_{l-1} = w_{l-1} \times h_{l-1}$. The total number of neurons in the $l-1$ layer is $n_{l-1} \times m_{l-1}$. The number of feature mapping groups in the l layer is n_l. If it is assumed that the input of each feature map $X^{(l,k)}$ of l layer is all the feature maps of $l-1$ layer,

then k feature map $X^{(l,k)}$ of l layer is

$$X^{(l,k)} = f\left(\sum_{p=1}^{n_{l-1}} W^{(l,k,p)} \otimes X^{(l-1,p)} + b^{(l,k)}\right), \tag{8}$$

where $W(l,k,p)$ represents the filter required from the p feature vector of $l-1$ layer to the k feature vector of l layer.

It can be found from the above formula that the neurons in the entire layer of the l layer get the input of the next layer, the $l+1$ layer, through filter convolution and bias adjustment. Different filters can get different inputs. The connection relationship between feature maps can be defined as a connection table T. The number of features is adjusted by setting the number of "0"s in the connection table to ensure that the desired features can be extracted and the computational complexity is reduced.

The convolutional layer is locally connected, which significantly reduces the number of connections compared to the fully connected layer, but the number of neurons does not change much. If the output is followed by a classifier, the input dimension of the classifier is still too high, overfitting will still occur, and the input image cannot be accurately classified. Pooling operation is introduced to reduce the dimensionality of features and avoid overfitting problems. The feature map $X^{(l)}$ obtained by convolution of the upper convolution layer through the filter can be divided into several regions $R_k, k = 1, \ldots, K$. To perform pooling operations on these regions, a subsampling function sub is defined as

$$X_k^{(l+1)} = f\left(w^{(l+1)} \cdot \mathrm{sub}\left(R_k\right) + b^{(l+1)}\right). \tag{9}$$

where $_{w}^{(l+1)}$ and $b^{(l+1)}$ are trainable weight and bias parameters, respectively.

As shown in Figure 7, the LR-CNN model designed in this paper is

(1) Input layer: the input data is a $32*32$ image block.

(2) Con1 : the first convolutional layer, using 8 $5*5$ filters, through convolution operation to obtain 8 $28*28$ feature maps.

(3) Pool2: the first subsampling layer uses the maximum pool sampling method, that is, one point is collected for every adjacent $2*2$ pixel area. Its value is the function value with the largest gray value among the four pixels.

(4) Con3 : the second convolution layer, using 15 $5*5$ filters, after convolution operation, $8*15$ $10*10$ feature maps are obtained.

(5) Pool4: the second subsampling layer uses the same subsampling as the Pool2 layer.

(6) Con5 : the last convolutional layer, using 5 $5*5$ filters.

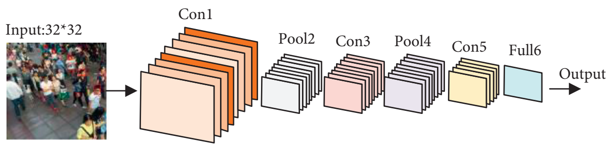


Figure 7: LR-CNN counting model.

(7) Ful6: it is a fully connected layer that converts 600 $1*1$ neurons in Cons into a feature vector.

(8) Output layer: input the feature vector obtained by CNN into the activation function to obtain the counting result. When training the model, it is also necessary to add the counting accuracy rate to estimate the accuracy rate of the counting and loss function layers.

The LR-CNN model proposed in this paper reduces the number of neurons when extracting features based on the same filter in the convolutional layer. However, since each convolutional layer requires multiple filters, different features of the image need to be extracted. Therefore, the total number of neurons is significantly increased after the convolution operation of the convolutional layer, and the purpose of convolution is to reduce the dimension of features. However, additional burdens are generated in this process. The layer-by-layer increase in the number of neurons and parameters will eventually cause the algorithm to crash and the computer will stop working. Thus, the subsampling layer is necessary, and it is an effective means to reduce the number of neurons and the number of parameters. Therefore, the subsampling layer must exist intermittently or uninterruptedly throughout the entire network. At the same time, it is considered that the influence of the subsampling layer on the feature is negative. Therefore, the alternate appearance of the convolutional layer and subsampling layer is the best design obtained by combining various factors.

4.2. Loss Function. This paper uses two loss functions to optimize the model. One is the Euclidean loss function, and the other is the cross-entropy loss function. Let $X = \{X_1, \ldots, X_N\}$ denote training samples and N denote the total number of training samples.

Euclidean loss function is used for density estimation

$$L_e = \frac{1}{2N}\sum_{i=1}^{N}\left\| F_h\left(X_i;\theta\right) - D_i\right\|_2^2, \tag{10}$$

where $F_h(\ ;\theta)$ represents the estimated density map. θ is the weight parameter of the counting model and D_i represents the true density map.

The cross-entropy loss function is

$$L_c = -\frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{K}\left[\left(y^i = j\right)F_C\left(X_i;\theta_c\right)\right]. \tag{11}$$

The total loss function is a linear combination of L_e and L_c, and the formula is as follows:

$$L = L_e + \alpha L_c, \tag{12}$$

where the parameter α is a scale factor, which is used to control the proportion of cross-entropy loss.

5. Experiment and Analysis

5.1. Dataset. The experiment uses two commonly used datasets, namely the Shanghai Tech dataset and the UCF_CC_50 dataset.

The Shanghai Tech dataset consists of two parts, part_A_final and part_B_final. The picture of part_A is a crowd image randomly selected from the Internet, and the data picture of part_B is taken by a camera on the streets of Shanghai. Compared with the part_A dataset, part_B has a sparse distribution, but the scene is relatively fixed, while the scene of part_A changes greatly. part_A training set: 300 pictures, test set: 182 pictures. part_A training set: 400 pictures, test set: 316 pictures, a total of 1198 pictures, 330,165 annotation headers.

The UCF_CC_50 dataset pictures are all grayscale images downloaded from the Internet. They have extremely dense crowds and smallscale changes. Large amounts of data only have head features and are severely blocked by pedestrians. The sample size of this dataset is small, but the number of people varies greatly. In the experiment, a 5-fold crossvalidation method was used to evaluate the performance of different counting models. The specific method is to randomly divide the picture into 5 parts, with 4 parts for training and 1 part for testing. Five sets of experiments are carried out, and the average value is taken as the final result.

5.2. Evaluation Index. This paper uses MAE and MSE as two indicators to evaluate the performance of the algorithm. MAE and MSE are the most commonly used standards to measure the performance of the algorithm. The calculation formula of MAE and MSE is as follows:

$$\begin{aligned} \mathrm{MAE} &= \frac{1}{N}\sum_{1}^{N}\left|y_i - \widetilde{y}_i\right|, \\ \mathrm{MSE} &= \sqrt{\frac{1}{N}\sum_{1}^{N}\left|y_i - \widetilde{y}_i\right|^2}, \end{aligned} \tag{13}$$

where N represents the total number of test images, y_i is the actual number of people in the i image, and $\widetilde{y}_i$ is the number of people estimated by the i algorithm.

5.3. Analysis and Comparison. In the use of the CLBP feature extraction algorithm and the CNN depth model for crowd density estimation and group detection, this paper has carried out 2000 iterations of training. In order to visualize the results, when the CNN network becomes stable, the 200 verified samples are extracted from the CLBP feature and then input to the trained CNN network. Figure 8 shows the comparison between the real predicted value and the CNN predicted value.

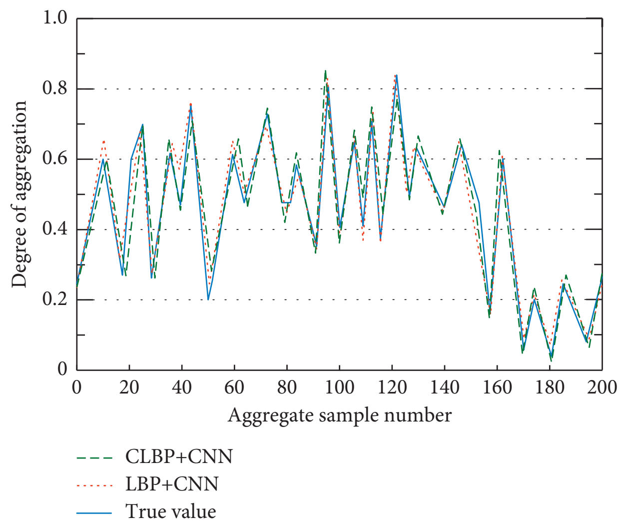


FIGURE 8: Comparison between output values and actual output values of different methods.

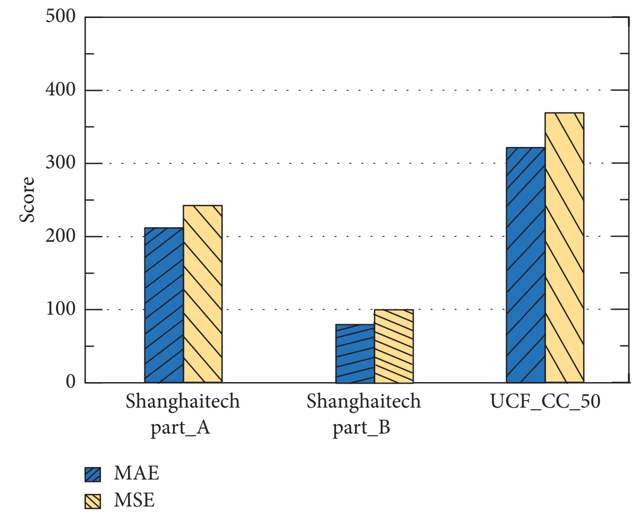


FIGURE 9: Test results of counting model on each dataset.

After deep neural network training, the predicted value of the degree of aggregation of each pixel position is obtained. In the actual prediction, the mask value of prediction results $200 * 200$ is tested in the range of $10 * 10$, and the average value in the range is calculated, and the threshold $Th = 0.5$ is set as the criterion. When the predicted average value of a certain detection area reaches or exceeds the set threshold, the area is regarded as an area where people gather. And through the inverse process of the compression process, the position is projected into the original RGB image, and the corresponding area is standardized in the figure. This paper tests CLBP + CNN and LBP + CNN. It can be seen from the results that CNN can do most of the correct detection of crowd gathering groups. The comparison between the predicted value and the actual predicted value is almost the same. In actual use, there is a strong result presentation that can ensure the robustness and accuracy of the data. However, the CNN network requires a lot of training time to obtain better weights to predict complex scenes.

The CNN counting model was tested on the UCF_CC_50 and Shanghai Tech datasets, and the results obtained are shown in Figure 9.

The method in this paper is compared with the methods in reference [5, 27, and 29] in the UCF_CC_50 dataset and the Shanghai Tech dataset. The experimental results are shown in Table 1 and Table 2. The MAE and MSE of the proposed method in the UCF_CC_50 dataset is 325.6 and 369.4, respectively. The MAE and MSE in the part_A part of the Shanghai Tech dataset are 213.5 and 247.1, respectively, and the MAE and MSE in the part_B part are 85.3 and 99.7 respectively. The experimental results show that the method proposed in this paper can solve the problem of counting dense crowds within the allowable error range. The comparison results show that the proposed method is better than the comparison method in counting accuracy under high crowd density scenarios. This is because the proposed model extracts the difference between the amplitude feature and the gray feature of the central pixel to form the CLBP feature, which obtains more detailed information about the population density. However, the lack of effective feature extraction methods in comparison methods makes MAE and MSE much higher than the proposed methods. Besides, using the dense block in the image as a training set instead of the entire image provides a feasible method to solve the counting problems caused by crowd image congestion and scene distortion.

TABLE 1: Comparison with other algorithms on the UCF_ CC_ 50 dataset.

Method	MAE	MSE
Reference [5]	456.5	489.7
Reference [29]	403.7	455.9
Reference [27]	357.4	378.1
The proposed method	325.6	369.4

TABLE 2: Comparison with other algorithms on the Shanghai Tech dataset.

Method	Part_A		Part_B	
	MAE	MSE	MAE	MSE
Reference [5]	335.4	387.9	157.3	187.9
Reference [29]	289.6	325.4	102.8	125.6
Reference [27]	256.3	289.7	95.4	108.5
The proposed method	213.5	247.1	85.3	99.7

6. Conclusion

Aiming at the problems of crowd distribution, scale feature, and crowd feature extraction difficulty in exhibition centers, this paper proposes a crowd density estimation method using deep learning for passenger flow detection systems in the exhibition center. The difference between the amplitude feature and the gray level feature of the center pixel are extracted to form the CLBP feature together to obtain more descriptive information about the crowd density. The LR activation function is used to add nonlinear factors to CNN and use dense blocks obtained by crowd density estimation to train the LR-CNN crowd density estimation model. Finally, the experimental results show that the proposed method can achieve the lowest MAE and MSE on the tested datasets. This shows that by extracting the difference between the amplitude feature and the gray feature of the center pixel, using the CLBP feature for feature extraction, you can extract more effective information.

However, deep learning has a complex network structure and requires a large amount of calculation, which requires faster hardware support. In the future, GPUs can be introduced to increase the speed of computer processing data, or the concept of parallel computing can be introduced into CNN, and the execution speed of algorithms can be accelerated by shunting.

Data Availability

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

Conflicts of Interest

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

Acknowledgments

This work was supported by the Yongchuan District Science and Technology Fund (no. Ycstc, 2019rb1202).

References

[1] S. A. M. Saleh, S. A. Suandi, and H. Ibrahim, "Recent survey on crowd density estimation and counting for visual surveillance," *Engineering Applications of Artificial Intelligence*, vol. 41, no. 5, pp. 103–114, 2015.

[2] V. A. Sindagi and V. M. Patel, "A survey of recent advances in CNN-based single image crowd counting and density estimation," *Pattern Recognition Letters*, vol. 107, no. 7, pp. 3–16, 2018.

[3] S. Elbishlawi, M. H. Abdelpakey, A. Eltantawy, M. S. Shehata, and M. M. Mohamed, "Deep learning-based crowd scene analysis survey," *Journal of Imaging*, vol. 6, no. 9, pp. 95–104, 2020.

[4] X. Zhang, Q. Yu, and H. Yu, "Physics inspired methods for crowd video surveillance and analysis: a survey," *IEEE Access*, vol. 6, no. 2, pp. 66816–66830, 2018.

[5] Z. Fan, Y. Zhu, Y. Song, and Z. Liu, "Generating high quality crowd density map based on perceptual loss," *Applied Intelligence*, vol. 50, no. 4, pp. 1073–1085, 2020.

[6] S. Pu, T. Song, Y. Zhang, and D. Xie, "Estimation of crowd density in surveillance scenes based on deep convolutional neural network," *Procedia Computer Science*, vol. 111, no. 5, pp. 154–159, 2017.

[7] V. J. Kok and C. S. Chan, "Granular-based dense crowd density estimation," *Multimedia Tools and Applications*, vol. 77, no. 15, Article ID 20227, 2018.

[8] H. Fradi and J. L. Dugelay, "Crowd density map estimation based on feature tracks," in *Proceedings of the 2013 IEEE 15th International Workshop on Multimedia Signal Processing (MMSP)*, pp. 040–045, IEEE, Pula, Italy, September 2013.

[9] M. V. Anees and S. G. Kumar, "Deep learning framework for density estimation of crowd videos," in *Proceedings of the 2018 8th International Symposium on Embedded Computing and System Design (ISED)*, pp. 16–20, IEEE, Cochin, India, December 2018.

[10] B. Yılmaz, S. N. H. S. Abdullah, and V. J. Kok, "Vanishing region loss for crowd density estimation," *Pattern Recognition Letters*, vol. 138, no. 7, pp. 336–345, 2020.

[11] H. Zheng, Z. Lin, J. Cen, Z. Wu, and Y. Zhao, "Cross-line pedestrian counting based on spatially-consistent two-stage local crowd density estimation and accumulation," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 29, no. 3, pp. 787–799, 2018.

[12] W. Yanqin, Y. Zujun, W. Yao, and L. Xingxin, "Crowd density estimation based on conditional random field and convolutional neural networks," in *Proceedings of the 2019 14th IEEE International Conference on Electronic Measurement & Instruments (ICEMI)*, pp. 1814–1819, IEEE, Changsha, China, November 2019.

[13] J. Guo, X. Wu, T. Cao, S. Yu, and Y. Xu, "Crowd density estimation via markov random field (MRF," in *Proceedings of the 2010 8th World Congress on Intelligent Control and Automation*, pp. 258–263, IEEE, Jinan, China, July 2010.

[14] S. Peng, B. Yin, X. Hao, Q. Yang, A. Kumar, and L. Wang, "Depth and edge auxiliary learning for still image crowd density estimation," *Pattern Analysis & Applications*, vol. 24, no. 4, pp. 1777–1792, 2021.

[15] Y. Li and B. Zhou, "A hybrid approach to crowd density estimation using statistical leaning and texture classification," in *Proceedings of the 2013 International Conference on Optical Instruments and Technology: Optoelectronic Imaging and Processing Technology*, pp. 9045–9550, International Society for Optics and Photonics, Beijing, China, November 2013.

[16] H. Jiang and W. Jin, "Effective use of convolutional neural networks and diverse deep supervision for better crowd counting," *Applied Intelligence*, vol. 49, no. 7, pp. 2415–2433, 2019.

[17] H. Fradi and J.-L. Dugelay, "Towards crowd density-aware video surveillance applications," *Information Fusion*, vol. 24, no. 3, pp. 3–15, 2015.

[18] Z. Duan, Y. Xie, and J. Deng, "HAGN: hierarchical attention guided network for crowd counting," *IEEE Access*, vol. 8, no. 9, Article ID 36376, 2020.

[19] M. Fu, P. Xu, X. Li, Q. Liu, M. Ye, and C. Zhu, "Fast crowd density estimation with convolutional neural networks," *Engineering Applications of Artificial Intelligence*, vol. 43, no. 5, pp. 81–88, 2015.

[20] L. G. Zhu, H. Zhang, S. Ali, B. L. Yang, and C. Y. Li, "Crowd counting via multi-scale Adversarial convolutional neural networks," *Journal of Intelligent Systems*, vol. 30, no. 1, pp. 705–715, 2020.

[21] Y. Hu, H. Chang, F. Nian, Y. Wang, and T. Li, "Dense crowd counting from still images with convolutional neural networks," *Journal of Visual Communication and Image Representation*, vol. 38, no. 6, pp. 530–539, 2016.

[22] Y. Zhang, D. Zhou, S. Chen, S. Gao, and Y. Ma, "Single-image crowd counting via multi-column convolutional neural network," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 589–597, Las Vegas, NV, USA, June 2016.

[23] D. Kang and A. Chan, "Crowd counting by adaptively fusing predictions from an image pyramid," pp. 569–578, 2018, https://www.researchgate.net/publication/325191555_Crowd_Counting_by_Adaptively_Fusing_Predictions_from_an_Image_Pyramid.

[24] J. Liu, C. Gao, D. Meng, and A. G. Hauptmann, "Decidenet: counting varying density crowds through attention guided detection and density estimation," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 5197–5206, Salt Lake City, UT, USA, June 2018.

[25] X. H. Jiang, L. Zhang, M. L. Xu et al., "Attention scaling for crowd counting," in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 4706–4715, Seattle, WA, USA, June 2020.

[26] X. Liu, J. Van De Weijer, and A. D. Bagdanov, "Leveraging unlabeled data for crowd counting by learning to rank," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 7661–7669, Salt Lake City, UT, USA, June 2018.

[27] S. Li, Z. Hu, M. Zhao, and Z. Sun, "Crowd counting using cross-adversarial loss and global feature," *Journal of Electronic Imaging*, vol. 29, no. 5, pp. 53–59, 2020.

[28] H. Nan, M. Tong, L. Fan, and L. I. Min, "Multi-task multi-level convolutional neural network for application of crowd counting," *Computer Engineering and Applications*, vol. 5, no. 9, pp. 506–514, 2019.

[29] Y. Zhang, H. Zhao, Z. Duan, L. Huang, J. Deng, and Q. Zhang, "Congested crowd counting via adaptive multi-scale context learning," *Sensors*, vol. 21, no. 11, pp. 3777–3785, 2021.

Hindawi
Scientific Programming
Volume 2022, Article ID 8514660, 8 pages
https://doi.org/10.1155/2022/8514660

Research Article

Solving Capacitated Vehicle Routing Problem by an Improved Genetic Algorithm with Fuzzy C-Means Clustering

Ji Zhu

Liupanshui Dahe Economic Development Zone Development & Construction Co., Ltd., Liupanshui 553000, Guizhou, China

Correspondence should be addressed to Ji Zhu; zhuji@dhkjgs.wecom.work

Received 25 November 2021; Revised 27 December 2021; Accepted 7 January 2022; Published 18 February 2022

Academic Editor: Ahmed Farouk

Aiming at solving the vehicle routing problem, an improved genetic algorithm based on fuzzy C-means clustering (FCM) is proposed to solve the vehicle routing problem with capacity constraints. On the basis of genetic algorithm, the FCM algorithm is used to decompose the large-scale vehicle routing optimization problem into small-scale subproblems, which can effectively improve the efficiency of the algorithm. At the same time, a generation method of the initial solution to CVRP problem is designed. The improved algorithm has good robustness and can also reduce the possibility of falling into local optimization in the search process. Finally, a simulation example is provided to verify the efficiency and superiority of the proposed algorithm.

1. Introduction

Capacitated vehicle routing problem (CVRP) [1], which is well known and has high research value in the logistics field, was proposed first time by Dantzig in 1956. Due to the exact solution of the algorithm based on strict mathematical description that cannot satisfy the performance requirement, in the past few decades, scholars from home and abroad have carried out extensive and profound research for this problem, and some heuristic algorithms were proposed to solve CVRP problem [2–6]. In [7], the authors analyzed and compared the performance of multiple heuristic algorithms under the CVRP conditions, according to the genetic algorithm characteristics of simple and high scalability, which can search information based on the objective function, can provide better solutions.

With the development of sensors and communication technologies, rich results have been achieved. In [8], the genetic algorithm was applied for the research of VRP for the first time in 1996. Since then, the genetic algorithm was used widely in CVRP. The optimizations of the traditional genetic algorithm can be separated into two types. The first one is improving the specific problems in the genetic algorithm in order to realize better performance. A double population genetic algorithm was designed for population schemes [9]. In [10], with an aim to improve the quality of population, a Jaccard coefficient that produces primary population was proposed. In [11], the two-step coding scheme was used for improvement was proposed by the coding scheme. In [12], the genetic algorithm solution by binary coding was designed for the coding proposal. In [13], a fixed-length real encoding was provided to solve the problem that the traditional genetic algorithm convergence rate is slow. In [14], an operator based on task redistribution was designed to improve the genetic algorithm. In [13], a new strategy was used to improve the selection strategy of the genetic algorithm. According to the individual adapting value, they mixed the individuations with the better adapting value and worse adapting value. In [15], a policy that detects mutation operation to improve the local optimization ability of the algorithm was studied. In addition, in [15], a method that uses a gene rearrangement operator for the chromosome recombination was provided. In [16], the impact of the location of the city on the path optimization was taken into consideration. Undoubtedly, these improvements can get better optimization.

The second one is that introducing the other intelligent optimization algorithms to mix into the traditional genetic algorithms and get the hybrid genetic algorithms, which is able to provide new ideas of genetic algorithms to solve

CVRP problems. In [17], a hybrid optimization algorithm based on the genetic algorithm and sparrow search algorithm was proposed. Based on the particle swarm optimization, genetic algorithm, and nonlinear programming theory, a hybrid optimization algorithm of particle swarm and genetic was proposed [18]. In [19], a solution algorithm based on genetic simulated annealing was designed, which owns the strong global search capability of the genetic algorithm, as well as the high rate of convergence of the simulated annealing optimization. In [20], the hybrid firefly genetic algorithm which combines the advantages from the firefly algorithm and other mathematical optimization algorithms was proposed, which effectively improved the effectiveness of the algorithm.

Inspired by the above two methods, in this paper, an improved genetic algorithm based on fuzzy C-means algorithm (FCM) is used to solve CVRP problems. First, the algorithm reduces the solution scale by FCM for generating population problems randomly by the traditional genetic algorithm. Then, a quantity of optimal initial solutions forming the initial population by referring to the thought of CW algorithm is constructed, which improves the efficiency of the algorithm effectively. Finally, the experiment by using benchmark examples is introduced, and the experiment demonstrates that this algorithm can solve CVRP problems with better precision and effectiveness.

2. Methodologies

2.1. Fuzzy Clustering. Clustering analysis is one of the multivariate statistical analyses [21, 22]. According to certain rules, it can divide the uncategorized samples into subsets and group the similar samples together. K-means [23] and K-medoid [24] are two common clustering methods. Hard clustering divides every unidentified objective into certain collections strictly, and the objectives of it have the either-or characteristics. While the fuzzy clustering established the uncertain description of collection from samples, it can reflect the objective world objectively; therefore, it has become the mainstream of clustering analysis.

In many fuzzy clustering algorithms, FCM is the most widely used algorithm. It can get the membership of all of the cluster centers by optimizing the objective function and get the aim of classifying the data automatically by determining the category of sample points. A membership function belonging from each cluster to each sample is assigned and sorted by the sample by comparing the value of membership.

There are three key parameters of fuzzy C-means clustering: fixed number of clusters, the center of each mass cluster, and each data point's cluster which closest to the corresponding center of mass.

Fuzzy C-means clustering can get the cluster center by minimizing the objective functions. The objective function is essentially the sum of Euclidean distances of each point to each cluster. The process of clustering is the process of minimizing the objective function. By iterative arithmetic, the error value of the objective function can be decreased step by step. When the objective function is convergent, we can get the final result of the cluster. The objective function can be expressed as

$$Jm = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} \|xi - vi\|^2, \tag{1}$$

where m is the weighting factor, N is the number of samples, c is the number of cluster centers, vi is the jth cluster center, which is the same as the sample's characteristics of dimension, xi is the ith sample, and u_{ij} is the membership of the sample xi to the cluster center cj.

The traditional FCM algorithm needs to give the cluster number of the data set in advance. If the cluster number is not selected properly, it will lead to classification failure. The determination of cluster number belongs to the research category of cluster effectiveness. The proposed method is modified based on the traditional FCM algorithm, so that the cluster number C can be determined adaptively according to the data set.

Pal and Bezdek have pointed out that the reasonable value range of weight factor M is [1.5, 2.5], so this paper takes its middle value. In all, in the beginning, we set the weighting factor as 2, the number of cluster centers is 2, and the number of iteration l is 0. The steps of improved FCM algorithm are as follows.

Step 1. Calculate cluster center $V = \{vi^{(l)}\}$.

$$v_i^{(l)} = \frac{\sum_{k=1}^{n} \left(u_{ik}^{(l)}\right)^m x_k}{\sum_{k=1}^{n} \left(u_{ik}^{(l)}\right)^m}. \tag{2}$$

Step 2. Update the Membership matrix $U^{(l)}$.

$$uik^{(l+1)} = \left(\frac{1}{\sum_{k=1}^{c} \left\|xk - vi^{(l)}\right\| / \left\|xk - vj^{(l)}\right\|}\right)^{2/m-1}. \tag{3}$$

The membership matrix is the matrix of N*C, which means each sample point belongs to extent of each cluster. For the single sample, the sum of the membership degree of each cluster is 1. Closer to 1 means a higher membership degree, and vice versa. Each sample point in which class the membership degree is the highest belongs to which class.

According to (2) and (3), the membership degree matrix and cluster center are connected with each other, and they constitute the positive feedback under the objective function. Therefore, it is only needed to iterate the membership degree matrix and cluster center until the objective function converges to a better solution. It should be pointed out that it is needed to assign a value that meets the conditions to $uik^{(0)}$ or $vi^{(0)}$ when the FCM algorithm program started.

Step 3. Compare $U^{(l)}$ and $U^{(l+1)}$; if

$$\left\|U^{(l)} - U^{(l+1)}\right\| \leq \varepsilon, \tag{4}$$

then stop the iteration; otherwise, $l = l + 1$, steering to Step 1.

Step 4. If the effective value function $PFm(U,c)$ reaches the minimum, the clustering process is supposed to end; otherwise, $c = c + 1$ and steering to Step 1. In other words, we take number that the effective value function $PFm(U,c)$ as the minimum point value with the increase of C. The effective value function $PFm(U,c)$ is defined by [25]

$$PFm(U,c) = \frac{1}{n}\sum_{i=1}^{c}\sum_{j=1}^{n}\left|u_{ij} - \left(u_{ij}\right)_{0.5}\right|. \tag{5}$$

The flow chart of the improved FCM algorithms is shown in Figure 1.

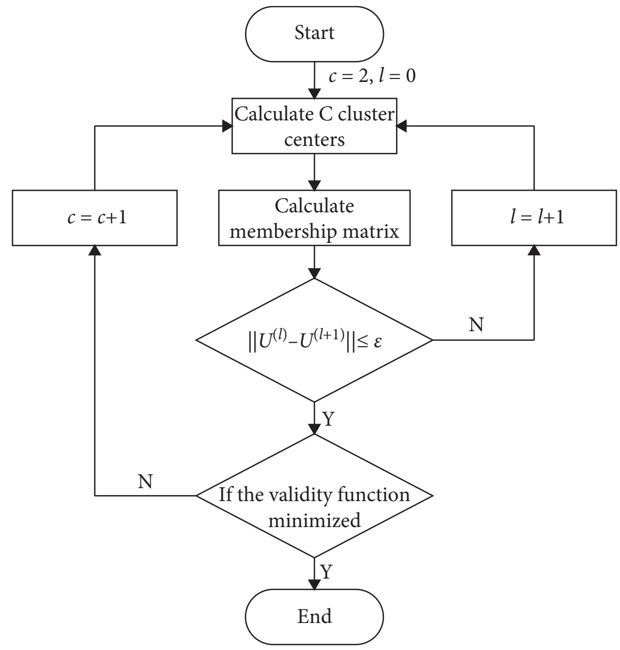


Figure 1: The flow chart of the improved FCM algorithms.

2.2. Construction of the Initial Solution. The initial solution to the traditional genetic algorithm is generated randomly. Therefore, the C–*W* algorithm mentioned by Clark and Wright in 1964 was considered, which aims to generate a better initial solution to expedite the speed of the program.

The number of customers as N is set, every vehicle capacity is 200, and 0 means distribution center. The steps of C–*W* algorithm are as follows:

Step 5. Assuming that each car serves only one customer, it generates *N* independent loops. Then, the saving value of distance by combining customer *i* and customer *j* into one route is calculated. The distance of reduction can be expressed as

$$S_{ij} = d_{oi} + d_{oj} - d_{ij}, \tag{6}$$

where S_{ij} is the saving value of distance and d_{ij} is the distance between customer *i* and customer *j*. d_{oi} and $p_{\mathrm{m}} = p_{\mathrm{mmin}} + \sqrt{\sum_{i=1}^{N}(f_i - f_{\mathrm{avg}})^2/N} \cdot p_{\mathrm{ma}}$ represent the distance from customer *i* and customer *j* to the distribution center, respectively.

The highest saving value that counterparts customer *i* and customer *j* is found out and then combine them into one route. The sketch map is shown in Figure 2.

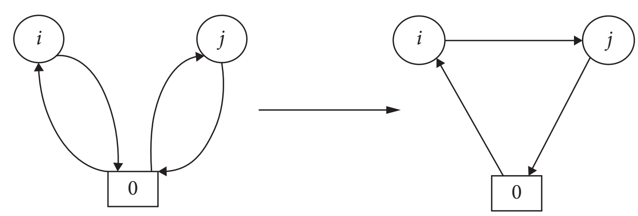


Figure 2: The sketch map of the CW algorithm.

Step 6. When two customers are on the same route (customer 1 and customer 2) and then by mixing customer 3 to this route, there are 3 different ways to mix (0123, 0312, and 0132). Lastly, the saving value is calculated by these three situations.

Step 7. When the requirement value of all customers is beyond the total capacity of vehicles, we need a new route, then calculate the saving value again that follows Step 5 and Step 6, and mix the route until all customers are distributed when delivery.

The flow path of constructing initial solutions by CW algorithm is shown in Figure 2, in which *n* is the position where the largest distance saving value, *Q* is the total vehicle capacity, $p_{\mathrm{m}} = p_{\mathrm{mmin}} + \sqrt{\sum_{i=1}^{N}(f_i - f_{\mathrm{avg}})^2/N} \cdot p_{\mathrm{ma}}$ is whether customer point *i* be served by car *k*. *qi* means the requirement of customer *i*.

2.3. Solutions of Genetic Algorithms. GA is one of the methods which used widely to search optimal solutions. It simulates the mechanism of life evolution. It is unnecessary to make model and complex calculation. Only need to use the three operators of GA, we can get the optimal solutions.

The GA algorithm sets the objective function as research information directly. It is simple to use and has high expansibility, but the algorithm's efficiency usually lower than the other traditional optimal methods. In addition, in the traditional GA algorithm, the production of the initial cluster is randomly generated, so that one of the better initial solutions can increase the probability of catching the optimal solution from the program and speed the program searching the optimal solution up. In order to overcome the disadvantage of the GA algorithm, this article makes improvements on the production of the initial solution method in the traditional GA algorithm.

First, based on some rules, this paper uses the FCM algorithm to divide all of the customer points into several subclusters.

Second, this paper constructs some better initial solution by using CW algorithm and codes the initial population which is made up of chromosomes, respectively. It can increase the probability of catching the adjacent territory solution that has high quality, which increases the efficiency of the traditional GA algorithm to solve the CVRP problem considerably.

Third, traditional genetic algorithms are prone to fall into local optimum. On the other hand, in the late stage of evolution, the fitness values of individuals in the population are relatively stable, and the diversity between them is greatly reduced, resulting in slow convergence of the algorithm. To solve this problem, this paper modifies the crossover and mutation operations in the traditional genetic algorithm, so that the crossover and mutation probability can be set dynamically. In the early stage of evolution, the fitness of individuals in the population is poor, and there is little difference between individuals. By increasing the crossover probability, the improved genetic algorithm can make the excellent individuals show up as soon as possible and reduce the search range of the optimal solution. In the late stage of evolution, the fitness of individuals in the population is generally good, but there is little difference between them. By increasing the mutation probability, the local search ability of the population is enhanced, which makes it quickly find the best solution and speed up the convergence of the algorithm.

2.3.1. Improvement of Crossover Probability. First, the minimum crossover probability is set, and then, with the increase of iterations, the standard deviation of the fitness value is used to control the change of crossover probability, so that the crossover probability is larger at the beginning of evolution and smaller at the end of evolution. That is, the crossover probability is

$$p_{\mathrm{c}} = p_{\mathrm{cmax}} - \sqrt{\frac{\sum_{i=1}^{N}\left(f_i - f_{\mathrm{avg}}\right)^2}{N}} \cdot p_{\mathrm{ca}}, \tag{7}$$

where p_{cmax} is the maximum value of crossover probability. f_i is the fitness value of individual i. f_{avg} is the average fitness value of all individuals in the population. N is population capacity. p_{ca} is the cross probability adjustment parameter.

2.3.2. Improvement of Mutation Probability. First, the minimum mutation probability is set, and then with the increase of iterations, the standard deviation of the fitness value is used to control the mutation probability, making the mutation probability smaller at the beginning of evolution and larger at the end of evolution. The mutation probability is

$$p_{\mathrm{m}} = p_{\mathrm{mmin}} + \sqrt{\frac{\sum_{i=1}^{N}\left(f_i - f_{\mathrm{avg}}\right)^2}{N}} \cdot p_{\mathrm{ma}}, \tag{8}$$

where p_{mmin} is the minimum mutation probability. p_{ma} is the adjusting parameter for mutation probability.

There are 4 main steps for the improved algorithm as follows:

Step 1: using FCM algorithm to divide the received data into several subcluster.

Step 2: using CW algorithm, and recording the several groups of better initial solutions which are produced by CW algorithm. Coding them as several chromosomes, and set them as a part of the initial population.

Step 3: under the limited of the number of iterations, using genetic algorithm to iterate constantly. Produce the optimal solutions by choosing, overlap, and aberrance.

Step 4: obtaining the optimal individual after iteration, outputting the optimal route.

3. Problem Description and Modeling

3.1. Problem Description. Vehicle routing problem is described as organizing the appropriate route for a series of loading and unloading points to make vehicles through them orderly. In the conditions of the quantity demanded (such as transmission quantity, time of delivery, vehicle capacity limitation, driving range, and time limitation), the aims are achieved (such as shortest distance, least cost, least time, and least vehicles).

There are many basic types of VRP problems. CVRP is the most basic type from them. CVRP has several constraints: 1. the vehicles have the same capacities of freight, 2. each customer only can be served by one car, and customer requirements cannot be separated, 3. vehicles depart from a single distribution center and need to get back, 4. all customers have to be served.

3.2. Problem Modeling. Based on the description of CVRP, the related parameters and variables of the CVRP model are defined. The CVRP model can be described as

$$\min f = \sum_{i\in N}\sum_{j\in N}\sum_{k\in K} d_{ij}x_{ijk}, \tag{9}$$

$$\sum_{i\in N} x_{ijk} = y_{jk}, \tag{10}$$

$$\sum_{i\in N} x_{ijk} = y_{jk}, \tag{11}$$

$$\sum_{i\in N} x_{ijk} = y_{jk}, \tag{12}$$

$$\sum_{j\in N} x_{ijk} = y_{ik}, \tag{13}$$

$$\sum_{j\in N} x_{0jk} = 1, \tag{14}$$

$$\sum_{j\in N} x_{i0k} = 1, \tag{15}$$

where $N0$ is the nodes of distribution center. $c = \{1, \ldots, n\}$ is the customer collection. $K = \{1, \ldots, k\}$ is the vehicle collection. Q is the total vehicle capacity. qi is the requirement of customer i. d_{ij} is the cost of the route from customer i to customer j. x_{ijk} means car k whether from customer point i to customer point j. y_{ik} means whether customer point i be served by car k.

In the above formula, (6) means to minimize the length of vehicle distribution path, (7) means the need of meeting the limitation of vehicle load when delivery, (8) means each customer only can be served by one car. When equations (12) and (13) are established at the same time, it can ensure that customers who are on the same line are served by the same distribution vehicle. Equations (14) and (15), respectively, mean that each distribution vehicle must start from distribution center 0 and each distribution vehicle must finally return to distribution center 0.

The aim of clustering analysis to solve CVRP is to separate this problem into several subproblems and use the optimization algorithm to solve these subproblems. Then, based on the optimal solutions of these subproblems, we can get the optimal solution of the main problem.

Based on the above algorithm and model, an improved genetic algorithm was proposed to solve the CVRP problem. The flow chart of the CM algorithm is shown in Figure 3. At the same time, the flow chart of the improved algorithm is shown in Figure 4.

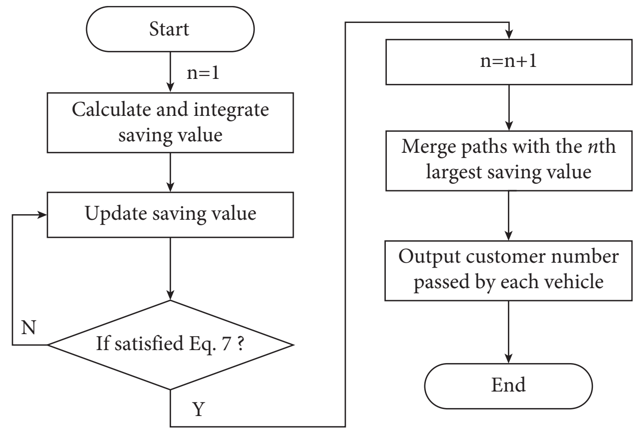


Figure 3: The flow chart of the CW algorithm.

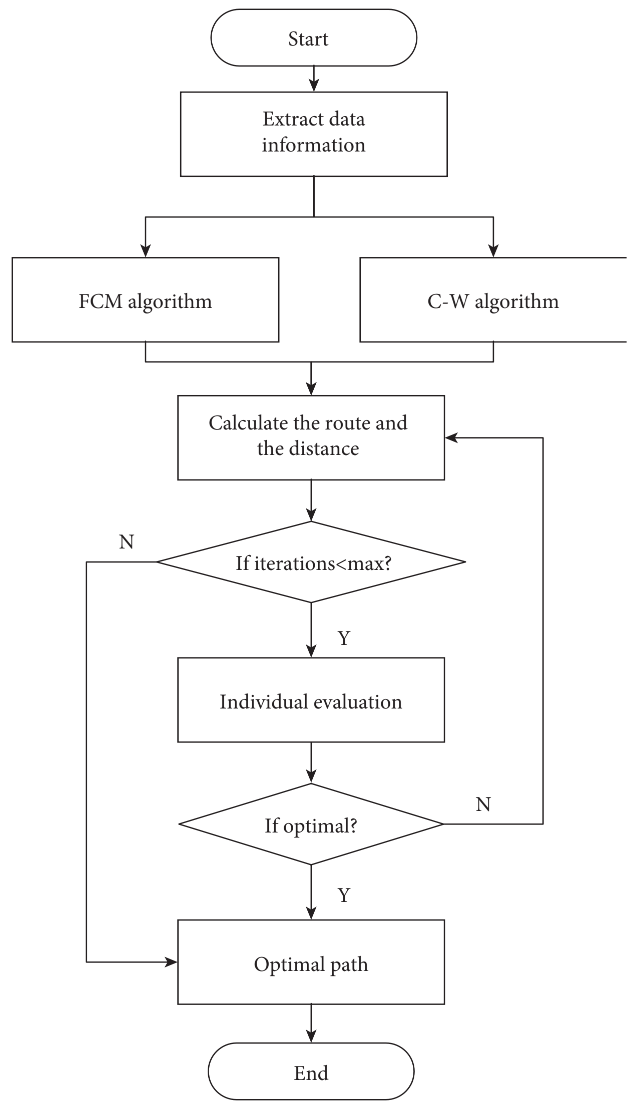


Figure 4: The flow chart of the proposed algorithm.

4. Case Studies

4.1. Introduction of Case. In order to verify the performance of the improved genetic algorithm, this paper uses data from 25 CVRP standard examples to take tests. The simulations are based on MATLAB R2020b environment with Win10 OS. CPU is AMD R7 5800H. Graphics card is Nvidia 3060 laptop. The gap in the experiment can be expressed as follows:

$$\text{gap} = \frac{BS - BSK}{BSK}\%, \tag{16}$$

where BS is the optimal solution obtained by algorithm optimization. BSK is the known optimal solution.

4.2. Experimental Parameter and Analysis. Table 1 shows the arithmetic partial parameter settings. Each benchmark example runs independently for 20 times to obtain the experimental results, as shown in Table 2. Cost is the value of the objective function (i.e., the total distance of the journey), AVS is the average optimal solution of the algorithm, and AVT is the average time-consuming of the algorithm. It can be seen from Table 2 that the algorithm proposed in this paper has good solution accuracy and fast solution speed for CVRP. In terms of solution accuracy, the algorithm proposed in this paper can obtain the optimal solution for 25 benchmark examples. In addition to the optimal solution, the error of the optimal solution of the algorithm optimization is not more than 1.0%, the average error of the optimal solution is not more than 5.85%, and the average error of the optimal solution is 0.11%. Among the 25 groups of standard examples, 18 groups have found the optimal solution, the number of vehicles has reached the optimal, and 9 groups of 18 groups of test examples can stably solve and obtain the optimal solution. In terms of solution speed, all examples are optimized in milliseconds, and none of them is more than 400 ms. Figures 5 and 6 are the FCM clustering results of some benchmark examples, and the optimal solution is obtained by the improved genetic algorithm. The optimal distribution path calculated by the improved genetic

Table 1: Arithmetic partial parameter settings.

Parameter name	Parameter setting
Population size	NIND = 50
Number of iterations	MAXGEN = 200
Intersect probability	Pcmax = 0.9
Aberrance probability	Pmmin = 0.05
Generation gap	GGAP = 0.9
Initial cluster center	2

Table 2: Simulation results of the proposed algorithm.

Instance	BSK	BS		AVS		AVT/s
	Cost	Cost	Gap (%)	Cost	Gap (%)	
A-n33-k5	661	661	0.0	666.25	0.79	0.24
A-n33-k6	742	743	0.13	749.1	0.96	0.15
A-n36-k5	799	799	0.0	800.05	0.13	0.14
A-n37-k6	949	955	0.63	986.75	3.98	0.3
A-n38-k5	730	730	0.0	747.05	2.34	0.16
A-n39-k5	822	822	0.0	848.0	3.16	0.26
A-n39-k6	831	855	0.48	864.5	4.03	0.19
A-n44-k7	937	937	0.0	984.2	5.04	0.33
B-n31-k5	672	672	0.0	683.1	1.65	0.15
B-n34-k5	788	788	0.0	798.35	1.31	0.19
B-n35-k5	955	955	0.0	974.3	2.02	0.17
B-n38-k6	805	805	0.0	822.1	2.12	0.24
B-n41-k6	829	832	0.36	853.5	2.96	0.24
B-n43-k6	742	742	0.0	785.55	2.23	0.26
B-n45-k5	751	755	0.53	768.85	2.38	0.36
B-n52-k7	747	744	0.0	766.2	2.57	0.42
P-n16-k8	450	450	0.0	450.0	0.0	0.1
P-n19-k2	212	212	0.0	212.0	0.0	0.02
P-n20-k2	216	216	0.0	216.0	0.0	0.03
P-n21-k2	211	211	0.0	211.0	0.0	0.04
P-n22-k2	216	216	0.0	216.0	0.0	0.04
P-n22-k8	590	590	0.0	590.0	0.0	0.05
P-n23-k8	529	529	0.4	531.1	0.4	0.16
P-n45-k5	510	515	5.85	539.85	5.85	0.29
P-n55-k8	588	590	5.48	620.25	5.48	0.55

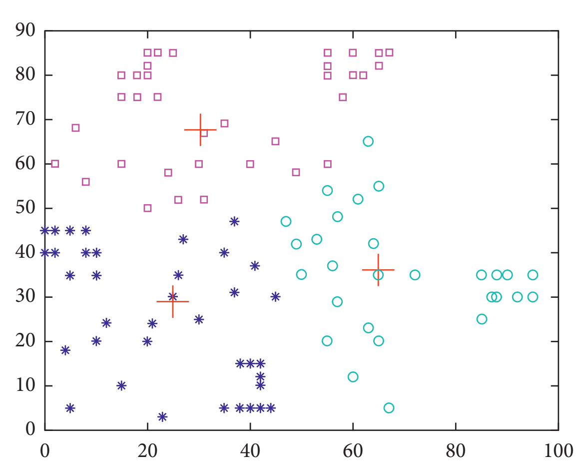


Figure 5: FCM clustering results.

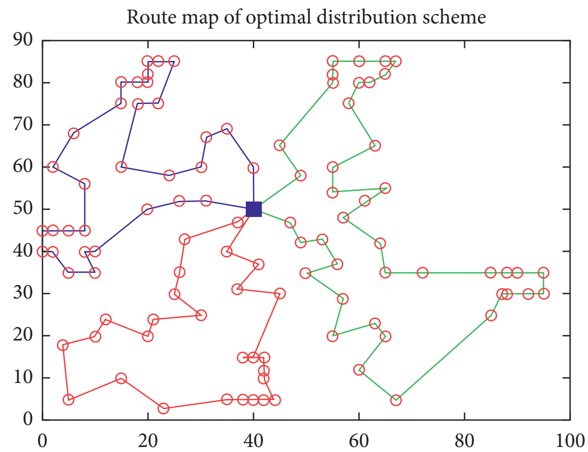


FIGURE 6: Diagram of optimal solution obtained by improved genetic algorithm.

TABLE 3: Comparison of results of each algorithm for solving the CVRP problem.

Algorithm	Average optimal value	Error rate (%)	Average time (s)
Improved genetic algorithm based on FCM	676.23	91.46	202.12
AFSA	688.45	95.12	280.77
Traditional genetic algorithm	690.24	97.56	291.47

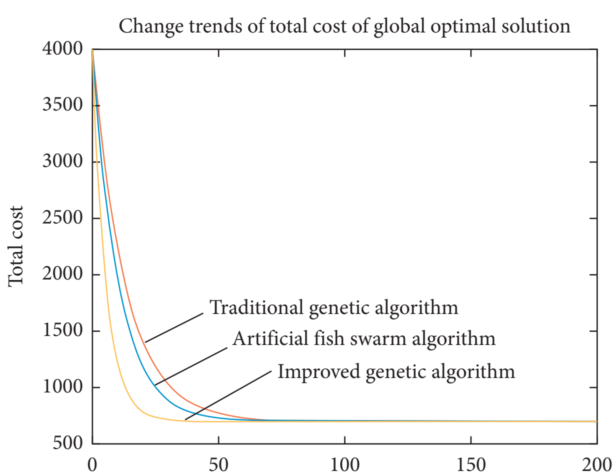


FIGURE 7: Iterative procedure.

algorithm is 661, and three vehicles are needed to complete the distribution task.

4.3. Modeling Simulation Comparison and Analysis. Comparison results among the improved genetic algorithm, artificial fish school algorithm (AFSA), and traditional genetic algorithm are performed in this paper. Twenty-five CVRP benchmark examples are selected for testing. Table 3 is the average optimal value by tested 20 times, the known error rate of the optimal solutions, and the average time. The convergence of the three algorithms is shown in Figure 7.

5. Conclusion

In this paper, FCM and CW algorithm are used to reduce the range of data group and construct a better initial population, separately. The proposed approach can increase the searching quality and efficiency effectively. Based on that, an improved genetic algorithm is proposed to solve the CVRP problem. Compared with the experimental results by using several algorithms, it can achieve a better result by using an improved algorithm to solve the CVRP problem. It is necessary to make further work in the future. In addition, it can also try to apply this algorithm to solve more complex combinatorial optimization problems, such as practical logistics transportation scheduling problems.

Data Availability

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

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

All the authors agreed to publish the article.

References

[1] L. Feng, Y.-S. Ong, M.-H. Lim, and I. W. Tsang, "Memetic search with interdomain learning: a realization between cvrp and carp," *IEEE Transactions on Evolutionary Computation*, vol. 19, no. 5, pp. 644–658, Oct. 2015.

[2] D. N. Nenchev, A. Miyata, S. Miyahara, and T. Hamano, "The VRP generalized inverse and its application in DCM/VRP-based walking control," *IEEE Robotics and Automation Letters*, vol. 4, no. 4, pp. 4595–4602, Oct. 2019.

[3] J. Yang, S. Yang, and P. Ni, "A vector tabu search algorithm with enhanced searching ability for pareto solutions and its application to multiobjective optimizations," *IEEE Transactions on Magnetics*, vol. 52, no. 3, pp. 1–4, Mar. 2016.

[4] J. Mandziuk, "New shades of the vehicle routing problem: emerging problem formulations and computational intelligence solution methods," *IEEE Transactions on Emerging Topics in Computational Intelligence*, vol. 3, no. 3, pp. 230–244, Jun. 2019.

[5] C. Lagos, "An improved particle swarm optimization algorithm for the VRP with simultaneous pickup and delivery and time windows," *IEEE Latin America Transactions*, vol. 16, no. 6, pp. 1732–1740, Jun. 2018.

[6] Y. Wang, J. Wang, L. Yao, and W. Y. Yin, "A hybrid method based on leapfrog ADI-FDTD and FDTD for solving multiscale transmission line network," *IEEE Journal on Multiscale and Multiphysics Computational Techniques*, vol. 5, pp. 273–280, 2020.

[7] A. Miyata, S. Miyahara, and D. N. Nenchev, "Walking with arm swinging and pelvis rotation generated with the relative angular acceleration," *IEEE Robotics and Automation Letters*, vol. 5, no. 1, pp. 151–158, Jan. 2020.

[8] S. Revollar, R. Lamanna, and P. Vega, "Algorithmic synthesis and integrated design of chemical reactor systems using genetic algorithms," *Proceedings World Automation Congress*, vol. 20, pp. 453–458, Aug. 2019.

[9] R. Cui, X. Su, H. Liang, and Z. Li, "A dual population multi-operator genetic algorithm for flight deck operations scheduling problem," *Journal of Systems Engineering and Electronics*, vol. 32, no. 2, pp. 331–346, Apr. 2021.

[10] J. Gao, L. Dai, and W. Zhang, "Improved genetic optimization algorithm with subdomain model for multi-objective optimal design of SPMSM," *CES Transactions on Electrical Machines and Systems*, vol. 2, no. 1, pp. 160–165, Mar. 2018.

[11] K. Dorling, J. Heinrichs, G. G. Messier, and S. Magierowski, "Vehicle routing problems for drone delivery," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 47, no. 1, pp. 70–85, Jan. 2017.

[12] J. P. Coon, M. Badiu, Y. Liu, F. Yarkin, and S. Dang, "Binary-tree encoding for uniform binary sources in index modulation systems," *IEEE Journal of Selected Topics in Signal Processing*, vol. 13, no. 6, pp. 1270–1285, Oct. 2019.

[13] C. Tao, X. Wang, F. Gao, and M. Wang, "Fault diagnosis of photovoltaic array based on deep belief network optimized by genetic algorithm," *Chinese Journal of Electrical Engineering*, vol. 6, no. 3, pp. 106–114, Sep. 2020.

[14] L. Chi, S. Lu, and Y. Yao, "Optimized electrode distributions of embedded four-electrode resistivity measurement in cement-based materials," *IEEE Sensors Letters*, vol. 4, no. 7, pp. 1–4, Jul. 2020.

[15] W. Zhao, A. Ma, J. Ji, X. Chen, and T. Yao, "Multiobjective optimization of a double-side linear vernier PM motor using response surface method and differential evolution," *IEEE Transactions on Industrial Electronics*, vol. 67, no. 1, pp. 80–90, Jan. 2020.

[16] C. Peng, X. Wu, W. Yuan, X. Zhang, Y. Zhang, and Li Ying, "MGRFE: multilayer recursive feature elimination based on an embedded genetic algorithm for cancer classification," *IEEE/ACM Transactions On Computational Biology And Bioinformatics*, vol. 18, no. 2, pp. 621–632, 2021.

[17] D. Pradhan, S. Wang, S. Ali, T. Yue, and M. Liaaen, "A cluster-based genetic algorithm with non-dominated elitist selection for supporting multi-objective test optimization," *IEEE Transactions on Software Engineering*, vol. 47, no. 1, pp. 86–107, Jan. 2021.

[18] A. Iqbal and G. K. Singh, "PSO based controlled six-phase grid connected induction generator for wind energy generation," *CES Transactions on Electrical Machines and Systems*, vol. 5, no. 1, pp. 41–49, Mar 2021.

[19] Y. Koshka and M. A. Novotny, "Comparison of D-Wave quantum annealing and classical simulated annealing for local minima determination," *IEEE Journal on Selected Areas in Information Theory*, vol. 1, no. 2, pp. 515–525, Aug. 2020.

[20] K. Jagatheesan, B. Anand, S. Samanta, N. Dey, A. S. Ashour, and V. E. Balas, "Design of a proportional-integral-derivative controller for an automatic generation control of multi-area power thermal systems using firefly algorithm," *IEEE/CAA Journal of Automatica Sinica*, vol. 6, no. 2, pp. 503–515, Mar. 2019.

[21] M. Jabi, M. Pedersoli, A. Mitiche, and I. B. Ayed, "Deep clustering: on the link between discriminative models and K-Means," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 43, no. 6, pp. 1887–1896, 1 Jun. 2021.

[22] J. He, K. Yu, Z. Huang, and Z. Chen, "Multi-column matrices selection combined with k-means scheme for mobile OCC system with multi-LEDs," *IEEE Photonics Technology Letters*, vol. 33, no. 12, pp. 623–626, 2021.

[23] J. Yuan and Y. Tian, "Practical privacy-preserving mapreduce based K-means clustering over large-scale dataset," *IEEE Transactions on Cloud Computing*, vol. 7, no. 2, pp. 568–579, June. 2019.

[24] F. Han, T. Pu, M. Li, and G. Taylor, "Short-term forecasting of individual residential load based on deep learning and K-means clustering," *CSEE Journal of Power and Energy Systems*, vol. 7, no. 2, pp. 261–269, 2021.

[25] S. Zhou, H. Tang, and N. Xiong, "Aggregation characteristics of anchored ships based on optimized fuzzy c-means algorithm," *Journal of Transportation Engineering*, vol. 19, no. 6, pp. 137–148, Jun. 2019.

Hindawi
Scientific Programming
Volume 2022, Article ID 6315063, 11 pages
https://doi.org/10.1155/2022/6315063

Research Article

An Intelligent Vehicle Alarm User Terminal System Based on Emotional Identification Technology

Liping Wu[1] **Maomao Liu**[1] **Jingpeng Li**[2] **and Yanjun Zhang**[1]

[1]*College of Information Science and Engineering, Shandong Agriculture and Engineering University, Jinan 250000, China*
[2]*Inspur Software Group Co., Ltd., Data Center Service Business Dept, Jinan 250000, China*

Correspondence should be addressed to Liping Wu; z2013463@sdaeu.edu.cn

Received 19 November 2021; Revised 21 December 2021; Accepted 30 December 2021; Published 14 February 2022

Academic Editor: Ahmed Farouk

Negative emotions could increase the risks of traffic accidents. However, the driver's emotional identification is rarely considered in the current design of intelligent vehicle alarm user terminals (IVAUTs). To solve the problem, this paper tries to design an IVAUT system based on emotional identification technology. Firstly, the transformer network was combined with a convolutional neural network (CNN) into a voice emotional identification system for intelligent vehicle alarm, and an emotional labeling approach was provided. Next, a bimodal fusion model was developed based on decompose-CNNs, which includes an appearance module, an optical flow module, and a bimodal fusion module. The proposed emotional identification approach was proved effective through experiments.

1. Introduction

Negative emotions could increase the risks of traffic accidents [1–8]. To assist with driving, it is necessary to effectively detect the driver's negative emotions and thus enhance his/her thinking ability, perception ability, and judgement ability [9–11]. Currently, emotions are mostly identified based on facial expressions, voices, postures, behaviors, texts, and physiological signals [12–18]. Among them, the identification technologies of voice signals, facial expressions, and physical behaviors are research hotspots. With the popularity of intelligent vehicle interaction equipment, emotional identification technology has been gradually introduced to assist with driving by monitoring fatigue driving and driver emotions [19, 20].

To prevent driving risks, Ooi et al. [21] proposed a new driver monitoring system. Specifically, a deep convolutional neural network (DCNN) was designed to recognize driver emotions, and an on-demand audio mechanism was developed to automatically collect audio resources with an online crawler, aiming to eliminate the driving risks induced by the driver's negative emotions. Based on a survey on electrodermal activities, Bi and Shen [22] recognized stress and anger as the main driver emotions that lead to accidents and develop a simulated driving operation with preset neutral, stress, and anger scenarios, according to emotional stimuli. Xie et al. [23] presented an emotion-based fatigue driving recognition algorithm for the drivers, who have been driving for a long time or have a poor mental state, and relied on the algorithm to prevent continuous fatigue driving, thereby avoiding incidents. Drawing on the Ortony-Clore-Collins (OCC) model of emotion, the Markov model of the automatic state transition of emotions, and the hidden Markov model of the state transition of emotions under stimuli, Neerincx et al. [24] modeled the driver emotions under two different road conditions and fixed road conditions and examined the variation in driver emotions during car following, lane changing, and overtaking. Riaz et al. [25] categorized the causes of driving emotions into two classes, namely, personal factors and specific driving conditions, pointing out that the nature and intensity of perceived emotions depend on the various evaluation factors under traffic conditions. Izquierdo-Reyes et al. [26] put forward an effective driver assistance model, which drives cognition by emotions. As an accident prevention scheme, the model considers the distraction of different types of drivers simultaneously.

After sorting out the domestic and foreign research, the studies on intelligent vehicle alarm user terminals (IVAUTs) focus on the design of terminals based on human-computer interaction and the development of information exchange interfaces based on design psychology. However, little attention has been paid to the emotional recognition of drivers in the IVAUT design. The proposed IVAUT system realizes the relevant functions based on techniques of voice emotion identification and facial emotion identification. The two emotion identification techniques were innovatively integrated to recognize and warn the negative emotions of drivers.

The available techniques of voice emotion identification cannot effectively recognize the individual difference in voice, while the current methods of facial emotion identification overlook the correlation between appearance modal and optical flow modal. Hence, this paper designs an innovative approach for the two identification technologies. Section 2 combines the transformer network with a convolutional neural network (CNN) into a voice emotional identification system for intelligent vehicle alarm and explains the emotional labeling approach. Section 3 develops a bimodal fusion model based on decompose-CNNs, which includes an appearance module, an optical flow module, and a bimodal fusion module. Section 4 verifies the effectiveness of our emotional identification approach through experiments.

2. Voice Emotion Identification System

With the technical advancement of various sensors and monitoring equipment, it is increasingly easier to acquire human voice signals and facial expression images with high accuracy. To ensure safe driving, it is particularly important to identify and warn drivers' negative emotions with artificial intelligence and machine learning algorithms, as well as the techniques of voice emotion identification and facial emotion identification. The IVAUTs can precisely monitor the real-time emotions of drivers, accurately grasp their psychological changes, and take timely countermeasures to prevent traffic accidents induced by negative emotions.

The voice features (e.g., pitch, tone, and loudness) of humans vary with emotional states. The existing techniques of voice emotion identification usually analyze the voice features corresponding to the known types of emotions, adjust the parameters and weights of the emotion identification model, making the model more effective in identifying emotions, and test the adjusted model.

This paper combines the transformer network with CNN to acquire voice emotional features more effectively. The primary voice emotional features were taken as the parameters of the two networks and transmitted them to the deep network. The selected CNN consists of four convolutional modules that optimize loss classifiers, a batch normalization module for regularization, a max-pooling layer that reduces the dimensionality of the feature map, a drop-out layer that prevents overfitting in training, and a rectified linear unit (ReLU) function to activate the standard layers. In the transformer network, the multihead attention encoder is connected to the fully connected feedforward network, which is followed by a ReLU function layer. The outputs of the transformer network and the CNN are combined and mapped by the softmax function to eight emotions.

2.1. Network Design. The transformer encoder structure was adopted to increase the number of features. If the data are batch-processed by instance normalization, the features extracted by the transformer network will differ slightly from those extracted by the CNN in terms of the internal relationship.

Moreover, the voice sample set for the IVAUTs covers the samples of 30 users. Since each user has unique voice features, the extracted features contain lots of personal features: the intraclass distance is even greater than the interclass distance. If the voice emotional features are classified by the softmax function, the intraclass distance would be enlarged, undermining the recognition effect of the model.

To solve the above problem, the voice emotion identification model with loss function was introduced to reduce the intraclass distance. The loss function learns the center of deep voice features in each class and penalizes the central features of the expected classes. In this way, the interclass distance is increased, and the intraclass distance is reduced. As shown in Figure 1, the established network consists of an input layer, multiple convolutional layers, a multihead attention mechanism, a fully connected layer, and an output layer.

The voice emotion model has a special requirement on the overall distribution of sample data. To keep the data distribution consistent, the batch normalization module in the network normalizes each batch of voice samples. The mean and variance of each batch are greatly affected by the data size of that batch. If the data are too few, it is impossible to characterize the sample distribution with the calculated mean and variance. Voice emotion recognition usually deals with the entire input sentence. Let F be the number of hidden units on each layer; k be the k-th hidden layer; v be the value of a node before activation. To obtain more, richer emotional features of voice sentences, layer normalization was adopted in our transformer encoder. The input of all nodes is regularized by

$$N^k = \frac{1}{F}\sum_{i=1}^{F} v_i^k, \tag{1}$$

$$\varepsilon^k = \sqrt{\frac{1}{F}\sum_{i=1}^{F}\left(v_i^k - N^k\right)^2}. \tag{2}$$

By formulas (1) and (2), the expectation N and standard error ε can be obtained for each layer. The hidden units in the same layer share the same normalized expectation N and standard error ε. However, the networks trained on different cases would have different normalized expectations N and

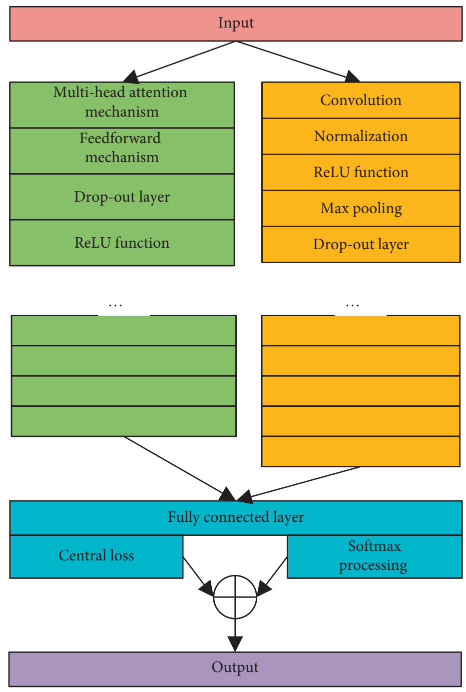


Figure 1: Structure of our voice emotion identification network.

standard error ε. Let h be the gain and r be the offset. Then, we have

$$v_i^{-k} = \frac{h^k}{\varepsilon^k} \cdot \left(v_i^k - N^k\right) + r. \quad (3)$$

This paper classifies the voice emotional features with softmax cross-entropy loss function. Identical to the m-classification problem, the inputs of our network can be mapped to real numbers in [0, 1] through regularization, with the sum of all inputs being 1. For any voice sample E, the probability of being assigned to voice emotion class D_i is GL_i. Then, we have

$$GL_1 + GL_2 + \cdots + GL_m = 1. \quad (4)$$

The voice emotion class of voice sample E can be expressed as

$$\max\left(GL_1, GL_2, \ldots, GL_m\right). \quad (5)$$

According to the requirements of the m-classification problem, the softmax function outputs the probability GL_i of each voice emotion class D_i. The maximum probability max (GL_1, GL_2, $\ldots GL_m$) is the most probable class of the inputs. The inputs of the softmax function consist of transformer network output and CNN output. Let δ and γ be the hyperparameters to be adjusted during the training; ω_{ij} be the j-th weight of node i related to the CNN output; ω_{nm} be the n-th weight of node m related to transformer network output. Then, the i-th output can be expressed as

$$C_i = \sum_j \omega_{ij}^C + r^C + \gamma\left(\sum_m \omega_{nm}^{TR} + r^{TR}\right). \quad (6)$$

Next, the softmax function is added to the network output. Then, the i-th output O_k can be expressed as

$$O_i = \frac{e^{C_i}}{\sum_{j=1}^m e^{C_i}}. \quad (7)$$

The cross-entropy function, which is easy to derive and compute, was selected as the softmax loss function [24]. Let b_i be the actual classification result. The cross-entropy function can speed up the network learning:

$$L = -\sum_i b_i \ln v_i. \quad (8)$$

2.2. Loss Function. To facilitate the design of the classifier for voice emotion identification, the distance between different classes of voice emotions should be maximized, while that between the same class of voice emotions under different scenarios should be minimized. As a common classification method for multiclass tasks, the softmax cross-entropy loss function can learn the separable features in order to differentiate between various voice emotions. For this purpose, the loss function was introduced to the proposed voice emotion identification model, which draws voice emotions to the center of their corresponding voice emotion classes. Let d_j be the center of the i-th class of voice emotions. Then, the loss function can be expressed as

$$L_{\text{Center}}^{*} = -\frac{1}{n}\sum_{i=1}^{n}\left\|c_i - d_{b_i}\right\|^2. \quad (9)$$

By optimizing the loss function, the distance between the same class of voice emotional features will become smaller.

After initializing d_j as 0 and defining the class center of each minibatch as $\dot{d}_j$, the class center d'_j of the j-th type of features in the minibatch can be calculated by

$$d'_j = \frac{\sum_{i=1}^{n} \xi(b_i = j)C_i}{\sum_{i=1}^{n} \xi(b_i = j) > 0}. \quad (10)$$

If $b_i = j$, then $\xi\ (b_i = j)C_i = 1$. Let δ be the hyperparameter that controls the update rate of d_j, if the new minibatch has the voice emotional features corresponding to the j-th class of emotions; d_j^{τ} and $\dot{d}_j^{\tau}$ be the values of d_j and $\dot{d}_j$ in the τ-th iteration, respectively. In other cases, $\xi\ (b_i = j)C_i = 0$. Then, the class center d_j can be defined as

$$d_j^{\tau+1} = \begin{cases} (1-\delta)d_j^{\tau} + \delta\dot{d}_j^{\tau}, & \sum_{i=1}^{n} \xi(b_i = j) > 0, \\ d_j^{\tau}, & \sum_{i=1}^{n} \xi(b_i = j) = 0. \end{cases} \quad (11)$$

Let θ_j be the inverse ratio of class j voice emotions in the entire voice sample training set. Because of the imbalance between voice emotion classes, two weights were assigned to softmax cross-entropy loss function and loss function:

$$\begin{aligned} L_{\text{SoftMax}} &= \frac{1}{\sum_{i=1}^{n} \theta_{b_i}} \sum_{i=1}^{n} \theta_{b_i} \ln v_i, \\ L_{\text{Center}} &= \frac{1}{\sum_{i=1}^{n} \theta_{b_i}} \left\| c_i - d_{b_i} \right\|^2. \end{aligned} \quad (12)$$

Hence, this paper uses a joint loss function to train the proposed voice emotion identification model. Let μ be the hyperparameter that balances central loss with softmax cross-entropy loss. Then, the joint loss function composed of softmax cross-entropy loss function and loss function can be expressed as

$$L = L_{\text{SoftMax}} + \mu L_{\text{Center}}. \quad (13)$$

2.3. Emotional Labeling. The proposed voice emotion identification model was trained on the Ryerson Audio-Visual Database of Emotional Speech and Song (RAVDESS), which contains eight types of emotions with a frame precision of nearly 80%. The voice samples were labeled directly by the naming rule of voice emotion data in that database. Each voice sample was named in the format of "audio number-data type-emotion label-data intensity-semantic content-repetition-user number.wav." Specifically, the data type is speech 01 or song 02; the emotion label could be one of the following: indifferent 01, calm 02, happy 03, sad 04, angry 05, fearful 06, disgust 07, and surprise 08; the data intensity is either normal 01 or strong 02; the repetition is 01 (first repetition) or 02 (second repetition).

In the RAVDESS, the emotions are classified into eight types 01–08, which are common in most datasets. To ensure the emotional recognition effect of our model on subjects of different voice features and maintain the diversity of voice emotions, this paper randomly divides the voice sample set into eight subsets. Five of them were used for training and the remaining three for testing.

3. Facial Emotion Identification System

Each facial expression is a dynamic process in a period of time, which is induced by the movement of facial muscles. Compared with the single frame-based static facial expression identification, the dynamic identification oriented at vehicle videos can acquire facial expression features with high accuracy. This paper sets up a bimodal fusion model based on decompose-CNNs (Figure 2), which mainly consists of an appearance module, an optical flow module, and a bimodal fusion module. Based on three-dimensional (3D) decompose-CNN, the appearance module processes the red-green-blue (RGB) image sequence of video frames. Based on two-dimensional (2D) decompose-CNN, the optical flow module processes a single optical flow image, which normally encompasses a start frame and vertex frames. The bimodal fusion module applies a consistency constraint on the emotion labels predicted by facial expressions of different modals, such as integrating the information of the appearance module with that of the optical flow module in the feature space.

The time information and spatial information of a frame can be extracted by one-dimensional (1D) convolution and 2D convolution, respectively. 1D convolution, which operates in the height and width directions, can be naturally decomposed through 2D convolution. Both 1D and 2D convolutions can be decomposed by 3D convolution. Let $\Gamma(.)$ be a complete 2D convolutional layer; Q^{φ} and Q^{ϕ} be kernels of the size $1 \times R$ and $R \times 1$, respectively; $\Gamma_{3D}(.)$ be a 3D convolutional layer; Q^{ρ} and Q^{σ} be the kernels of the size$1 \times R \times R$ and $R \times 1 \times 1$, respectively; $P \in \mathbb{R}^{S \times Q \times U\phi}$ and $P \in \mathbb{R}^{\Psi \times S \times Q \times U\sigma}$ be the final feature maps output by the decompose-CNNs, respectively; Ψ, S, and Q be the time length, height, and width, respectively; U^{ϕ} and U^{σ} be the number of channels. Then, this paper defines the two types of decompose-CNNs. The feature maps G and G output by the preceding network layer can be, respectively, calculated by the following decompose-convolutions:

$$\begin{aligned} \mathrm{P} &= \Gamma\left(Q^{\varphi}, \Gamma\left(Q^{\phi}, G\right)\right), \\ P &= \Gamma_{3D}\left(Q^{\sigma}, \Gamma_{3D}\left(Q^{\rho}, G\right)\right). \end{aligned} \quad (14)$$

The decomposition of 2D and 3D convolutions greatly reduces the number of parameters and computing complexity of the network, resulting in more efficient recognition of facial expressions. Besides, the network layers are increased to enhance the ability of the network to handle nonlinear data. Figure 3 shows the decomposition process of 2D convolution. The decomposition process of 3D convolution is similar to Figure 3.

The optical flow indicates the direction and intensity of pixel motion in video frames. Suppose pixel (a), (b) moves to $(a+\Delta a,\ b+\Delta b)$ from moment ψ to moment $\psi+\Delta\psi$. Let v and s be the horizontal and vertical components of the optical flow. Then, the vector of the optical flow can be calculated by

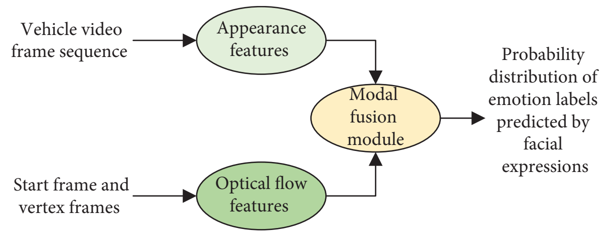


Figure 2: Architecture of bimodal fusion model.

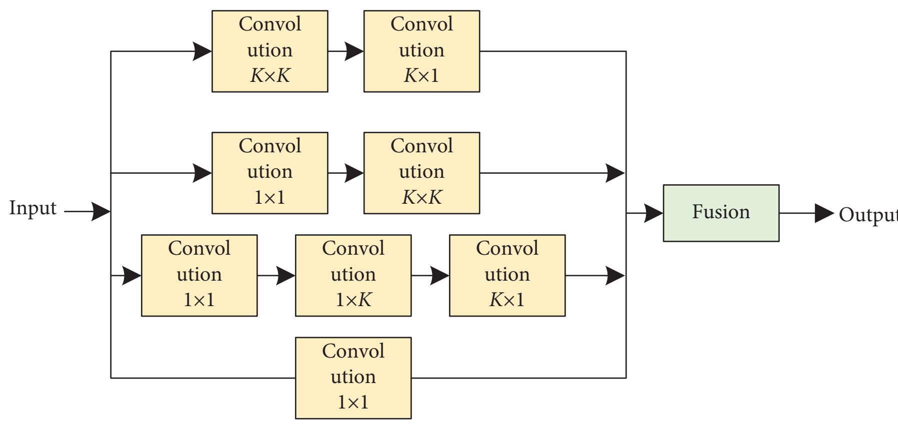


Figure 3: Decomposition process of 2D convolution.

$$q = (v, s)^T = \left(\frac{\Delta a}{\Delta \psi}, \frac{\Delta b}{\Delta \psi}\right)^T. \quad (15)$$

The motion state between frames can be described by the optical flow vector between the dense optical flow images of adjacent car video frames. If the car video contains k frames, it is possible to obtain k-1 optical flow images. The more the frames, the more complex the extraction of optical flow.

The facial expressions in car video frames can be perceived synergistically from different angles, for example, appearance information and optical flow information. Figure 4 shows the structure of 2D decompose-CNN. If the two modals of appearance features and optical flow features of facial expressions are simply connected in series, the correlation between the two kinds of features will be ignored. To fully utilize the correlation, this paper fuses the two modals consistently and constructs a classification constraint based on fused features, aiming to reduce the classification difference of facial expressions between the two modals.

Let χ_i be the eigenvector of the i-th sample; GL_1 and GL_2 be the probability distributions of the same length. Then, the matching degree of GL_2 to GL_1 can be measured by relative entropy Φ:

$$\Phi(GL_1 \| GL_2) = -GL_1(\chi_i)\log\frac{GL_1(\chi_i)}{GL_2(\chi_i)}. \quad (16)$$

Because of the asymmetry of relative entropy Φ, that is, $\Phi(GL_1||GL_2) \neq \Phi(GL_2||GL_1)$, the difference between the two probability distributions can be characterized by symmetric relative entropy Φ^*:

$$\Phi^*(GL_1 \| GL_2) = \frac{1}{2}\Phi(GL_1 \| GL_2) + \frac{1}{2}\Phi(GL_2 \| GL_1). \quad (17)$$

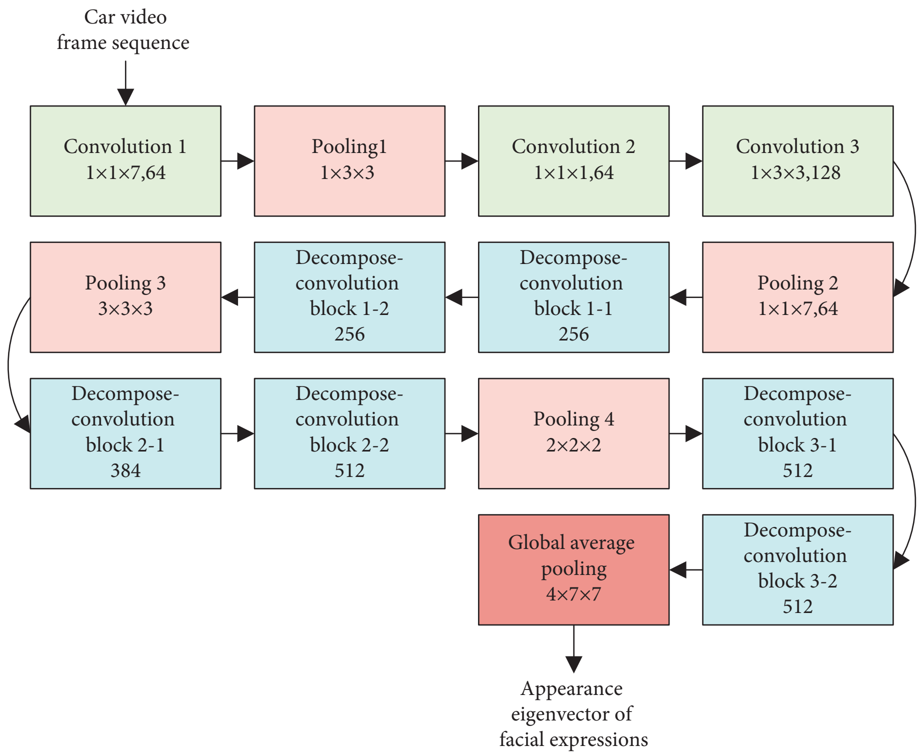
Let χ^t be the eigenvector obtained through the consistent fusion between appearance eigenvector χ^n and optical flow eigenvector χ^m; M be the number of samples; β_i be the probability distribution of the actual labels of the i-th sample; $GL(\chi^t{}_i)$ be the probability distribution of predicted labels obtained based on the fused eigenvector $\chi^t{}_i$ of the i-th sample. Then, the classification constraint can be calculated by

$$\Omega = \sum_{i \in M} \Phi^*\left(\beta_i \| GL\left(\chi_i^t\right)\right). \quad (18)$$

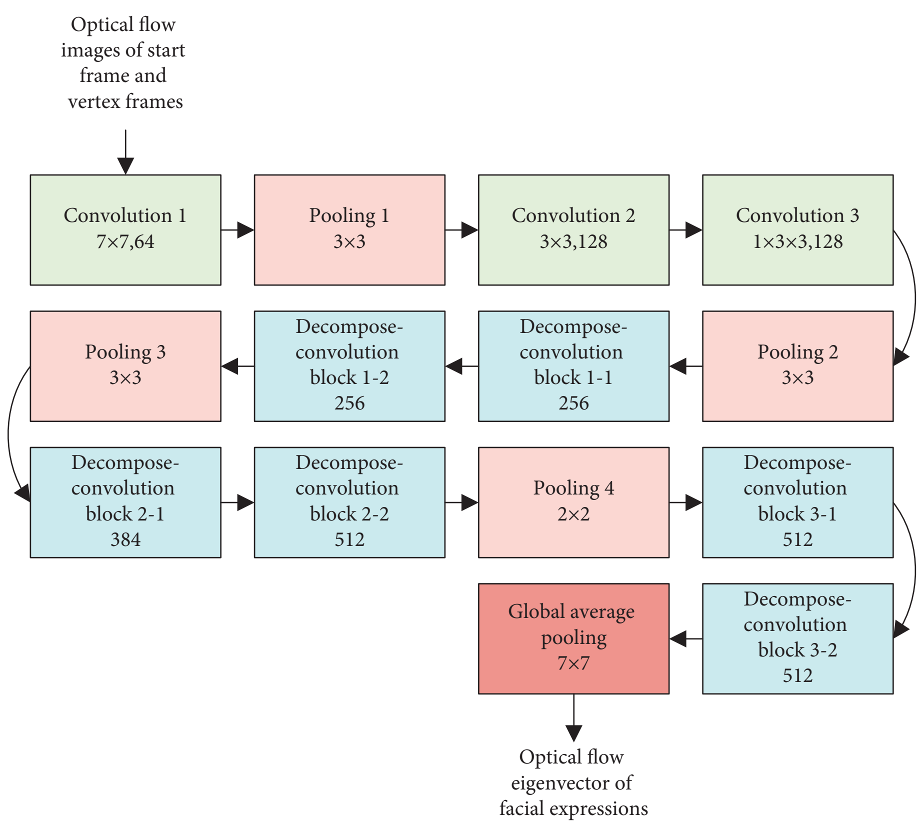
Let W be the number of classes; ζ_χ be the parameter vector of class w prediction. Then, $GL(\chi^t{}_i)$ can be calculated by softmax function:

$$GL(\chi_i) = \frac{1}{\sum_{w=1}^{W} e^{\zeta_a^T \chi_j}}\left[e^{\zeta_1^T \chi_i}, e^{\zeta_2^T \chi_i}, \ldots, e^{\zeta_w^T \chi_i}\right]^T. \quad (19)$$

In theory, the appearance features and optical flow features predicted for the same input should have similar modals; that is, the two types of features should be consistent. To prevent the extraction error of a single modal from affecting the model output, this paper applies a



(a)



(b)

Figure 4: Structure of 2D decompose-CNN.

consistency constraint on the probability distributions $GL(\chi_i^{n})$ and $GL(\chi_i^{m})$ of predicted feature labels corresponding to the two modals:

$$\mathrm{PLPD} = \eta \sum_{i\in M} \Phi^{*}\left(GL\left(\chi_i^{n}\right) \| GL\left(\chi_i^{m}\right)\right), \tag{20}$$

where η is a hyperparameter. Formula (20) ensures the effective synthesis of complementary information of the two modals. Let $\Delta = \{\zeta^{n}, \zeta^{m}, \zeta^{t}\}$ be the online parameter of the modal fusion module. The final loss function can be given by

$$L(\Delta) = \Omega + \mathrm{PLPD}. \tag{21}$$

Figure 5 explains the flow of modal fusion. Gradient descent was further adopted to optimize the network loss function, such that the probability distribution of predicted feature labels based on fused facial expressions approximates the probability distribution of actual feature labels. The partial derivative of the loss function can be solved by

$$\begin{aligned}
\frac{\partial L(\Delta)}{\partial \zeta^{n}} &= \eta \sum_{i=1}^{M} \frac{\partial \Phi^{*}\left(GL\left(\chi_i^{n}\right) \| GL\left(\chi_i^{m}\right)\right)}{\partial \zeta^{n}} \\
&= \frac{\eta}{2} \sum_{i=1}^{M} \frac{\partial \Phi\left(GL\left(\chi_i^{n}\right) \| GL\left(\chi_i^{m}\right)\right)}{\partial \zeta_{jk}^{n}} + \frac{\partial \Phi\left(GL\left(\chi_i^{m}\right) \| GL\left(\chi_i^{n}\right)\right)}{\partial \zeta_{jk}^{n}} \\
&= -\frac{\eta}{2} \sum_{i=1}^{M} \left[\sum_{w=1}^{W} \left(\frac{GL\left(w|\chi_i^{m}\right)}{GL\left(w|\chi_i^{n}\right)} + \ln GL\left(w|\chi_i^{m}\right)\right) \frac{\partial GL\left(w|\chi_i^{n}\right)}{\partial \zeta_{jk}^{n}}\right],
\end{aligned} \tag{22}$$

where

$$\begin{aligned}
\frac{\partial GL\left(w|\chi_i^{n}\right)}{\partial \zeta_{jk}^{n}} &= \frac{\partial e^{\zeta_w^{nT} \chi_i^{n}} / \sum_{w=1}^{W} e^{\zeta_w^{nT} \chi_i^{n}}}{\partial \zeta_{jk}^{n}} \\
&= \left(\xi(w=j) - GL\left(w|\chi_i^{n}\right)\right) GL\left(w|\chi_i^{n}\right) \chi_{ik}^{n}.
\end{aligned} \tag{23}$$

The probability distribution of labels predicted by appearance features approaches that of labels predicted by optical flow features, enhancing the robustness of the joint optimization and fused features. Hence, the emotion identification effect of our model could be improved. Let $\zeta^{n}{}_{j}$ be a subvector of ζ^{n}; $\zeta^{n}{}_{jk}$ be the k-th element in $\zeta^{n}{}_{j}$. The derivatives of the first and second terms of formula (21) can be solved similarly relative to ζ^{m} and ζ^{t}.

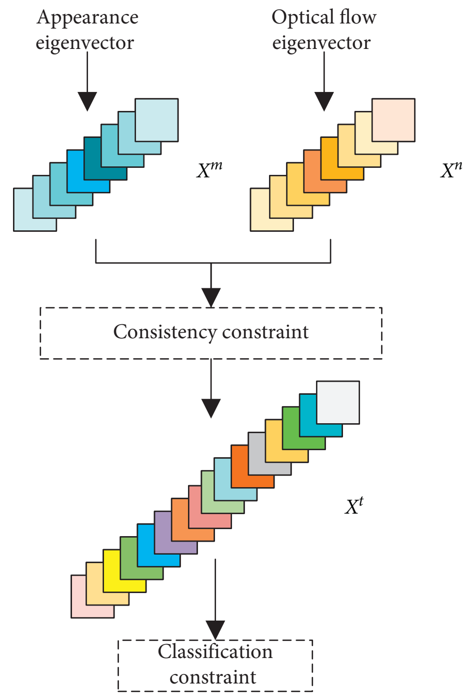


FIGURE 5: Flow of modal fusion.

4. Experiments and Results Analysis

Hyperparameters δ, μ, and γ are the weight of class center update rate, weight of loss function, and weight of encoder output, respectively. This paper designs a contrastive experiment to explore the influence of these hyperparameters on the voice emotion recognition effect. The voice emotion recognition accuracy under different hyperparameter settings is reported in Figure 6, where features A and B are Mel cepstral coefficient (MCC) and Mel frequency cepstral coefficient (MFCC), respectively. Comparing the three subgraphs of Figure 6, the voice emotion recognition accuracy was not sensitive to δ but significantly affected by μ and γ. If μ and γ are too large or too small, the recognition accuracy would be very low.

Figure 7 displays the confusion matrix of our voice emotion identification network based on MFCC. Our model performed excellent on the recognition of calm, sad, surprise, and disgust but made a few errors in recognition of the other four emotions.

Table 1 compares the emotion recognition rates of different models. Compared with traditional CNN, the combined network achieved relatively high accuracy in emotion recognition: the recognition rate surpassed 80% on all emotions, except calm (77.45%); the highest recognition rate was realized on disgust (91.72%). After introducing L_{center}, our model became much more accurate than the combined network. Therefore, the introduction of L_{center} can enhance the effectiveness of our model in voice emotion identification.

Furthermore, MCC was imported to our network. The hyperparameters were set to $\delta = 0.85$, $\mu = 0.15$, and $\gamma = 1$ after sensitivity analysis. Six experiments were carried out, and the most accurate results were selected for analysis. Figure 8 presents the MCC-based confusion matrix, and Table 2 lists the recognition rate of each voice emotion. Obviously, the classification effect of voice emotions could be improved by transformer network and loss function.

This paper compares the MCC- and MFCC-based emotion recognition scores of CNN, combined network, and our model. The results of the three models are compared in Table 3. The results show that our model coupled with MCC achieved the best results among all possible combinations. This is the best combination for emotion recognition of the selected voice emotion sample set.

Figure 9 compares the emotion recognition accuracies of facial expressions under different fusion mechanisms. Different fusion mechanisms had similar accuracy and

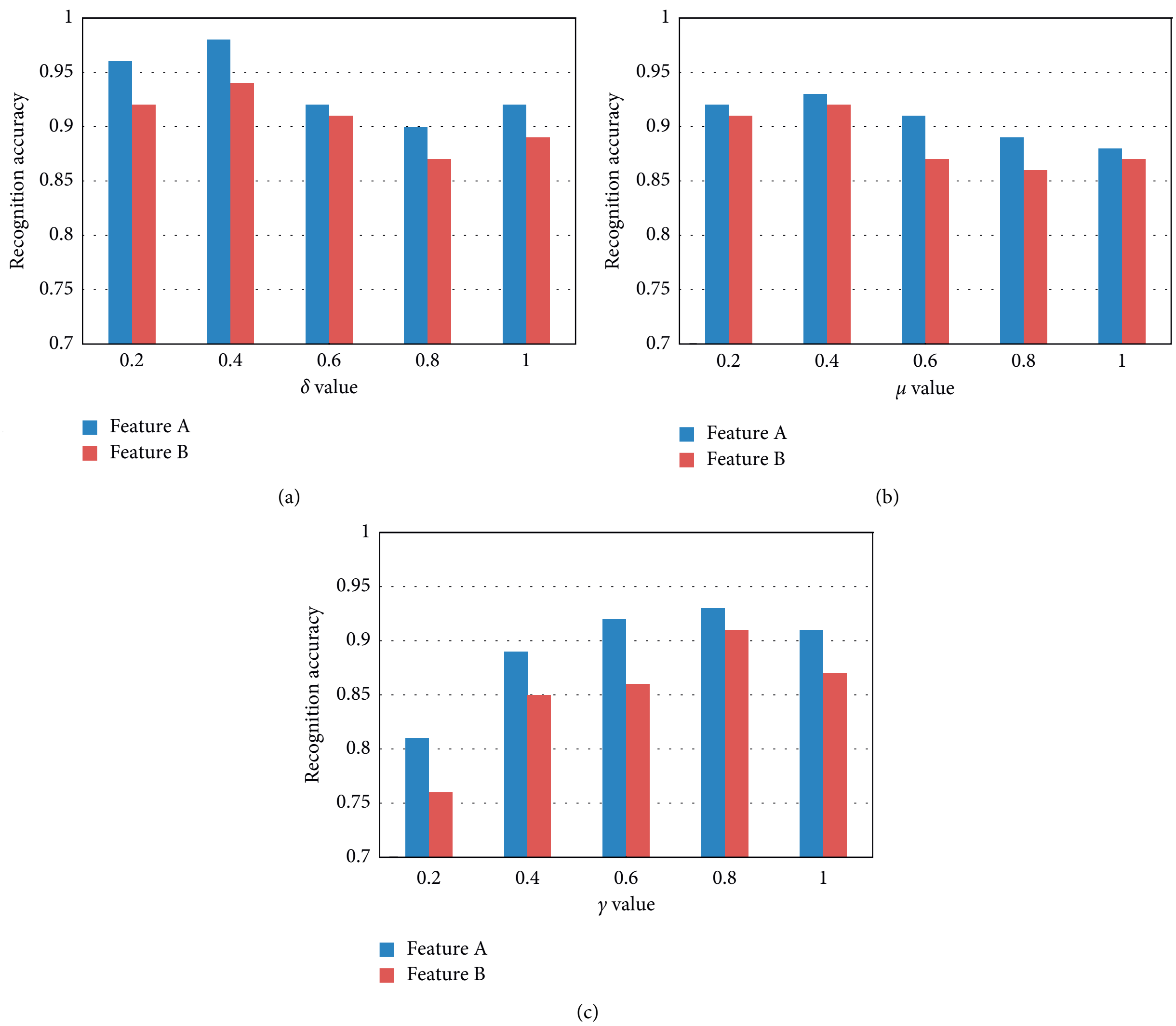


FIGURE 6: Voice emotion recognition accuracy under different hyperparameter settings.

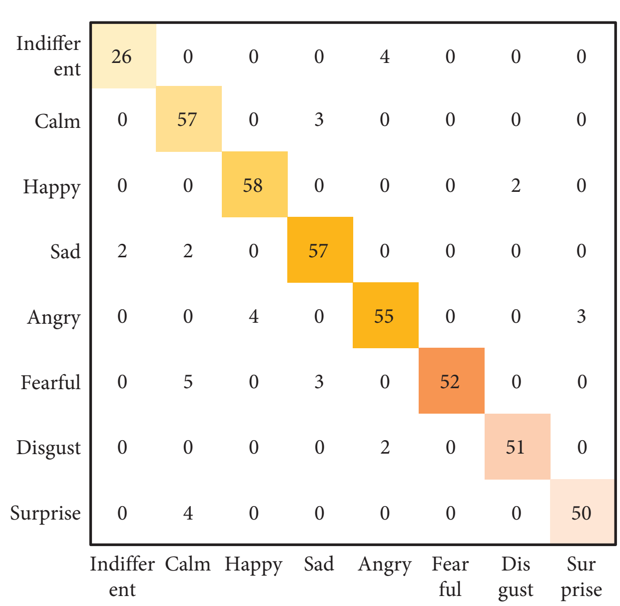


FIGURE 7: MFCC-based confusion matrix.

Table 1: MFCC-based emotion recognition rates.

Name of model	CNN	Combined network (before introducing L_{center})	Our model (after introducing L_{center})
Indifferent (%)	83.46	85.79	87.35
Calm (%)	82.72	77.45	97.45
Happy (%)	82.35	88.72	86.54
Sad (%)	87.54	81.26	97.72
Angry (%)	87.36	84.54	88.46
Fearful (%)	88.41	88.46	88.72
Disgust (%)	83.58	91.72	93.27
Surprise (%)	83.21	90.21	95.31

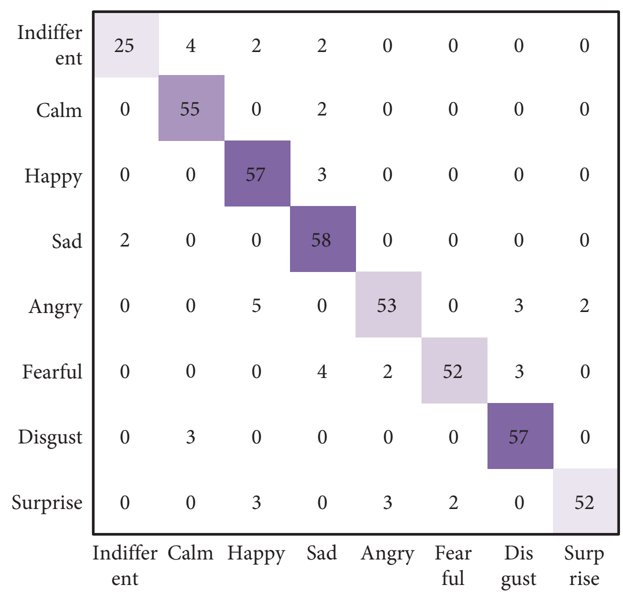


Figure 8: MCC-based confusion matrix.

Table 2: MCC-based emotion recognition rates.

Name of model	CNN	Combined network (before introducing L_{center})	Our model (after introducing L_{center})
Indifferent (%)	87.22	91.26	94.26
Calm (%)	79.75	83.21	83.21
Happy (%)	82.35	90.72	96.72
Sad (%)	81.54	92.38	98.38
Angry (%)	84.26	88.46	88.46
Fearful (%)	85.58	89.72	89.72
Disgust (%)	87.21	90.21	96.21
Surprise (%)	89.54	82.34	92.34

Table 3: Performance scores of different models.

Name of model		Precision (%)	Recall (%)	F1-score (%)
	CNN	92.35	90.72	91.54
MFCC	Combined network (before introducing L_{center})	92.35	92.31	92.23
	Our model	94.23	94.20	94.20
	CNN	91.62	91.23	91.76
MCC	Combined network (before introducing L_{center})	93.57	93.62	93.85
	Our model	95.48	94.48	94.48

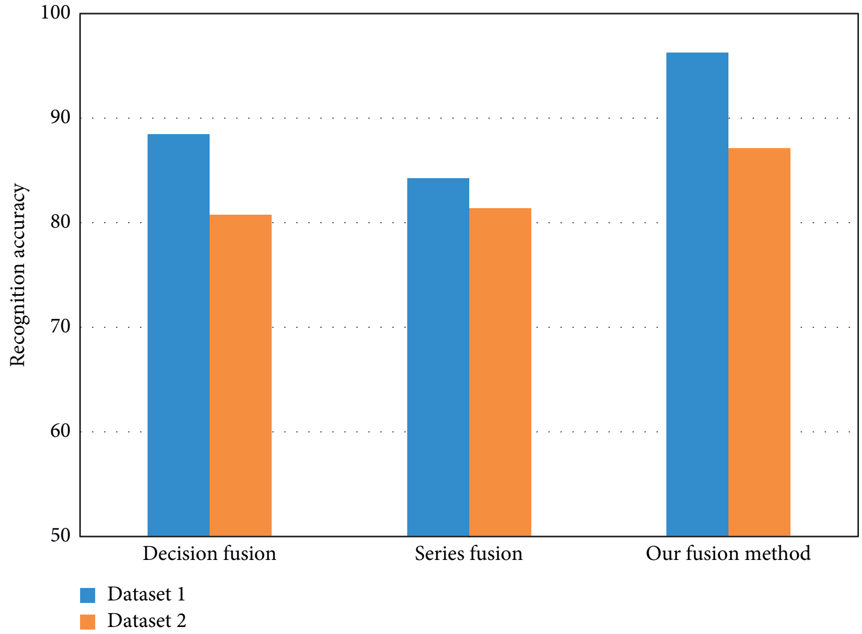


FIGURE 9: Emotion recognition accuracies of facial expressions under different fusion mechanisms.

precision trends on the two datasets, which involve different users. Our model achieved better recognition accuracy than decision fusion, which cannot characterize the distribution features of different features, and series fusion, which merely stitches up the information from different modals. The main reason is that our model further refines the loss function and thus shortens the distance between the predicted label distributions of different modals.

5. Conclusions

This paper mainly develops an IVAUT system based on emotion identification technology. Specifically, a combined network was designed to identify voice emotions for IVAUTs, based on the transformer network and the CNN, and the setting of emotion labels was explained in detail. Next, a bimodal fusion model was developed based on decompose-CNNs. There are three major modules in the model: appearance, optical flow, and bimodal fusion. After that, the voice emotion recognition accuracy was analyzed under different hyperparameter settings, the confusion matrices of our model were established based on MFCC and MCC, respectively, and the emotion recognition accuracies of different models on MFCC and MCC were calculated. The results show that our model, coupled with MCC, achieved better results than any other combination. Finally, the authors tested the emotion recognition accuracies of facial expressions under different fusion mechanisms and confirmed the effectiveness of our emotion identification approach.

The significance of this research lies in identifying the negative emotions of drivers in voices and facial images and making warning and intervention via IVAUTs, aiming to prevent emotional driving behaviors. The research provides a reference for the design and development of future smart transportation systems.

Due to the difficulty in acquiring lots of real data, this research faces several limitations: the conditions and means of emotional identification experiments are very limited, and the test and evaluation data were insufficiently quantified for the voice and facial emotion identification techniques applied in IVAUTs. Future work will try to overcome these limitations through in-depth research.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] T. E. Guerrero, J. de Dios Ortuzar, and S. Raveau, "Traffic accident risk perception among drivers: a latent variable approach," *Transportation Planning and Technology*, vol. 43, no. 3, pp. 313–324, 2020.

[2] H. T. Zhao, H. L. Cheng, Y. Ding, H. Zhang, and H. B. Zhu, "Research on traffic accident risk prediction algorithm of edge internet of vehicles based on deep learning," *Dianzi Yu Xinxi Xuebao/Journal of Electronics and Information Technology*, vol. 42, no. 1, pp. 50–57, 2020.

[3] A. Fang, C. Qiu, L. Zhao, and Y. Jin, "Driver risk assessment using traffic violation and accident data by machine learning approaches," in *Proceedings of the 2018 3rd IEEE International Conference on Intelligent Transportation Engineering (ICITE)*, pp. 291–295National University of Singapore, Singapore, September 2018.

[4] G. Waizman, S. Shoval, and I. Benenson, "Traffic accident risk assessment with dynamic microsimulation model using range-range rate graphs," *Accident Analysis & Prevention*, vol. 119, pp. 248–262, 2018.
[5] L. Eboli, G. Mazzulla, and G. Pungillo, "Measuring the driver's perception error in the traffic accident risk evaluation," *IET Intelligent Transport Systems*, vol. 11, no. 10, pp. 659–666, 2017.
[6] R. Ngueutsa and D. R. Kouabenan, "Accident history, risk perception and traffic safe behaviour," *Ergonomics*, vol. 60, no. 9, pp. 1273–1282, 2017.
[7] Y. Shiomi, K. Watanabe, H. Nakamura, and H. Akahane, "Assessing safety of signalized intersections: Influence of geometric attributes and regionality on traffic accident risk," *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2659, no. 1, pp. 71–79, 2017.
[8] I. Norros, P. Kuusela, S. Innamaa, E. Pilli-Sihvola, and R. Rajamäki, "The Palm distribution of traffic conditions and its application to accident risk assessment," *Analytic methods in accident research*, vol. 12, pp. 48–65, 2016.
[9] A. Eherenfreund-Hager, O. Taubman – Ben-Ari, T. Toledo, and H. Farah, "The effect of positive and negative emotions on young drivers: A simulator study," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 49, pp. 236–243, 2017.
[10] Y. Zhu, Y. Wang, G. Li, and X. Guo, "Recognizing and releasing drivers' negative emotions by using music: evidence from driver anger," in *Adjunct Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pp. 173–178, New York, NY, USA, October 2016.
[11] M. Jeon, J. B. Yim, and B. N. Walker, "An angry driver is not the same as a fearful driver: effects of specific negative emotions on risk perception, driving performance, and workload," in *Proceedings of the 3rd international conference on automotive user interfaces and interactive vehicular applications*, pp. 137–142, New York, NY, USA, November 2011.
[12] X. Zhang, C. Xu, W. Xue, J. Hu, Y. He, and M. Gao, "Emotion recognition based on multichannel physiological signals with comprehensive nonlinear processing," *Sensors*, vol. 18, no. 11, p. 3886, 2018.
[13] K. P. Seng, L. M. Ang, and C. S. Ooi, "A combined rule-based and machine learning audio-visual emotion recognition approach," *IEEE Transactions on Affective Computing*, vol. 9, no. 1, pp. s3–13, 2016.
[14] N. Jain, S. Kumar, A. Kumar, P. Shamsolmoali, and M. Zareapoor, "Hybrid deep neural networks for face emotion recognition," *Pattern Recognition Letters*, vol. 115, pp. 101–106, 2018.
[15] A. Rajasekhar and M. K. Hota, "A study of speech, speaker and emotion recognition using Mel frequency cepstrum coefficients and support vector machines," in *Proceedings of the 2018 International Conference on Communication and Signal Processing (ICCSP)*, pp. 0114–0118, Chennai, India, April 2018.
[16] C. Maramis, L. Stefanopoulos, I. Chouvarda, and N. Maglaveras, "Emotion recognition from haptic touch on android device screens, precision medicine powered by phealth and connected health," in *Proceedings of the International Conference on Biomedical and Health Informatics*, pp. 205–209, Thessaloniki, Greece, November 2017.
[17] S. Klaylat, Z. Osman, L. Hamandi, and R. Zantout, "Emotion recognition in Arabic speech," *Analog Integrated Circuits and Signal Processing*, vol. 96, no. 2, pp. 337–351, 2018.
[18] Z.-T. Liu, Q. Xie, M. Wu, W.-H. Cao, Y. Mei, and J.-W. Mao, "Speech emotion recognition based on an improved brain emotion learning model," *Neurocomputing*, vol. 309, pp. 145–156, 2018.
[19] E. Roidl, B. Frehse, M. Oehl, and R. Höger, "The emotional spectrum in traffic situations: Results of two online-studies," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 18, pp. 168–188, 2013.
[20] G. Leu, N. J. Curtis, N. J. Curtis, and H. Abbass, "Modeling and simulation of road traffic behavior: artificial drivers with personality and emotions," *Journal of Advanced Computational Intelligence and Intelligent Informatics*, vol. 17, no. 6, pp. 851–861, 2013.
[21] J. S. K. Ooi, S. A. Ahmad, Y. Z. Chong, S. H. M. Ali, G. Ai, and H. Wagatsuma, "Driver emotion recognition framework based on electrodermal activity measurements during simulated driving conditions," in *Proceedings of the 2016 IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES)*, pp. 365–369, Kuala Lumpur, Srilanka, December 2016.
[22] B. Hongzhe and S. Gongzhang, "Recognition and applications of emotion detection in driving fatigue," *The Open Automation and Control Systems Journal*, vol. 7, no. 1, 2015.
[23] L. Xie, Z. Wang, R. Dongchun, and S. Teng, "Research of driver emotion model under simplified traffic condition," *Acta Automatica Sinica*, vol. 36, no. 12, pp. 1732–1743, 2010.
[24] M. A. Neerincx, M. Harbers, D. Lim, and V. van der Tas, "Automatic feedback on cognitive load and emotional state of traffic controllers, engineering psychology and cognitive ergonomics," in *Proceedings of the International Conference on Engineering Psychology and Cognitive Ergonomics*, pp. 42–49, Berlin, Germany, June 2014.
[25] F. Riaz, S. Khadim, R. Rauf, M. Ahmad, S. Jabbar, and J. Chaudhry, "A validated fuzzy logic inspired driver distraction evaluation system for road safety using artificial human driver emotion," *Computer Networks*, vol. 143, pp. 62–73, 2018.
[26] J. Izquierdo-Reyes, R. A. Ramirez-Mendoza, M. R. Bustamante-Bello, S. Navarro-Tuch, and R. Avila-Vazquez, "Advanced driver monitoring for assistance system (ADMAS)," *International Journal on Interactive Design and Manufacturing*, vol. 12, no. 1, pp. 187–197, 2018.

Hindawi
Scientific Programming
Volume 2022, Article ID 4953516, 14 pages
https://doi.org/10.1155/2022/4953516

Research Article

Sustainability and Enterprise Economic Growth Management Based on Intelligent Signal Processing

Yanchao Che[1,2] and Xiang Gao[3]

[1]Graduate School, University of Chinese Academy of Social Sciences, Beijing 100102, China
[2]Haier Real Estate Group, Qingdao 266000, Shandong, China
[3]School of Health Management, Guangzhou Medical University, Guangzhou 511436, Guangdong, China

Correspondence should be addressed to Xiang Gao; 2012990047@gzhmu.edu.cn

Received 2 December 2021; Revised 29 December 2021; Accepted 8 January 2022; Published 12 February 2022

Academic Editor: Ahmed Farouk

With the rapid development of China's market economy and the continuous deepening of system reforms, enterprises are also facing more problems while facing greater challenges. In order to deeply explore the role of intelligent signal processing in the development of enterprises in the context of 5G technology, this article uses data collection methods, questionnaire methods, and model building methods to collect data and analyze economic and institutional factors in the development of enterprises. The algorithm has been streamlined. First the impact of environmental factors in sustainable economic development is studied. The results show that, in the optimal economic growth plan, the optimal GDP is 27.65 trillion yuan, and the proportions of the three industries are 8.8%, 38.5%, and 49.7%, respectively; in the optimal pollution emission plan, the proportions of the three industries are 11.8%, 20.15%, and 65.5% respectively. In the neutral plan, the optimal GDP is 27.89 trillion yuan, and the proportions of the three industries are 8.5%, 39.7%, and 49.8%, respectively. This shows that, under the goal of pursuing the optimal environment, the economy can still be maintained. Further the advantages of the system in this article are discussed by analyzing the degree of synergy between them and the continuous growth of the enterprise; we can find that, from 2001 to 2006, the degree of synergy between enterprise technological innovation and institutional innovation has been continuously improved, and it has increased by 332.7% during this period, which shows that technological innovation, institutional innovation, and enterprise growth are coordinated development. It was basically realized that, starting from the intelligent signal processing technology, the economic model and innovation system that can develop together with the environment have been designed.

1. Introduction

Over the past 30 years of reform and opening up, China has experienced rapid economic growth, with an average annual growth rate of about 12%. This figure is a conclusion drawn by the national economic department through the general economic development. However, with the rapid economic growth, China has also paid heavy material and environmental costs. In terms of sustainability, as a large developing country, China has become one of the driving forces of global economic growth. If the economic system reform is not carried out in time, China and the world economy will pay huge institutional and social costs. More importantly, if the economy and enterprises are allowed to follow this trend, this will bring a devastating blow to the economic and environmental system.

The continuous growth of an enterprise is a necessary condition for an enterprise to succeed in other areas, and every enterprise hopes that it can continue to grow and develop. But people sometimes see inefficiency and institutional destruction in their daily lives. With the development of economic and cultural systems, our life information has multiplied from wireless communication systems such as mobile phones, Bluetooth, GPS, and WIFI. Intelligent signal processing technology is a new method and process based on the existing knowledge of mankind. It can effectively improve the status quo of China's economic growth and can revitalize the economic development.

In fact, there are countless relevant studies on the application of intelligent signal processing technology to enterprise economic development and institutional setting. In 2018, Arief aimed to test and analyze regional financial independence, capital expenditures, and governments with medium regional and income gaps. His conclusion was as follows: regional financial independence has a significant positive impact on economic growth, while regional financial independence with a moderate regional difference effect has a negative but not significant impact on economic growth. However, his research data is not transparent [1]. In 2018, Hughes disclosed information management techniques that can be used during the automated processing of biological growth media. In one embodiment, a method includes reading identification elements associated with a biological growth medium, as well as processing the biological growth medium in an automated system according to the processing parameters. Unfortunately, the processing parameters are not expressed [2]. In 2018, Bletsas combined the recent advances in multiple access and realized communication ranges (on the order of hundreds of meters to kilometers). Thanks to intelligent signal processing, backscatter radio was upgraded to a de facto communication principle. However, it does not fit the actual situation very well [3]. In 2018, Havangi proposed target tracking based on H unscented particle filter and particle swarm optimization. The proposed algorithm combines the unscented particle filter and the H filter to estimate the target state. The performance of the proposed algorithm is demonstrated by Monte Carlo running and compared with the performances of other methods. Unfortunately, the research depth is not enough [4]. In 2016, Koppal believed that the ubiquity of smartphones and other mobile vision systems had begun to change the way humans and machines interact with each other and the way they interact with the world. These types of platforms are rapidly maturing from research laboratories. Devices as described above described in are commercially available and may allow the creation of enterprise remote sensor networks. However, theoretical research is still not perfect [5]. In 2017, Ziani proposed an enterprise system detection scheme based on support vector machine as an information classification method and binary particle swarm optimization (BPSO) algorithm based on maximum class separability as a feature selection method. In order to maximize the separability of classes, the regularized Fisher criterion is used as the fitness function in the proposed BPSO algorithm. Unfortunately, there is no data to support this study [6]. In 2017, Wahlstrm proposed a particle-based framework. The filter uses dead reckoning to estimate the position of the propagating particles and then uses two measurement functions to update the particle weights. The results reveal the sensitivity and commercial value of speed data collected in many insurance telematics programs today, which are used to adjust premiums and provide corporate economic feedback. Although the research is more relevant, the content is more obscure and difficult to understand [7].

The innovations of this paper are as follows: (1) Based on the industrial structure of the industrial economy, it analyzes the impact of environmental policies on the corporate system reform and eliminates the impact of environmental policies on corporate system reform. (2) It formulates a comprehensive process for scientific analysis of the impact of scientific and technological innovation synergy on corporate sustainable development. (3) It constructs a technical model from multiple perspectives and builds a strong model. Through the above work, the research content of this article has been improved and the research depth has been expanded.

2. Methods Based on Intelligent Signal Processing on the Sustainability and Institutional Research of Economic Growth

2.1. Wireless Communication System and Intelligent Signal Processing Technology. Signal processing technology refers to the use of computer technology to process information. Computers operate extremely fast and can process large amounts of information automatically and with a high degree of accuracy. Intelligent signal processing technology is a process and method that transforms incomplete, inaccurate, and uncertain information into complete, reliable, accurate, and timely information. The creation of intelligent signals involves many fields of information science and is a complete tool for modern signal processing, artificial intelligence networks, complex system design, and evolutionary analysis, including artificial intelligence and technology [8]. Database technology is a core technology of information systems. It is a computer-aided approach to managing data, which investigates how data can be organised and stored and how it can be accessed and processed efficiently.

To understand the intelligent signal processing technology, we must first understand what a wireless communication system is, go back to the source of wireless communication, and discuss how the wireless communication system developed [9].

Compared with wired communication, wireless communication has the advantages of flexible cost control, reliable performance, and good growth expectations. However, the development of wireless communication is no different from the support of communication transmission. Around the 1980s, cellular communications entered a historical stage. In 1979, Japan and the United Kingdom took the lead in using cellular communication technology, followed by the United States. The cellular system is usually called a cellular system because of its low base station carrying capacity and its signal structure resembles a hexagon of a cell. The emergence of cellular systems makes people feel the beginning of wireless communication time [10]. Wireless communication is communication over long distances transmitted between multiple nodes without propagation via conductors or cables, and it can be through radios and other means. Smart communication is the process of introducing more artificial intelligence to make communication more convenient. Its structure is shown in Figure 1.

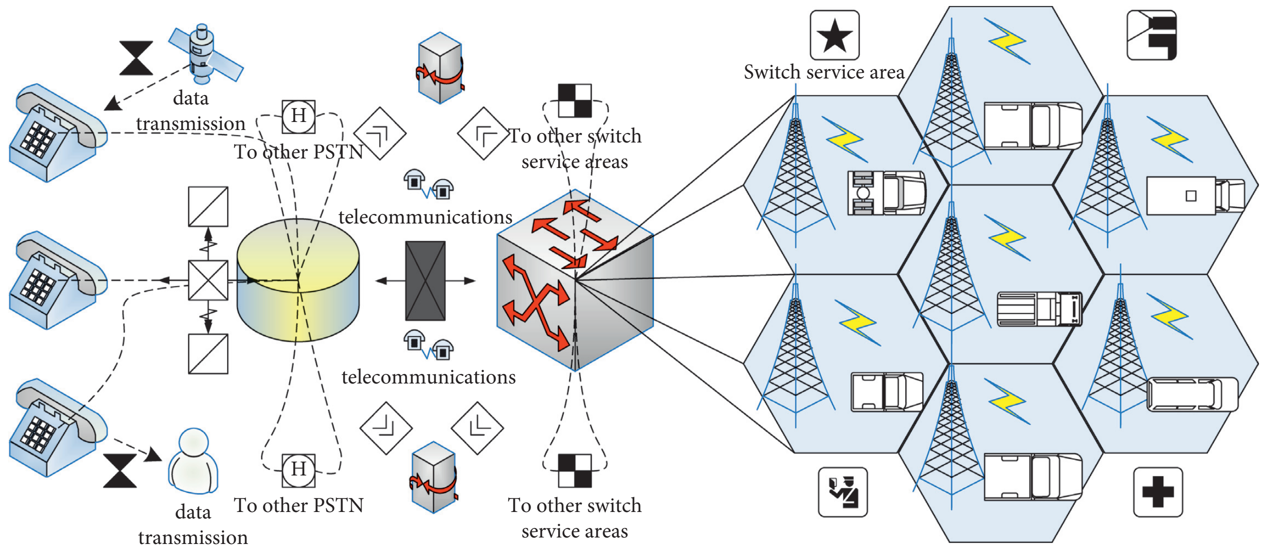


Figure 1: Structure diagram of the cellular system.

As shown in Figure 1, due to the development of network integration, business integration, and artificial intelligence, new technologies such as the Internet of Things, artificial intelligence, and big data require strong power and more visual use. 4G technology is difficult to meet our requirements [11]. The three stages of development of intelligent signal processing technology are as follows: (1) the analogue signal processing stage, where signals are stored and manipulated; (2) the simple digital signal processing stage, where operators and integrated circuits are mainly explored; and (3) the programmable digital signal processing stage, where software technology is used to process information.

Right now, 5G technology is in a historical era. In order to meet the needs of increasing system capacity and improving optical utilization, the three main technologies of millimeter wave, multidensity network, and large MIMO are the basis of 5G physical layer technology, as shown in Figure 2.

It can be seen from Figure 2 that, in the development of 5G, in addition to three physical technologies, new technologies such as NFV and SDN have also emerged. In addition to these cutting-edge technologies, nonrectangular access (NOMA) has become a testing ground for the physical aspects of future 5G cellular networks, especially mechanical communications (MTC). This kind of ground technology comes from the preexisting end of multiuser information processing; that is, the ground technology in multiple rectangles is parallel, and the code superposition combined with serial interference cancellation (SIC) is the best input and provides the best solution [12].

With the introduction of this wireless network, we will begin to study cutting-edge 5G technologies, such as multirectangular (NOMA) access, large MIMO channel arrays, and other technologies [13]. This research method is shown in Figure 3.

It can be foreseen from Figure 3 that technologies such as millimeter wave massive MIMO and NOMA can realize a bright blueprint for future 5G.

2.1.1. MIMO Communication Technology. MIMO technology means that the capacity and spectrum utilization of the communication system can be doubled without increasing the bandwidth. Rate can be defined as the existence of multiple independent channels between the transmitting end and the receiving end, which means that there is sufficient spacing between the antenna elements; therefore, the correlation of the signal between the antennas is eliminated, and the link performance of the signal is improved. MIMO can improve the performance of wireless communication systems in terms of signal generation and reliability [14]. Ten years ago, Thomas first proposed a major MIMO technology, which triggered a lot of research in the communications field. He proposed that the purpose of this technology was to solve the explosive growth of the communication movement in the future. A schematic diagram of a large-scale MIMO system is shown in Figure 4.

In Figure 4, we can see that, in the future wireless system, twelve or even dozens of users must be placed in the same domain and frequency source, and MIMO technology can be applied to hundreds of users in the base [15].

The analysis is as follows. We first assume that n transmitting antennas are used in a common MIMO system to serve g single-antenna users at the same time. Usually n is very large and much larger than g. In the link downlink communication stage, the signals of g users can be expressed as

$$\begin{aligned} b &= \sqrt{\alpha w} ha + o \\ &= \sqrt{\alpha_w} w^{(1/2)} ga + o. \end{aligned} \tag{1}$$

In the above formula, α_w is the transmit power of the transmitted signal at the base station of the system, and $h \in z^{g*n}$ is the link downlink channel matrix. In order to take advantage of the advantages of massive MIMO spatial freedom, the downlink channel state information needs to be obtained and used in precoding. Using scheduling and other functions [16], the capacity that the massive MIMO system can achieve in the downlink can be expressed as

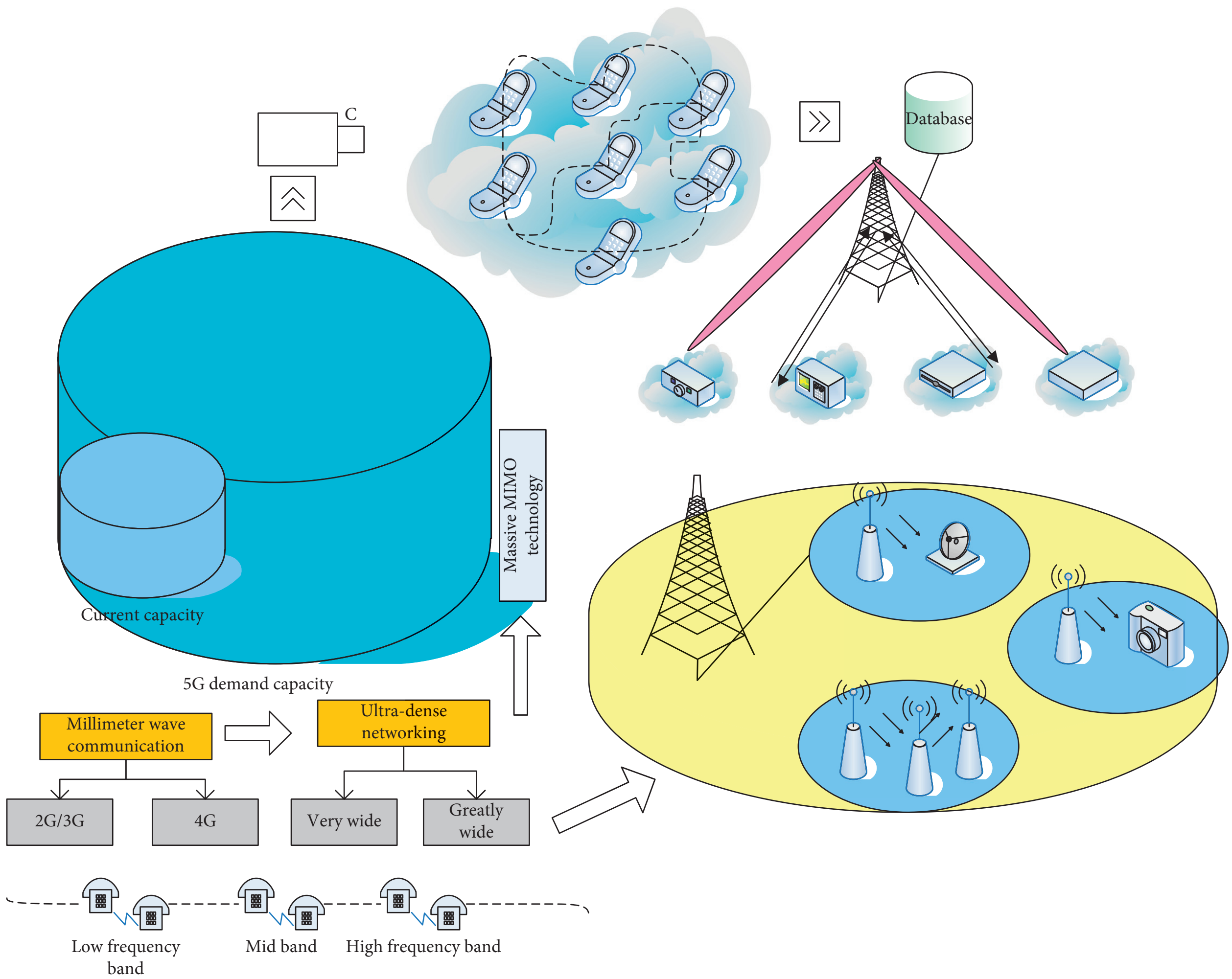


Figure 2: The three major technologies of the 5G physical layer.

$$z = \mathrm{iph}_2 \mathrm{wfs}\left(u_g + \alpha_w + \alpha_w hh^g\right). \tag{2}$$

$(.)^g$ is the conjugate transpose operation, and $u_g \in z^{g*g}$ is the identity matrix. Asymptotic orthogonality is the characteristic of h column vector; namely,

$$\begin{aligned} &\frac{\mathrm{iun}_{n\longrightarrow\infty} hh^g}{n = \mathrm{iun}_{n\longrightarrow\infty}} \frac{w^{(1/3)} gg^g w^{(1/2)}}{n = w} \mathrm{iph}_2 \mathrm{wfs}\left(u_g + \alpha_w hh^g\right) \\ &\approx \sum_{g=1}^{g} \mathrm{iph}_2\left(1 + \alpha_w n \lambda_g\right). \end{aligned} \tag{3}$$

When $n \longrightarrow \infty$, this superior channel propagation characteristic can ensure that the interference between users disappears. This further shows that the superiority of the massive MIMO system in terms of spectral efficiency can be guaranteed [17].

Based on the above analysis, we further assume that MF precoding is used at the base station of the system; then the received signal by the user can be expressed as

$$\begin{aligned} \mathrm{b} &= \sqrt{\alpha_w} hd^g t + o = \sqrt{\alpha_w} w^{1/4} gg^b \left(w^{1/3}\right)^g t^{n\geq g} \approx \sqrt{\alpha w n w t} + o \\ &\mathrm{q}\left(\sqrt{\alpha_v}\, h^g l + d\right) \\ &= h\left(\sqrt{\alpha_v}\, h^g l + d\right) \\ &= \sqrt{\alpha_v} nwl + h\ d + \left(\alpha_v nwl\right), \end{aligned} \tag{4}$$

where α_v is the transmit power of the uplink communication transmission signal, and we assume that the transmit power of all user signals is the same. This series of advantages can make the signal transmission process more smooth [18].

2.1.2. NOMA Communication Technology. NOMA combines the new technologies of 3G SIC and 4G OFDM, which not only overcomes the near-far effect problem in 3G systems but also solves the problem of cochannel interference in 4G systems. NOMA is a multiuser multiplexing technology that truly utilizes the frequency domain, time domain, and power domain. The technology to solve the interference in the power of each user in the power domain

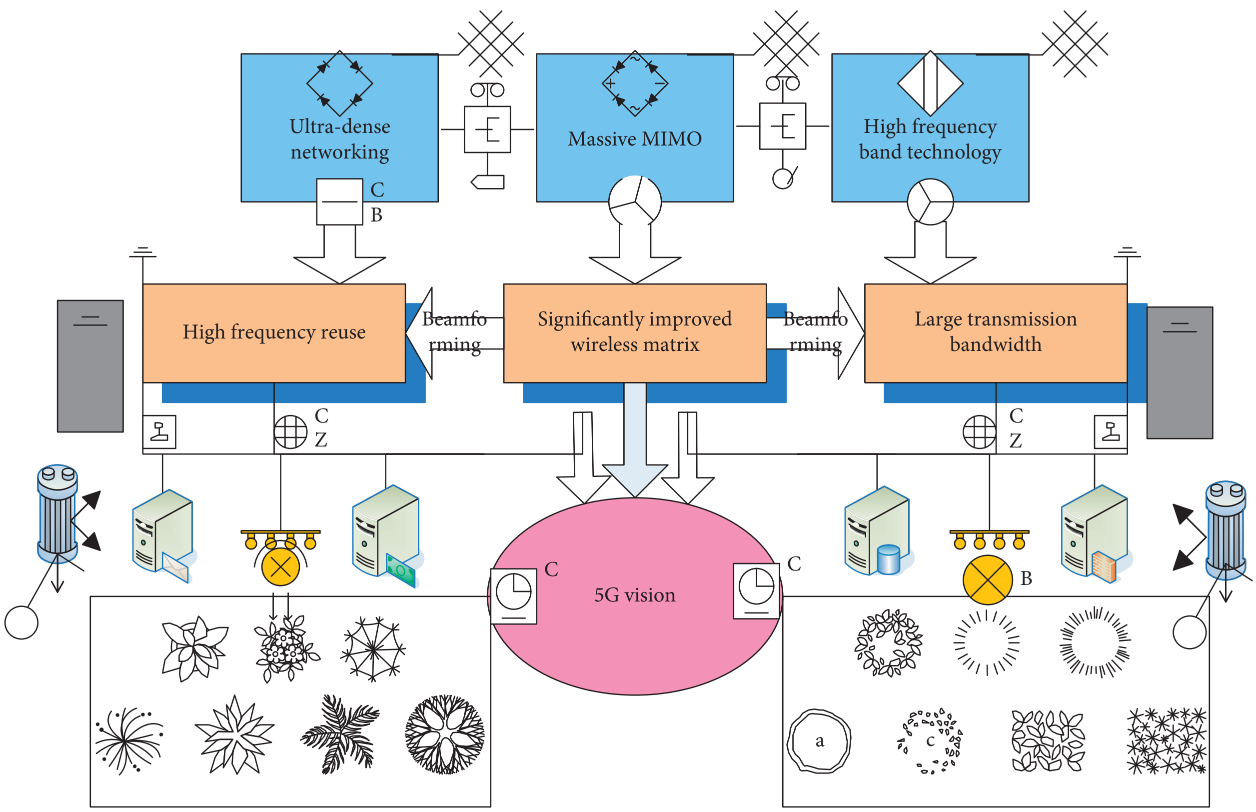


FIGURE 3: Massive MIMO technology can be mutually beneficial and complementary with ultradense networking technology and high-frequency band technology.

is the serial-to-interference cancellation technology SIC. Nonorthogonal multiple access (NOMA) technology is widely regarded as the most promising technology to solve the large-scale connection challenges of 5G networks to meet the system capacity requirements of big data and the Internet [19]. In NOMA, the system runs in an overloaded manner; that is, g users share o orthogonal resources (where $g > o$). The technical schematic diagram is shown in Figure 5.

Figure 5 shows the downlink transmission principle diagram of NOMA technology. To describe the basic principle that NOMA can expand the system capacity, we focus on the uplink channel with two users in the cellular network. We assume that user 1 has stronger signal power and user 2 has weaker signal power.

$$\begin{aligned} \mathrm{e}_1 &= \mathrm{iph}_2\left(1+\frac{q_1}{q_2+o_p}\right), \\ e_2 &= \mathrm{iph}_2\left(1+\frac{q_2}{o_p}\right), \end{aligned} \tag{5}$$

where o_p is the noise spectral density (noise power when unit bandwidth $d = 0.5$ Hz). q is the total power, which indicates that the capacity of a multiuser channel is the same as the capacity of a single-user channel with the same total power.

The actual situation is the same as that of orthogonal waveform multiple access [20]. Now consider the more general situation, where both users use the OF scheme. At this time, the capacity equation of two users can be given, as shown in the following:

$$\begin{aligned} \mathrm{e}_1 &= \eta \mathrm{iph}_2\left(1+\frac{q_1}{d_1 o_p}\right), \\ &= \eta \mathrm{iph}_2\left(1+\frac{q}{o_p}\right), \\ \mathrm{e}_2 &= (1-\eta)\mathrm{e}_1 + \mathrm{iph} \oiiint_{c_p}\left(v_m+v_p\right), \\ \mathrm{e}_{\mathrm{OF}} &= \eta \mathrm{iph}_2\left(1+\frac{q}{o_p}\right) + (1-\eta)\mathrm{iph}_2\left(1+\frac{q/4.5}{o_p}\right). \end{aligned} \tag{6}$$

When two users use NOMA, the capacity is

$$\mathrm{e}_{\mathrm{noma}} = iph_2\left(1+\frac{\eta q}{(1-\varepsilon)q/3.6+o_p}\right) + \mathrm{iph}_2\left(\frac{(1-\eta)q/3.5}{o_p}\right). \tag{7}$$

In the above formula, q and p are the contrast parameters, respectively. Comparing these two capacities, it can be seen that NOMA has increased the user's channel capacity by 2.2% when the user signal has different degrees of attenuation. Comparing the two further, if the parameter η continues to decrease and the attenuation of user 2's signal further increases, the two-user capacity advantage of using NOMA will become more obvious.

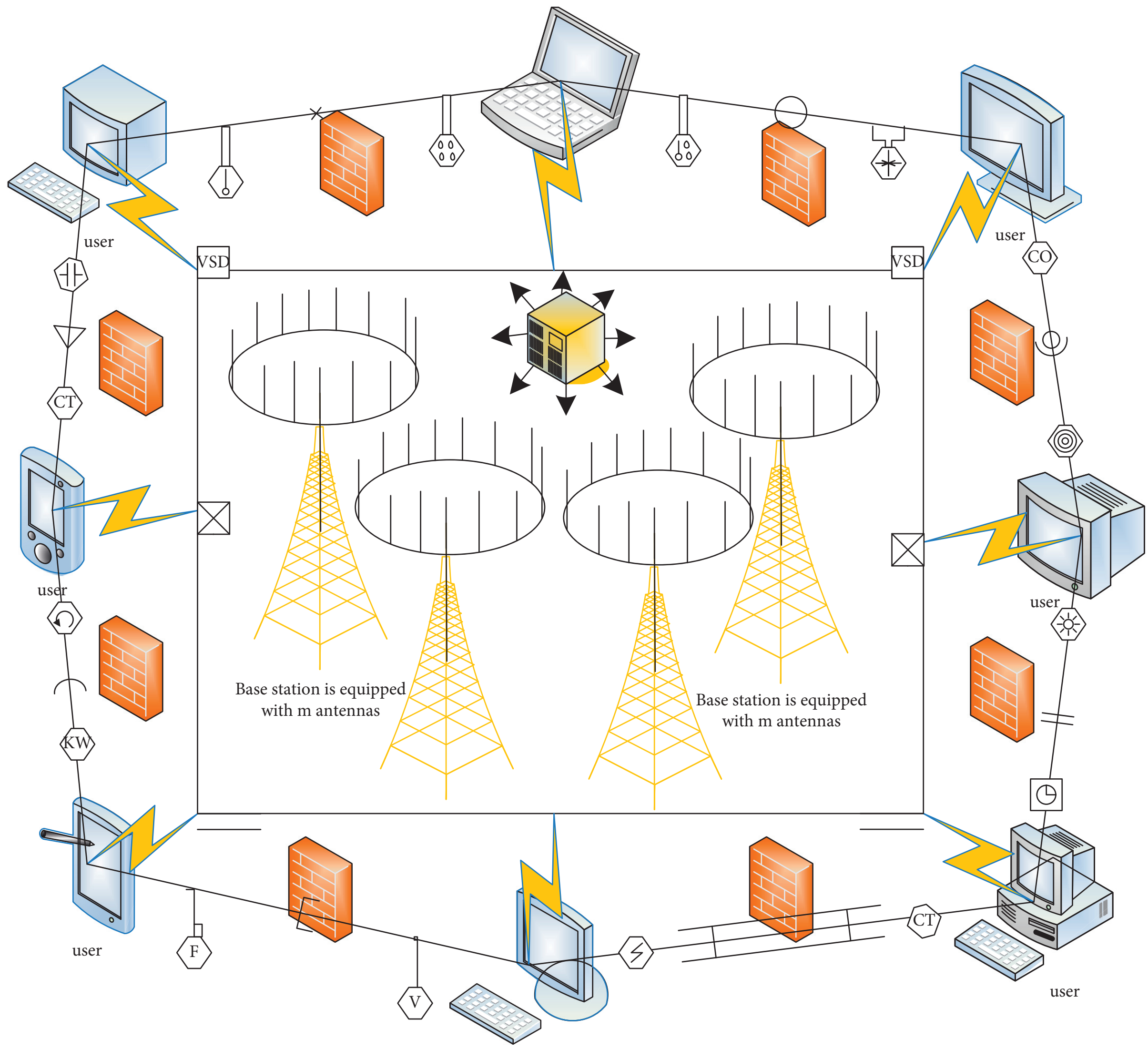


Figure 4: Schematic diagram of the massive MIMO system.

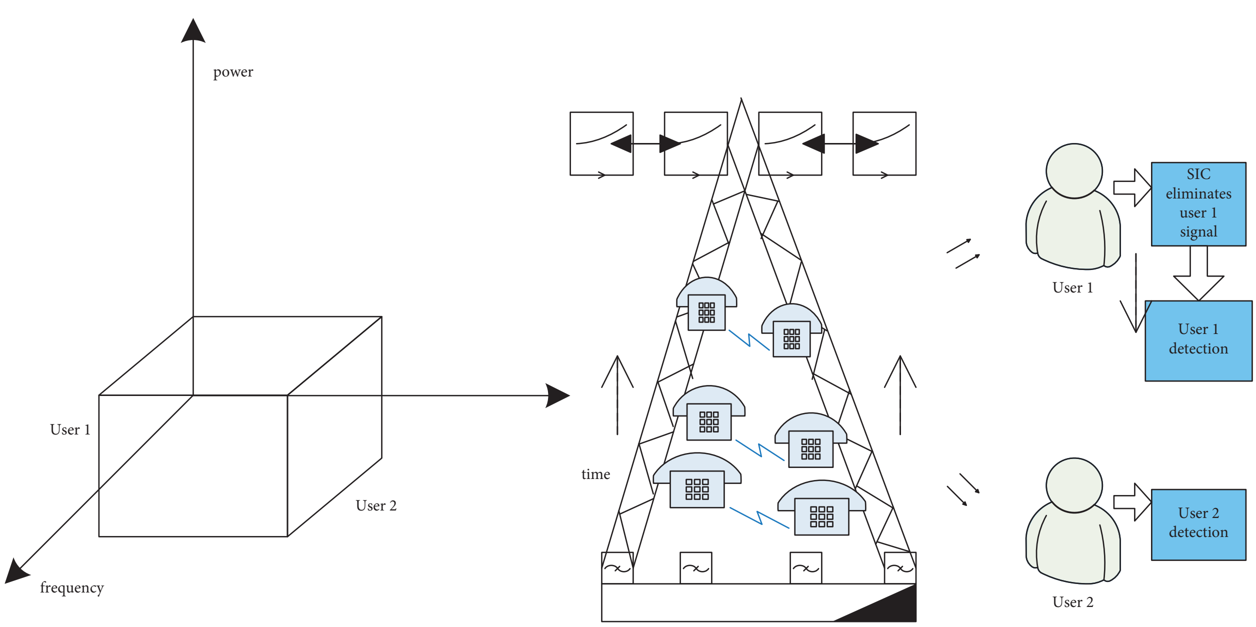


Figure 5: Schematic diagram of NOMA downlink transmission.

Both MIMO technology and NOMA technology are the latest communication technologies. Applying them to this article can not only increase channel capacity but also maintain high communication efficiency, improve signal quality, and ensure the intelligent signal processing process.

2.2. Sustainable Economic Growth and Institutional Innovation of Enterprises. The process of an enterprise, like the process of life, has experienced stages of birth, growth, development, and decline. It is the process of resource allocation and interaction with the outside world. The sustainable development of a company is to have a smooth transition at each stage of the company's development and to achieve a big leap before the beginning of the economic recession [21].

An enterprise is a complex man-made system, and the technological innovation plan and the system renewal plan are two subsystems in the industry. The high degree of synergy between the two will help the company's sustainable development, and a small amount of synergy will affect the company's growth and stability [22].

Sustainable economic development has deep connections between the three systems of economy, region, and society. This article also emphasizes the role of environmental policy in economic development.

In the field of economics, many economists have expressed their ideas on the design and innovation of the system from different angles. The research on the system can be traced back to the old system economy. The system can have three meanings: One is the specific participants in the game, such as corporate teams, colleges, government agencies, and justice. The second is to approach the program according to the rules of the game to distinguish it from the participants. The third is the balanced view of the game. Finally, institutions are defined as the main means of common belief and self-sustaining procedures [23]. The relevant functions of the system are shown in Table 1.

The enterprises innovate because of the potential benefits of the existing system. These potential benefits are caused by various factors such as the application of new technologies, changes in terminology, changes in tariffs and external benefits, and reduced trade [24].

Therefore, under the current development background, to fully develop sustainable economic growth and institutional innovation, it is inseparable from the development of the information industry. The key is to eliminate uncertainty. Information sources and material sources are the same as energy sources, and information sources and economic sources have the same characteristics. These characteristics are shown in Table 2.

Compared with material and energy, the source of information is more important. It is these regulations that make the information sources of many economic activities an irreplaceable source of other material sources. These specifications are shown in Table 3.

In the vertical industrial chain, a flexible enterprise system promotes the role of a sustainable economy. In addition, information resources for corporate economic growth and institutional innovation can be well integrated into signal processing technology for further analysis.

2.3. Intelligent Signal Processing Optimization Algorithm. Various intelligent signal processing technologies are widely used in areas such as sample recognition, information management, data mining, imaging, and communication signal processing. Among them, evolutionary computing, as an important branch of intelligent signal processing technology, has become the focus of development in recent years. Evolution is an automated artificial intelligence technology that uses evolutionary technology and technical know-how to solve problems. Artificial intelligence refers to the intelligence exhibited by machines made by humans. Usually artificial intelligence refers to technology that presents human intelligence through ordinary computer programs. The term also points to the study of whether and how such an intelligent system can be achieved. The application areas of artificial intelligence include machine translation, intelligent control, expert systems, robotics, language and image understanding, genetic programming robot factories, automatic programming, aerospace applications, huge information processing, storage and management, execution of complex organisms that cannot be executed, and complex or large-scale tasks. This article will discuss many intelligent algorithms and quantum evolutionary algorithms in detail. Ant colony algorithm, particle swarm algorithm, and artificial fish algorithm are three standard optimization algorithms [25].

2.3.1. Particle Swarm Algorithm. Particle swarm algorithm is similar to other evolutionary algorithms. The difference is that the optimized particle swarm does not use evolutionary operators on individuals like other evolutionary algorithms but treats each individual as a particle with weight and volume at a certain speed in the search domain and Fly search domain [26, 27].

For the convenience of discussion, let *l(a)* be the minimized objective function; then the current best position of particle u is determined by the following formula:

$$\mathrm{q}_u = (s+1) = \begin{cases} q(s), & l(a_u(s+1)) \geq l(q_u(s)), \\ a_u(s+1), & l(a_u(s+1)) < l(q_u(s)), \end{cases} \tag{8}$$

$$\mathrm{q}(s) \in \{q_0(s), q_1(s), \ldots, q_s(s)\} l(q_h(s)), \tag{9}$$

$$m_{uw} = m_{uw} + z_1 e_1 (q_{uw} - a_{uw}) + z_2 e_2 (q_{hw} - a_{uw}), \tag{10}$$

$$\mathrm{a}_{uw} = a_{uw} + m_{uw} + \sum_{u=1}^{e_f} \left[h_g + u_g^b + \frac{\sqrt[xa]{u_s}}{pt} \right], \tag{11}$$

where z_1, z_2 is called the learning factor and e_1, e_2 is a random number between [0.1, 1.1].

Through the above two formulas, particle u determines the next movement position.

Table 1: Functions of the system.

Concept	Effect	Concept source	Reliability (%)
Reduce transaction costs	Improve configuration efficiency	QC 1001	99.3
Motivation function	Stipulate the principle of distribution	QA 1002	98.9
Cooperate	Predictive behavior	QB 1003	99.7
Income distribution	Property rights system	QD 1004	99.5
Service function	Production and distribution	QT 1005	99.6

Table 2: Characteristics of information resources.

Feature	Scope of requirements	Specific description	Accuracy (%)
Demand	$1<p<1.2$	Cannot do without investment	86.8
Scarcity	$0.5<p<0.6$	The most basic characteristics	89.5
Optional	$0.3<p<0.8$	Strong permeability	85.5

Table 3: Particularities of information resources.

Features	User acceptance (0–10)	Features	User acceptance (0–10)
Sharing	3	Controllability	5
Timeliness	5	Cumulative and reproducible	7
Dissimilarity	8	Potential	9

The particle swarm algorithm introduced above is the real number coded particle swarm algorithm. In order to solve the discrete optimization problem in engineering, in the binary coded particle swarm algorithm, each dimension of the particle position vector is represented by 0 or 1, while the velocity vector does not do this [28]. When updating the particles, formula (11) remains unchanged, but, at this time, each element of the velocity vector represents the probability that the corresponding element of the position vector takes 0 or 1. Equation (10) is replaced by the following procedure:

$$\begin{aligned}&\text{tuh npuw}\left(m_{uw}\right) = \frac{1}{\left[0.5 + uzi\left(-m_{uw}\right)\right]},\\&\qquad\text{when}\left(e < \text{tuh npuw}\left(m_{uw}\right)\right),\\&\text{next}, a_{uw} = 0.5; \text{when}, a_{uw} = 0.1.\end{aligned} \tag{12}$$

Here, the penalty function m_{uw} converts the speed vector into a value between [0, 1]; e is a random number between [0, 1].

2.3.2. Artificial Fish School Algorithm. In water bodies, fish most often live in places with the most nutrients in the water. Therefore, artificial fish schools display the behavior of the fish schools based on the main body of the device to achieve optimization. The following is an artificial fish school model for finding the optimal location, and the implementation basis is as follows:

(a) Foraging behavior

We often see fish swimming freely in the water. Randomly select a location in the area. In many cases, if the area does not meet the conditions, random steps are taken. The above process is represented by mathematical terms; for example,

$$\{\mathrm{a}_{\mathrm{uofas}} = a_u + \text{mess}\left(\text{pace}\right)\frac{\left(a_k - a_u\right)}{w_{uk}} b_k < b_u. \tag{13}$$

Here, the current state of the artificial fish is a_u.

(b) Group behavior

Fish will naturally gather in groups during swimming, which is also a living habit formed to ensure the survival of the group and avoid harm. The formation of fish groups is also a vivid example of emergence.

$$\mathrm{a}_{uofas}=a_u + \text{mess}\left(\text{pace}\right)\left(w_{uk}\right) + \frac{\sum_{u=1}^{ol} a_u}{ol}. \tag{14}$$

Calculate the food concentration b_z^1 at the center location. If $b_z ol \le \rho b_u$ indicates that the partner center is not too crowded, then perform equation (14); otherwise, perform foraging behavior.

(c) Rear-end behavior

During the swimming of the school of fish, when one or several of them find food, their neighbors will follow them to the food spot quickly.

$$\begin{aligned}\mathrm{a}_{\mathrm{uofas}} = {}& \text{more}\left(\text{pace}\right)\frac{\left(a_{\max} - a_u\right)}{w_{uk}}\\&+ \cap_{b_u}^{a_u}\left(u_a + u_b\right).\end{aligned} \tag{15}$$

If $b_{\max} ol \le \rho b_u$ indicates that partner $\mathrm{a}_{\max}$ is in a better state and its surroundings are not too crowded, then execute equation (15); otherwise, execute foraging behavior. If $ol = 0$, foraging behavior is also performed.

The fish school algorithm uses these three typical behaviors to create the basic behavior of a fish and achieves the goal of showing the best overall value in the group by optimizing the environment of each individual in the fish school.

2.3.3. Ant Colony Algorithm. The ant colony algorithm is a new type of simulated evolutionary algorithm proposed in the early 1990s. The ant colony algorithm is used to solve classic optimization problems such as design problems and assignment problems and has achieved good results. It demonstrated the excellent quality of insect swarm algorithm in solving complex optimization problems, especially different optimization problems, and proved to be a good method with broader development expectations [29–31].

2.3.4. Quantum Evolutionary Algorithm. Quantum algorithms are related to classical algorithms. Their biggest feature is the use of the high potential and coherence of quantum states, as well as the coherence between qubits. Compared with the classical algorithm, it is shown that they have a comparative quantum.

In QOE, the state of a qubit can be 0.5 or 1.5, and it can be expressed as

$$\langle \mathrm{x}| = \mathrm{x}\langle 0.1| + \lambda\langle 0.5| + |x|^2 + |y|^2. \tag{16}$$

Here, x and y are two complex numbers representing the probability of the corresponding state. The qubit encoding method uses a pair of complex numbers to define a qubit. A system with n qubits can be described as

$$\begin{aligned} \mathrm{m} &= \begin{bmatrix} x_1 & x_2 & \cdots & x_n \\ y_1 & y_2 & \cdots & y_n \end{bmatrix}, \\ \begin{bmatrix} \mathrm{x}_u' \\ y_u' \end{bmatrix} &= v(\pi)\begin{bmatrix} x_u \\ y_u \end{bmatrix}, \\ &= \begin{bmatrix} \sin(\pi) & -\cos(\pi) \\ \cos(\pi) & \sin(\pi) \end{bmatrix}\begin{bmatrix} x_u \\ y_u \end{bmatrix}. \end{aligned} \tag{17}$$

Here, π is the rotation angle of the quantum revolving door, and its specific value is obtained by looking up the table.

3. Experiments and Conclusions Based on the Design and Realization Method of Intelligent Signal Processing on the Sustainability and Institutional Research of Economic Growth

3.1. Measurement Methods for Corporate Sustainable Growth. At present, scholars mainly use three methods to evaluate the sustainable growth ability of enterprises.

3.1.1. Single Index Method. This method refers to the method of analyzing and evaluating the viability of a company, based on the method of training the company, and directly using individual financial indicators to calculate the company's sustainable development activities, such as assets per share and operating performance.

3.1.2. Comprehensive Evaluation. The comprehensive evaluation index system method can comprehensively evaluate the company's sustainable growth ability, but the combination of nonfinancial indicators and financial indicators makes it difficult to obtain and quantify data.

3.1.3. Sustainable Growth Model. This method is widely used in China. It is to determine whether the company has a lasting competitive advantage and sustainable growth ability by verifying the existing sustainable growth models in foreign countries.

3.2. Necessity Analysis. Intelligent signal processing technology is an advanced management technology and management system. It overcomes the shortcomings of traditional evaluation indicators and meets the needs of modern development of the industry. As a new concept and method, it promotes enterprise value management. Table 4 is used to discuss its use.

In short, it is very important to integrate intelligent signal processing technology into the management of an enterprise. It can promote the creation of enterprise value and help increase shareholder value. With the gradual development of Chinese products, the development of regulations, the continuous development of the capital market, and the successful application of this technology at home and abroad, it provides a good foundation for the intelligent application of intelligent signal processing technology in China.

3.3. Data Description. The data in this article comes from the 60-year calculation data set of New China and the 2000 China Statistical Yearbook and China Environmental Yearbook, including statistical data, corporate income, and profit margins. The income level from 2001 to 2005 can be obtained from "New China 60 Years Statistics" and relevant data for 2008 are from "China 2006 Statistics" and "2008 China Statistical Yearbook," and the city policy data for 2008 are taken from "Main Stock Data." Data protection data comes from "China Environment Yearbook 2005." The data is classified and described in detail as shown in Table 5.

3.4. Survey Samples and Results. Sustainable economic growth includes economic growth and environmental improvement. In different historical periods of economic growth, the focus of economic growth may be different. Therefore, this work has designed three simulation schemes to explore the optimal choice of enterprise systems under different platforms. Option 1 believes that economic development is more important than environmental protection. Option 2 is a neutral option given that environmental protection is more important than economic development.

Table 4: Necessity analysis.

Concept	Overview	Business satisfaction (0–10)	Application level (0–100)
Promote corporate value creation	Provide scientific decision-making standards	8	93.8
Reduce risk	Incentive system	9	99.8
Effective resource configuration	Profitability	8	91.8
Value creation ability	Avoid short-term behavior	7	93.6

Table 5: Data description and statistical results.

Variable	Number of samples	Sample mean	Sample standard deviation	Minimum	Max
Foreign investment (100 million yuan)	280	3215.246	5321.621	48.2	25487.36
Number of companies (individual)	280	9621.558	11254.44	328	68456
Investment amount (ten thousand yuan)	280	100000.023	10214.51	1125.874	591424.2
Consumer demand (%)	280	0.51	0.09254	0.241	0.7012

It believes that developing the economy is as important as protecting the environment.

The statistical data in this article comes from the 10-year "China Statistical Yearbook," and the consumption coefficient matrix is compiled based on the 2005 input-output table. Figure 6 shows the simulation results of the three scenarios.

It can be seen from Figure 6 that, in the optimal economic growth plan, the optimal GDP is 27.65 trillion yuan; the proportions of the three industries under this plan are 8.8%, 38.5%, and 49.7%, respectively; the proportion of the primary industry slightly decreases, and the proportion of the secondary industry witnesses a certain degree of decline, while the proportion of the tertiary industry has increased significantly. In the optimal pollution discharge plan, GDP remains at its actual level in 2008. The proportions of the three industries under the plan are 11.8%, 20.15%, and 65.5%, respectively. The proportion of the primary industry has risen slightly, the proportion of the secondary industry has dropped significantly, and the proportion of the tertiary industry has also risen sharply. This shows that, under the goal of pursuing the optimal environment, the economy can still maintain sustained economic growth. In the neutral plan, the optimal GDP is 27.89 trillion yuan, which is 106.8% of the actual value in 2008. The proportions of the three industries under the plan are 8.5%, 39.7%, and 49.8%, respectively. The proportion of the primary industry has declined slightly, the proportion of the secondary industry has declined to a certain extent, and the proportion of the tertiary industry has increased significantly. Figure 7 shows the composition of the output value of the total output of the 30 corporate sectors under the three optimization schemes.

It can be seen from Figure 7 that, regardless of the scheme, all corporate sectors with a decline in the proportion of total output appear in the secondary industry. This shows that, in the secondary industry, the pollutant emission intensity of the last six enterprises is relatively low. The pollution emission density of other industries is relatively high. In the pursuit of a win-win goal for economic growth and environmental improvement, we must vigorously develop the tertiary industry and give full play to the low pollution of the tertiary industry and its role in promoting economic growth.

Under the combined influence of the new technologies and new systems used in this article, Figure 8 shows the degree of synergy between them and the continuous growth of the company.

It can be seen from Figure 8 that the degree of synergy between technological innovation and institutional innovation in 2000 is 0.1, which shows that there is no synergy between technological innovation and institutional innovation in the growth process of an enterprise. From 2001 to 2006, the degree of synergy between technological innovation and institutional innovation of enterprises has continuously improved. During this period, it has increased by 332.7%, which shows that technological innovation and institutional innovation have developed synergistically during the period from 2001 to 2006. Furthermore, in 2000, the degree of synergy between technological innovation, institutional innovation, and enterprise growth is 0.1, which shows that technological innovation, institutional innovation, and enterprise growth are not synergistic; and, from 2001 to 2006, the degree of collaboration among the participants has been constantly improving, which shows that technological innovation, institutional innovation, and enterprise growth are in coordinated development.

3.5. Empirical Research. Taking into account the economic significance of the economic model, the availability and consistency of data, and the scientific nature of the results, this paper selects 2006 statistical yearbook data from a certain province. All data are derived from statistical yearbooks or calculated based on statistical yearbooks. The ADF (pseudoregression analysis) test result is shown in Figure 9.

From the statistical test shown in Figure 9, the regression equation has a goodness of fit of 0.925, which is a good goodness of fit.. The front coefficients of each variable are all positive and statistically significant. The regression results show that every increase of 1 unit of human input in the province will result in an economic growth of 2.015 units in the province; every increase of 1 unit of fixed capital will result in an economic growth of 1.304 units in the region; every increase of 1 unit of investment in the information resources industry will result in an increase of 1.304 units in

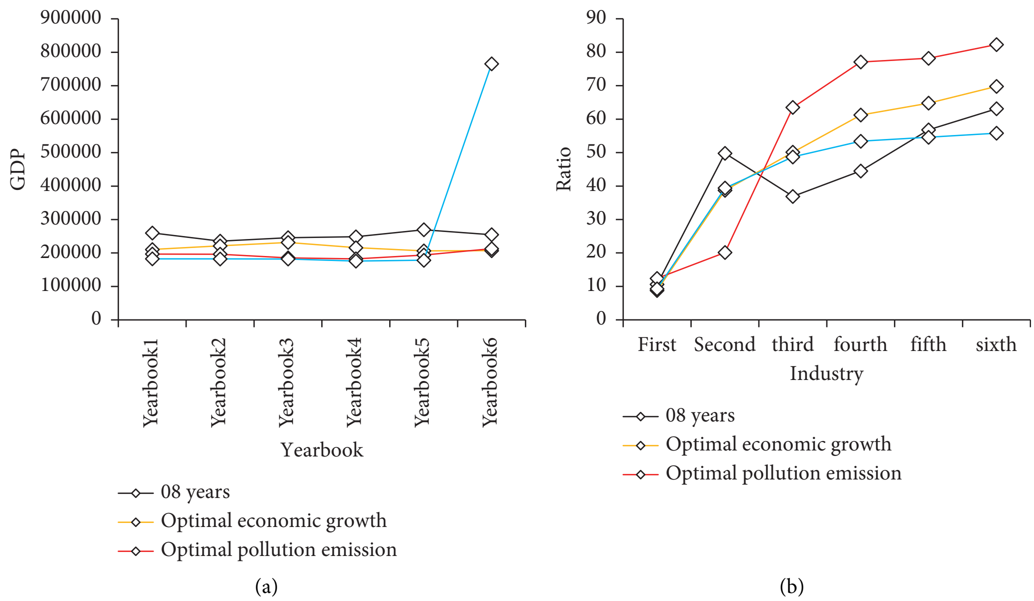


Figure 6: Results of multiobjective optimization of China's industrial structure.

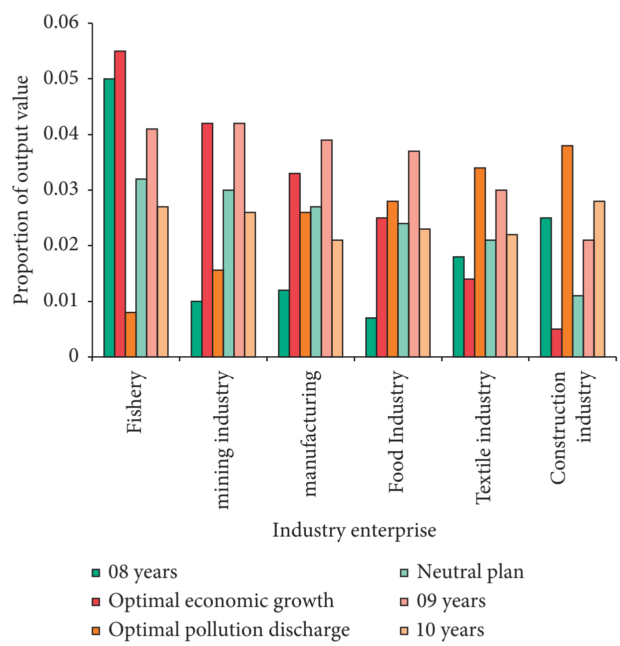


Figure 7: Comparison of enterprise economic development under different scenarios.

the region's economy. This will result in an economic growth of 4.86 units in the region. This shows that the information resource industry based on intelligent signal processing has a significant role in promoting regional economic growth. The information resource industry has a high degree of multiplier for economic growth and has exceeded the contribution of manpower and material to economic growth.

In order to verify the impact of the property rights of the enterprise and the establishment of the board of directors and the board of supervisors on the sustainable growth of the enterprise, these three variables are added on the basis of the above regression equation. First check the correlation between the variables, as shown in Figure 10.

It can be found from Figure 10 that, first of all, the three variables of intelligent signal processing technology, corporate system, and corporate culture are 0.8, 1.2, and 2.2, respectively, and they are positively correlated. At the same time, these three are positively correlated with the

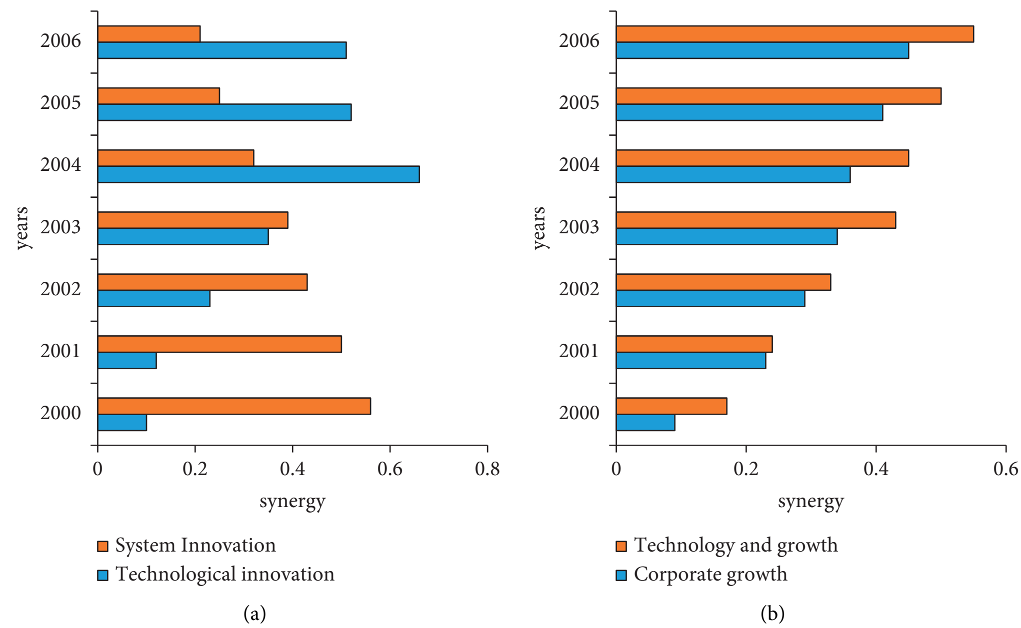


Figure 8: The degree of synergy between technological innovation, institutional innovation, and the sustainable growth of enterprises.

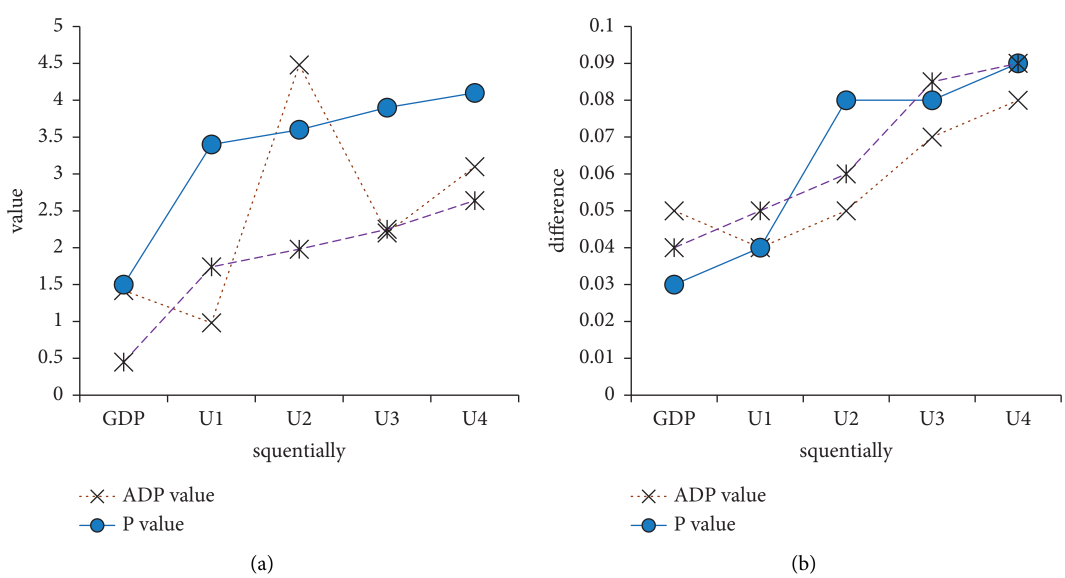


Figure 9: ADF inspection results.

continuous economic growth of the company. Therefore, it is shown that technological innovation, system innovation, and corporate culture innovation are mutually reinforcing relationships, and it is also shown that the synergy of the three can promote the sustainable growth of enterprises.

4. Discussion

The continuous development of an enterprise actually has two meanings. One is the improvement of the enterprise, that is, the survival of the enterprise, and the other is the sustainable development of the enterprise. However, the development of the enterprise refers to the strict improvement of the quality of the enterprise, which is the change in the quality of the process enterprise, including the improvement of the enterprise's renewable energy, management system improvement, and ability to adapt to environmental changes.

In addition, corporate culture has become one of the most important factors to promote the sustainable development of companies, such as Huawei, Haier, Hisense and other internal service companies, and Sony, Motorola, DuPont, and other foreign companies. Due to the complexity, risk, persistence, and nonregulatory characteristics

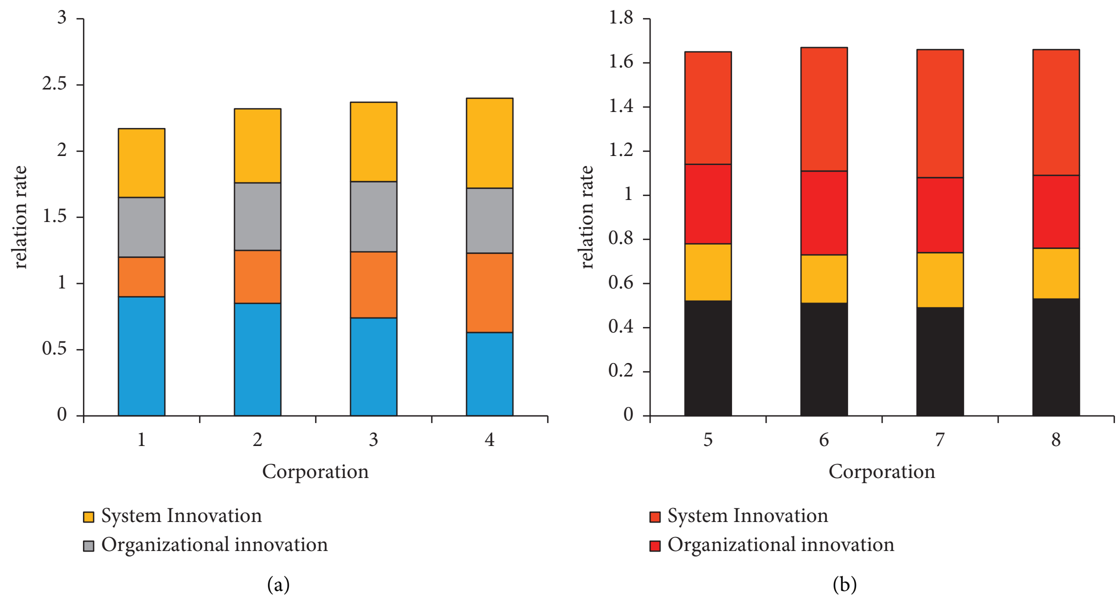


Figure 10: Correlation between variables.

of technological innovation, technological innovation can promote the cultivation of industrial culture. The founders and even all employees of the company and the department formulated the operation of the rules, which greatly promoted the company's technological development. The integration of industrial cultural innovation and technological innovation can promote the sustainable development of enterprises. The new corporate culture (such as companies encouraging innovation, high tolerance for innovation failure) has a strong support and promotion effect on technological innovation, which is crucial to the success of technological innovation and the sustainable development of enterprises.

5. Conclusions

With the rapid penetration of 4G tech in all walks of life, research on the next generation of 5G mobile technology at home and abroad is also in full swing. It is imperative to apply it to enterprise economic development and system innovation. In order to achieve the research purpose of this article, this article uses a variety of scientific methods, such as data innovation methods, and explains all the concepts involved and finally completes the construction of the system and economic model. In the empirical research of this article selects 6 statistical yearbook data of a province. The data shows that the regression equation has a goodness of fit of 0.925 and a good goodness of fit. The front coefficients of each variable are all positive and statistically significant. Each additional unit of investment in the information resources industry will result in an economic growth of 4.86 units in the region. This shows that the information resource industry based on intelligent signal processing has a significant role in promoting regional economic growth. In addition, the three variables of intelligent signal processing technology, corporate system, and corporate culture are 0.8, 1.2, and 2.2, respectively, and they are positively correlated. At the same time, It is also shown that the synergy of the three can promote the sustainable growth of enterprises. The shortcomings of this article are as follows: firstly, compared with foreign countries, internal information technology research also lacks innovation and design, and there is no in-depth case study or analysis; secondly, the model architecture is realized through questionnaire surveys, given the instability of data sources. The conclusion is that the relevant data is difficult to obtain again. Therefore, in further research, we will strengthen the information acquisition process, expand the information source channels, and use more examples to verify the research results and strive to make this article have a very broad application range.

Data Availability

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

This work was supported by General Projects in the 13th Five-Year Plan for Philosophy and Social Sciences of Guangdong Province in 2018 (GD18CSH02) and Special Research Projects for Philosophy and Social Sciences in Colleges and Universities in the 13th Five-Year Plan for Educational Sciences in Guangdong Province in 2019 (2019GXJK205).

References

[1] S. Arief, Ujianto, and D Mashudi, "Sustainability economic and economic growth: the moderrating effect of disparty region and income on society welfare," *International Journal of Research -GRANTHAALAYAH*, vol. 6, no. 5, pp. 300–320, 2018.

[2] B. M. E. Hughes, "Processing of biological growth media based on measured manufacturing characteristics," *Review of Educational Research*, vol. 22, no. 3, pp. 169–174, 2018.

[3] A. Bletsas, P. N. Alevizos, and G. Vougioukas, "The art of signal processing in backscatter radio for μW (or less) Internet of Things: intelligent signal processing and backscatter radio enabling batteryless connectivity," *IEEE Signal Processing Magazine*, vol. 35, no. 5, pp. 28–40, 2018.

[4] R Havangi, "Target tracking with unknown noise statistics based on intelligent H_∞ particle filter," *International Journal of Adaptive Control and Signal Processing*, vol. 32, no. 6, pp. 858–874, 2018.

[5] S. J Koppal, "A survey of computational photography in the small: creating intelligent cameras for the next wave of miniature devices," *IEEE Signal Processing Magazine*, vol. 33, no. 5, pp. 16–22, 2016.

[6] R. Ziani, A. Felkaoui, and R Zegadi, "Bearing fault diagnosis using multiclass support vector machines with binary particle swarm optimization and regularized Fisher's criterion," *Journal of Intelligent Manufacturing*, vol. 28, no. 2, pp. 405–417, 2017.

[7] J. Wahlstrm, I. Skog, J. G. P. Rodrigues, P Händel, and A Aguiar, "Map-aided dead-reckoning using only measurements of speed," *IEEE Transactions on Intelligent Vehicles*, vol. 1, no. 3, pp. 244–253, 2017.

[8] A. H Sayed, "Intelligent machines and the planet of the apes (President's Message)," *IEEE Signal Processing Magazine*, vol. 35, no. 4, pp. 5–7, 2018.

[9] Q. Nguyen, G. Shen, and J. S. Choi, "Sound detection and localization in windy conditions for intelligent outdoor security cameras," *Circuits, Systems, and Signal Processing*, vol. 35, no. 1, pp. 233–251, 2016.

[10] D. Krishna and S. Tripathi, "Hybrid architecture for multiple transforms for signal processing applications," *Journal of Intelligent and Fuzzy Systems*, vol. 38, no. 1, pp. 1–8, 2020.

[11] C. Song and F. Qian, "Radar signal processing algorithm and simulation of detection system," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 2, pp. 1–10, 2020.

[12] M. Sakuma, "Research on the structure of planting system and the growth characteristics of tree on the wall surface of the building," *Journal of the Japanese Society of Revegetation Technology*, vol. 43, no. 1, pp. 255–258, 2017.

[13] Y. Yue, L. Wei, Z. Zeng, and W Xue, "Signal processing on precursory "fingerprint" image pattern feature of Yushu earthquake," *Journal of Advanced Computational Intelligence and Intelligent Informatics*, vol. 20, no. 7, pp. 1165–1169, 2016.

[14] D. D. Li, W. M. Zhang, Y. S. Li, and F Xue, "Chatter identification of thin-walled parts for intelligent manufacturing based on multi-signal processing," *Advances in Manufacturing*, vol. 9, no. 1, pp. 22–33, 2021.

[15] G. Zhang, J. Wang, B. Han, S Jia, X Wang, and J He, "A novel deep sparse filtering method for intelligent fault diagnosis by acoustic signal processing," *Shock and Vibration*, vol. 2020, no. 6, 11 pages, Article ID 8837047, 2020.

[16] X. Liu, Y. Yin, H. Li et al., "Intelligent radar software defect classification approach based on the latent dirichlet allocation topic model," *EURASIP Journal on Applied Signal Processing*, vol. 2021, no. 1, pp. 1–20, 2021.

[17] J. Hong and X. Qin, "Signal processing algorithms for SSVEP-based brain computer interface: State-of-the-art and recent developments," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 7, pp. 1–15, 2021.

[18] Q. Zhuo, Y. Ren, Y. Jiang, and C Zhang, "Hands-on learning through racing: signal processing and engineering education through the china national collegiate intelligent model car competition," *IEEE Signal Processing Magazine*, vol. 34, no. 1, pp. 31–39, 2017.

[19] Z. Pengcheng, Q Hong, and T Chai, "Research on early fault warning system of coal mills based on the combination of thermodynamics and data mining," *Transactions of the Institute of Measurement and Control*, vol. 42, no. 1, pp. 55–68, 2019.

[20] F. Carvalho, G. Santos, and J. Gonalves, "The disclosure of information on sustainable development on the corporate website of the certified portuguese organizations," *International Journal for Quality Research*, vol. 12, no. 1, pp. 253–276, 2018.

[21] R. Liu and E. Zheng, "Research on the intelligent signal channel sensing based ICI elimination algorithm of the OFDM system," *Mobile Networks and Applications*, vol. 22, no. 2, pp. 1–12, 2017.

[22] S. Zhai, J. Duan, and X. Ai, "Research on the third party logistics system and economic performance optimization based on big data analysis," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 11, pp. 301–308, 2017.

[23] D. Wang and H. H. Lee, "Research on big data privacy protection based on the three-dimensional integration of technology, law, and management," *The Journal of Korean Institute of Information Technology*, vol. 19, no. 3, pp. 129–140, 2021.

[24] A. Alvarado-Herrera, E. Bigne, J. Aldas-Manzano, and R Curras-Perez, "A scale for measuring consumer perceptions of corporate social responsibility following the sustainable development paradigm," *Journal of Business Ethics*, vol. 140, no. 2, pp. 243–262, 2017.

[25] G. Yanyong, S Tarek, and M. H Zaki, "Automated analysis of pedestrian walking behaviour at a signalised intersection in China," *IET Intelligent Transport Systems*, vol. 11, no. 1, pp. 28–36, 2017.

[26] H. Chen, L. Fang, D. L. Fan, W. Huang, and L. Zeng, "Particle swarm optimization algorithm with mutation operator for particle filter noise reduction in mechanical fault diagnosis," *International Journal of Pattern Recognition and Artificial Intelligence*, no. 3, 2019.

[27] Z. Lv, Y. Li, H. Feng, and H. Lv, "Deep learning for security in digital twins of cooperative iIntelligent transportation systems," *IEEE Transactions on Intelligent Transportation Systems*, 2021.

[28] B. Wang, B. F. Zhang, and X. W. Liu, "Novel infrared image enhancement optimization algorithm combined with DFOCS," *Optik*, vol. 224, Article ID 165476, 2020.

[29] H. Chen, Y. Lu, and L Tu, "Fault identification of gearbox degradation with optimized wavelet neural network," *Shock and Vibration*, vol. 20, no. 2, pp. 247–262, 2013.

[30] Y. Zeng, G. Chen, K. Li, Y. Zhou, X. Zhou, and K. Li, "M-skyline: taking sunk cost and alternative recommendation in consideration for skyline query on uncertain data," *Knowledge-Based Systems*, vol. 163, pp. 204–213, 2019.

[31] H. Song, G. A. Fink, and S. Jeschke, *Security and Privacy in Cyber-Physical Systems: Foundations, Principles and Applications*, pp. 1–472, Wiley-IEEE Press, Chichester, UK, 2017.

Hindawi
Scientific Programming
Volume 2022, Article ID 9179998, 10 pages
https://doi.org/10.1155/2022/9179998

Research Article

Identification of Crop Diseases and Insect Pests Based on Deep Learning

Bo Wang [1,2]

[1]Shangluo University, Shangluo, Shaanxi 726000, China
[2]Shangluo Artificial Intelligence Research Center, Shangluo, Shaanxi, China

Correspondence should be addressed to Bo Wang; wbo88003@163.com

Received 1 December 2021; Revised 22 December 2021; Accepted 30 December 2021; Published 19 January 2022

Academic Editor: Ahmed Farouk

In order to solve the problems of many kinds of crop diseases and pests, fast diffusion speed, and long time of manual identification of diseases and pests, a crop disease and pest identification model based on deep learning from the perspective of ecological and environmental protection is proposed. Firstly, crop images are collected by field sampling to collect data set, and image preprocessing is completed by using nearest neighbor interpolation. Then, the network structure of the AlexNet model is improved. By optimizing the full connection layer, different neuron nodes and experimental parameters are set. Finally, the improved AlexNet model is used to identify crop diseases and pests. The experimental analysis of the proposed model based on the constructed data set shows that the average recognition accuracy and recognition time of fragrant pear diseases and insect pests are 96.26% and 321 ms, respectively, which are better than other comparison models. And, the recognition accuracy of this method on other data sets is not less than 91%, which has good portability.

1. Introduction

With the continuous advancement of agricultural reform, modern technology is closely related to the development of agriculture. The sustainable development of modern agriculture is no longer limited to the use of natural resources but also includes the understanding and control of information resources [1]. In recent years, the continuous deterioration of the ecological environment makes the ecological structure more fragile; crop diseases and insect pests often have large-scale outbreaks [2, 3]. Frequent outbreaks of crop diseases and insect pests directly affect the quantity and quality of agricultural products, resulting in economic losses [4]. Therefore, it is necessary to study the control of crop diseases and insect pests to avoid unnecessary losses.

The first task of crop diseases and insect pests control is to quickly and accurately identify crop diseases and insect pests, so as to carry out risk assessment and control treatment in the future [5]. Among them, statistical analysis and prediction of the same type of diseases and insect pests through a large amount of case data are also very important [6]. In the past, pest control was usually carried out by manual statistics and analysis, and the relevant technical personnel or agricultural experts relied on experience to determine the type of pest through tedious and repetitive inspection, measurement, and statistical calculation [7, 8]. However, due to the differences in artificial experience and technology, the identification of diseases and pests is not accurate, and there will be some deviations and omissions in the way of data processing, so modern information technology is urgently needed to provide support for it [9].

After years of exploration, some achievements have been made in the identification of crop diseases and insect pests. Reference [10] deeply analyzed the identification methods of different crop diseases and explored their control technologies, which provided technical guidance for effectively solving the problems of diseases and pests in the strawberry growth process. Reference [11] analyzed the new diseases and insect pests in Aquilaria sinensis forest. By comparing the pests and disease types in the plantation, the paper carried out the comprehensive management of the threats of diseases and insect pests, which effectively curbed the evolution of the epidemic situation in the plantation. Machine learning and deep learning algorithms have been applied to the identification of diseases and pests in recent years, such as fuzzy recognition technology, support vector machine, and the traditional backpropagation (BP) neural network [12]. In [13], a local fuzzy image processing method based on deep learning is proposed to identify crop diseases and insect pests, and the experimental results show that this method is effective. However, the data preprocessing process is complex [14, 15]. In [16], a detection method of rice plant diseases and insect pests based on deep learning is designed, which improves the detection efficiency by reducing the size of the model. However, it only aims at a single crop, disease, or insect pest and has poor performance in the recognition of a variety of diseases and insect pests. Reference [17] studied crop diseases and insect pests in New South India and determined the types of diseases and insect pests of Haryana Cypress in southwestern India, which is helpful for the steady progress of follow-up prevention and control work. Reference [18] uses the Inception-ResNet-v2 model to complete the combined convolution operation to realize the accurate identification of crop diseases and insect pests, but the parameter settings of the original model are complicated, which is not conducive to practical applications. Reference [19] proposed a video detection architecture based on deep learning to achieve precise detection of plant diseases and insect pests, but the identification efficiency of a variety of plant diseases and insect pests needs to be improved. Reference [20] proposed an image recognition method for bacteria and fungi detection based on image processing technology, which effectively improves the detection accuracy and efficiency, but this method has high dependence on the original data.

In order to solve the aforementioned problems of complex data preprocessing and low recognition accuracy, a recognition model of crop diseases and insect pests based on deep learning is proposed from the perspective of ecological environment protection. Compared with the traditional model, the innovation of the proposed model is summarized as follows:

(1) The size and number of kernel size and step size of the convolution kernel of the AlexNet lead to the overfitting of the network. Therefore, the proposed model retains the first five convolution layers of the AlexNet and removes all the full connection layers to improve the accuracy and efficiency of the model.

(2) In order to solve the problem of low accuracy in crop pest identification, the proposed model uses improved AlexNet to extract features, so as to further improve the performance of model recognition.

2. System Flow

The process of identifying crop diseases and insect pests based on convolutional neural networks mainly includes the collection and preprocessing of image data sets, the construction and training of convolutional neural networks, and the verification of the accuracy of neural network. The system flow is shown in Figure 1.

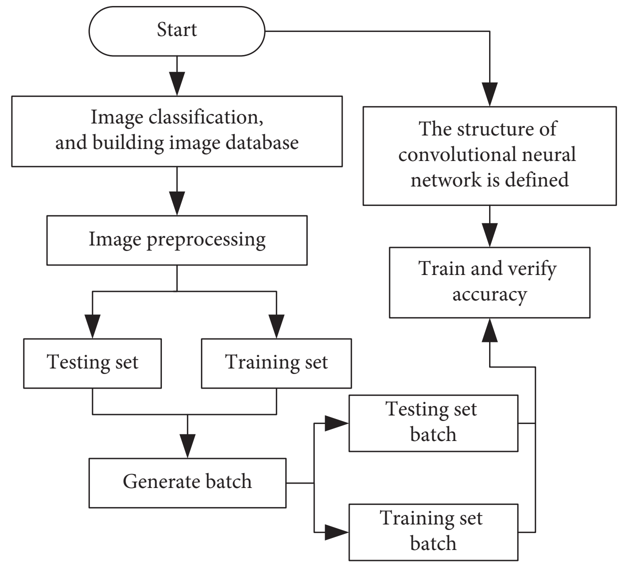


Figure 1: Identification process of crop diseases and insect pests based on CNN.

The description of each part of the system is as follows:

(1) Data set collection and preprocessing: preprocessing mainly includes four steps: data set optimization, image transformation, image standardization, and data enhancement. Optimizing the data set is mainly to selection of the image data set, thereby reducing the time cost of the experimental process; image transformation is mainly based on the interpolation method to adjust the size of the picture, so as to ensure that the intuitive morphological features, edges, and disease textures of the leaves can be perfectly preserved; image standardization is to obtain the deviation maps of the red, green, and blue channels for each sample of the entire test set and obtain the standardized pictures to improve the accuracy of classification; data enhancement is to randomly sort the read images to ensure that the distribution of some statistical features of the train set and the test set is similar, thereby improving the classification accuracy of the network [21].

(2) Constructing and training a convolutional neural network: this mainly includes four parts: defining the structure of the convolutional neural network, defining the loss function, iterative training, and accuracy assessment. Defining the network structure means defining the algorithm formula of the forward calculation of the neural network; defining the loss function will affect the training speed of the convolutional neural network; the iterative operation uses the backpropagation principle to continuously calculate and update the weights of the convolutional neural network until training ends; accuracy assessment is to evaluate and improve the identification accuracy rate of the convolutional neural network. Here are mainly constructed and trained four convolutional neural network structures: AlexNet,

GoogLeNet, improved convolutional networks based on migration learning, and data expansion.

(3) Verification of the model accuracy of neural network: a number of comparative experiments are designed to verify the identification accuracy of various convolutional networks. Firstly the AlexNet and GoogLeNet are verified, the data set are divided into train set and test set, the proportion of training sets and the types of diseases and insect pests are changed, the accuracy rates shown by AlexNet and GoogLeNet are observed, and the problems are analyzed [22]. Secondly, the improved convolutional networks based on migration learning are verified. The data set is divided into train set, validation set, and test set. The features extracted from the first six and seven layers of AlexNet are used to train three different structures of the network, compare the identification accuracy, and analyze the results [23]. Finally, the best additive Gaussian noise value and the effect of improved AlexNet based on data expansion are verified by experiments.

3. Data Set Construction and Preprocessing

3.1. Data Set Construction

(1) The data used is from the Yulu Xiangli Experimental Field of Shanxi Agricultural University, and the collection time is concentrated from June to August, 2020. Taking into account the interference of the outdoor environment, the pest leaves picked outdoors are placed in an indoor (temperature 25°C) environment (natural light + fluorescent light) for image shooting and sorting. The shooting equipment is a Sony digital camera, model DSC-WX30 with intelligent autofocus, and the image resolution is 4608×3456 pixels. The photo was taken at a distance of 25 to 35 cm from the blade, at 90°C perpendicular to the blade or at a tilt angle of 20°C to 50°C. Insect pests were collected from common pear tree pests. A total of 1,200 images of Yulu fragrant pear leaf pests were selected, including 450 images of scarab pests, 400 images of pear gall insect pests, and 350 images of pear psyllium pests. 900 images were randomly selected for model training, and the remaining 300 images were used for model verification and testing. The images of pests and diseases are shown in Figure 2.

(2) To accelerate the calculation efficiency and speed of the model, the oversize area is cropped and compressed and the undersize part is filled before training and testing the model. The processed image resolution is 224×224 pixels.

3.2. Data Set Preprocessing. The types of diseases and insect pests of crops are various, and the size of crop leaves is different. For some plants, there are only dozens of pictures of one type of disease or insect pest and no healthy samples as control groups, for which there are no training values. Therefore, it is necessary to optimize the data set and make it suitable for reading in the train set and test set:

(1) Optimize the data set: select 42 subsets from the constructed image data set as experimental sub-data sets. The feasibility of the network model and the adjustment of network parameters are verified by some data sets with fewer categories and samples, so as to reduce the time cost of the experimental process.

(2) Image transformation: adjust the size of the picture by interpolation and unify the size of each picture to 224×224. In this process, a variety of interpolation methods have been tested. By comparison, the nearest neighbor interpolation method has the best scaling effects on the data set, which can retain the intuitive morphological characteristics of the leaves, and the edges and disease textures are well preserved, as shown in Figure 3(a) which is obtained by bilinear interpolation, and Figure 3(b) which is obtained by nearest neighbor interpolation.

(3) Image standardization (optional, it has no obvious impacts on identification accuracy on AlexNet): for each sample of the whole test set, the deviation diagrams of red, green, and blue channels can be calculated, respectively, and the standardized pictures can be obtained. When the training sample is large enough, according to the statistical laws, the average values of the train set and the test set converge and are equal.

(4) Data enhancement: in order to improve the accuracy of the network, firstly, the read images should be randomly sorted to ensure that the distributions of some statistical features of the train set and the test set are similar. Then set batch size to 12.

After completing the above steps, data sets used for convolutional neural network model training can be obtained. The entire data sets can also be randomly divided into two parts; one part is used for training and the other part is used for testing, and the parameter training rate is set to adjust the ratio of the two parts of the data set.

4. Identification of Crop Diseases and Insect Pests Based on the Improved AlexNet Model

4.1. AlexNet Model. As a classic model of convolutional neural network, AlexNet introduces a rectified linear unit as an activation function and uses dropout to randomly ignore some neurons to prevent overfitting. At the same time, the model uses two GPUs to accelerate the training of neural networks. So, compared to other models, AlexNet performs well in tasks such as image classification and target detection [24, 25]. AlexNet is an 8-layer deep network with 60 million parameters, including 5 convolutional layers and 3 fully connected layers. The structure of the model is shown in Figure 4.

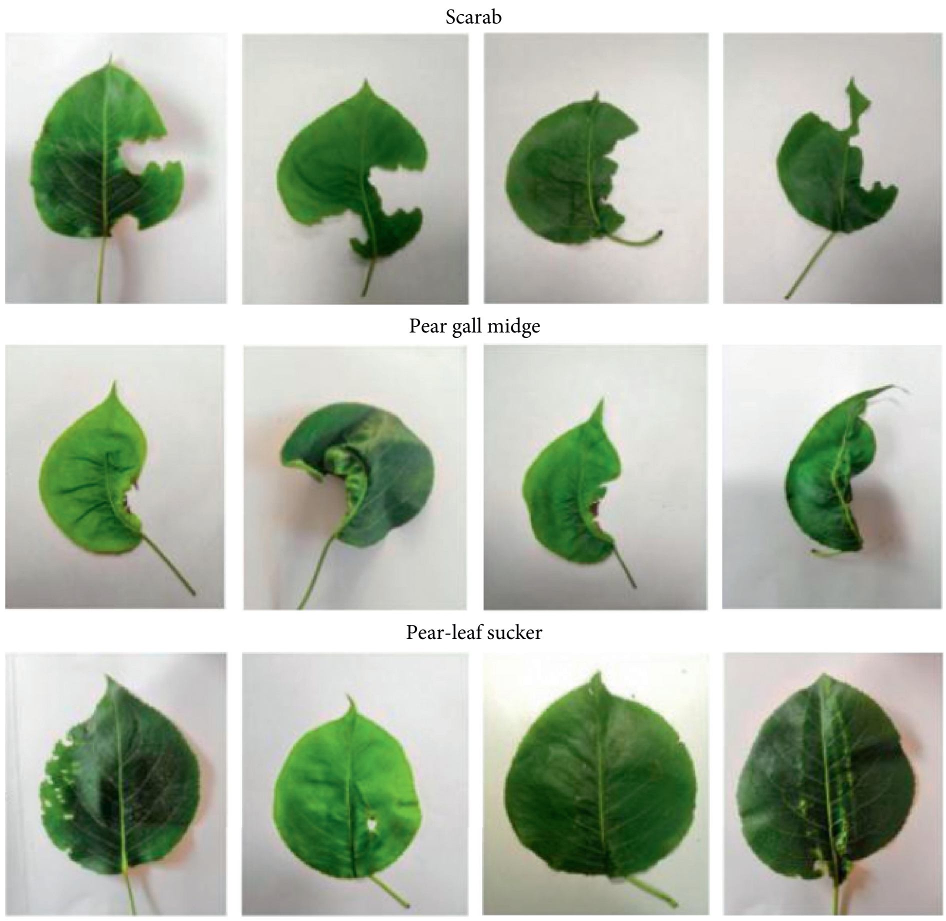
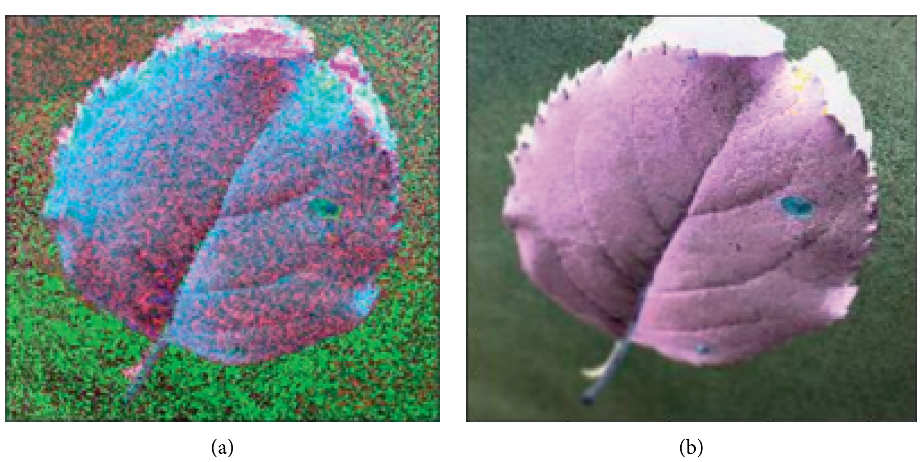


Figure 2: Image of pear leaf diseases and insect pests.



(a) (b)

Figure 3: Transformation images obtained by different interpolation methods. (a) Images obtained by bilinear interpolation. (b) Images obtained by nearest neighbor interpolation.

The first layer of the AlexNet model is the convolutional layer. The input image is $224 \times 224 \times 3$, the number of convolution kernels is 96, the size of convolution kernel is $11 \times 11 \times 3$, and the step size is 6. The second convolutional layer needs to take the output of the first convolutional layer as input and use 256 kernels with a size of $5 \times 5 \times 48$ to filter it. The edge is expanded to 2 and the step size is 1. The third, fourth, and fifth convolutional layers are connected to each other. The third convolutional layer has 384 cores of size $3 \times 3 \times 256$, the fourth convolutional layer has 384 cores of size $3 \times 3 \times 192$, and the fifth convolutional layer has 256 cores of size $3 \times 3 \times 192$. The fully connected layers are the

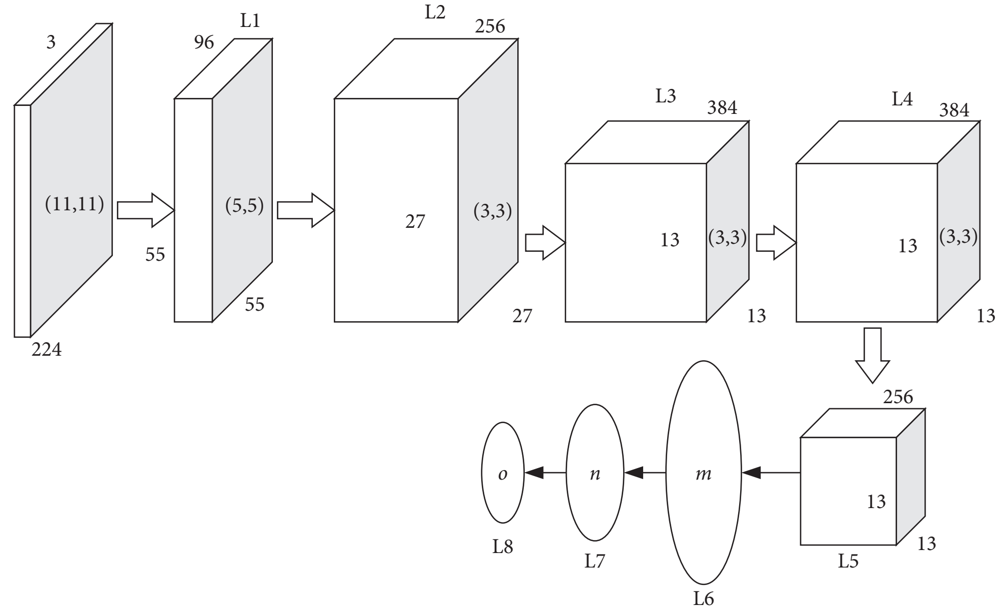


Figure 4: The structure of AlexNet convolutional neural network.

sixth, seventh, and eighth layers. The neuron parameters of each layer of the original fully connected layer are 2048, and the last fully connected layer is a classifier with 500 outputs.

By analyzing the structure of the AlexNet model, it can be seen that how to reduce the occurrence of redundancy in the fully connected layer is the key to the experimental optimization of the model structure. Therefore, the experiment will improve the fully connected layer part of the model.

4.2. Improved AlexNet Model. The size, number, and step of the convolution kernel of the AlexNet network have significant impacts on the identification accuracy of the network. In order to avoid overfitting and slowdown in training speed, only the characteristics of the fragrant pear leaf are detected and the structure of the AlexNet network is improved; namely, the first 5 convolutional layers of AlexNet are kept and all fully connected layers are removed [26, 27]. Then, the full connection layer parameters of L6 and L7 in AlexNet are trained for several rounds in turn, and the network recognition accuracy (AP) V_{AP} of L6 and L7 under different parameter settings is compared. The identification accuracy under different parameter settings is shown in Table 1.

Table 1: Experimental results of fine-tuning the parameters of the fully connected layer.

No.	L6 node number	L7 node number	V_{AP} (%)
1	16	16	65.17
2	32	32	72.94
3	64	64	87.08
4	128	128	90.52
5	256	256	93.66
6	384	512	94.71
7	512	256	96.93
8	768	512	95.36
9	1024	1024	91.74
10	2048	2048	85.23

It can be seen from Table 2, when the number of nodes in L6 and L7 is 512 and 256, the improved AlexNet has the highest identification accuracy of fragrant pear pests, reaching 96.93%.

The function of convolution layer is to extract image features. By retaining convolution layer and pretraining weight, the network can converge faster and extract target features more easily. Therefore, the proposed model does not change the convolution layer parameters of AlexNet network. Among them, the remaining size of the first layer of AlexNet convolution kernel is $11 \times 11 \times 3$; the size of the second layer of convolution kernel is $5 \times 5 \times 48$, which is consistent with the convolution layer setting of the original network. Therefore, it can be seen that the improved AlexNet used for pest identification includes 5 convolutional layers, 2 fully connected layers, and 1 output layer. Considering that the fragrant pear pest identification is a two-class problem, the last fully connected layer parameter is set to 2. The specific network parameter configuration after network modification and adjustment is shown in Table 2.

4.3. Experimental Parameter Description and Model Training. In the experiment, the data set is divided into three parts: train set, verification set, and test set. The train set size is 900, the verification set is 121, and the test set is 121. In order to avoid memory overflow, batch training method is adopted to set up contrast experiments on training set and verification set of AlexNet model, and the batch size of

Table 2: Parameter setting of improved AlexNet network.

Network layer	Convolution kernel	Step	Number of convolution kernels
Conv1	$11\times11\times3$	6	96
Pool1	$1\times3\times3\times1$	2	
Conv2	$5\times5\times48$	1	256
Pool2	$1\times3\times3\times1$	2	
Conv3	$3\times3\times256$	1	384
Conv4	$3\times64\times192$	1	384
Conv5	$3\times3\times192$	1	256
Pool5	$1\times3\times3\times1$	2	3×3
FC6	64×256		256×1
ReLU6			512
Dropout			
FC7	32×256		2×1
ReLU7			256
Dropout			
FC8	256×2		2
	Softmax		
Output			

verification set is synchronized with that of training set. Traversing all training set data once is called one iteration; that is, one iteration will traverse all training set data, not just one batch data. The number of iterations is set to 150, and the evaluation index value of the model is calculated on the test set after each iteration.

The experiment uses the loss function categorical crossentropy in Keras as the cost function, which is defined as follows:

$$\text{Loss} = -\sum_{i=1}^{n}\left(\hat{y}_{i1}\ln y_{i1} + \hat{y}_{i2}\ln y_{i2} + \cdots + \hat{y}_{im}\ln y_{im}\right), \quad (1)$$

where n is the number of samples, m is the number of categories, y_i and $\hat{y}_i$ are the output type and the corresponding true type, respectively, and this function is a multioutput loss function.

In order to solve the problem of gradient disappearance and explosion in the process of backpropagation, batch normalization is introduced to standardize the network layer input. The dropout mechanism is used to inhibit the neuron nodes from participating in the backpropagation process with a probability of 0.3. To improve the efficiency of parameter adjustment, the adaptive motion estimation (Adam) algorithm is used to optimize the model, and the initial learning rate is set to 0.00001. In order to save the optimal model parameters, the model checkpoint mechanism is introduced. After each iteration, the current model is saved by observing whether the accuracy of the training set is improved.

5. Experimental Results and Analysis

5.1. Evaluation Index. AP is used to evaluate the identification performance of the improved AlexNet network. AP is the integration of the precision-recall (PR) curve on the basis of the accuracy. The evaluation index is calculated as follows:

$$\begin{aligned} P &= \frac{D_T}{D_F + D_T}\times 100\%,\\ R &= \frac{D_T}{D_T + D_N}\times 100\%, \\ V_{\text{AP}} &= \int_0^1 P(R)\,\mathrm{d}R, \end{aligned} \quad (2)$$

where P is the accuracy rate, R is the recall rate, D_T is the number of fragrant pear disease and insect pest leaves that are correctly identified by the algorithm, D_F is the number of fragrant pear disease and pest leaves that are misrecognized, and D_N is the number of fragrant pear disease and pest leaves that are not recognized.

5.2. Model Stability. In order to demonstrate the stability of the proposed model, the accuracy of the model in the 60^{th} iteration in the literature 13, 19, and 20 is compared. The changes are shown in Figure 5.

It can be seen from Figure 5 that, compared with other models, the overall recognition change of the proposed model is the smallest; the recognition accuracy shows an inverse trend as the number of input images gradually decreases, and, compared with the other three models, the accuracy rate of overall recognition is highest. When the number of input images is 128, the change of the broken line tends to be gentle after the 40^{th} iteration of the four models, indicating that the model has entered a stable stage of leaf pest feature extraction. When the number of contrast input images is 64 and 32, respectively, the proposed model is basically stable after the 45th iteration, but the other three models all show a small increase, especially the gradual increase trend of the model in [13] which is obvious.

Similarly, the change of the loss function on each model verification set during the 60th iteration is shown in Figure 6.

It can be seen from Figure 6 that the loss index of each model decreases as the number of input images decreases

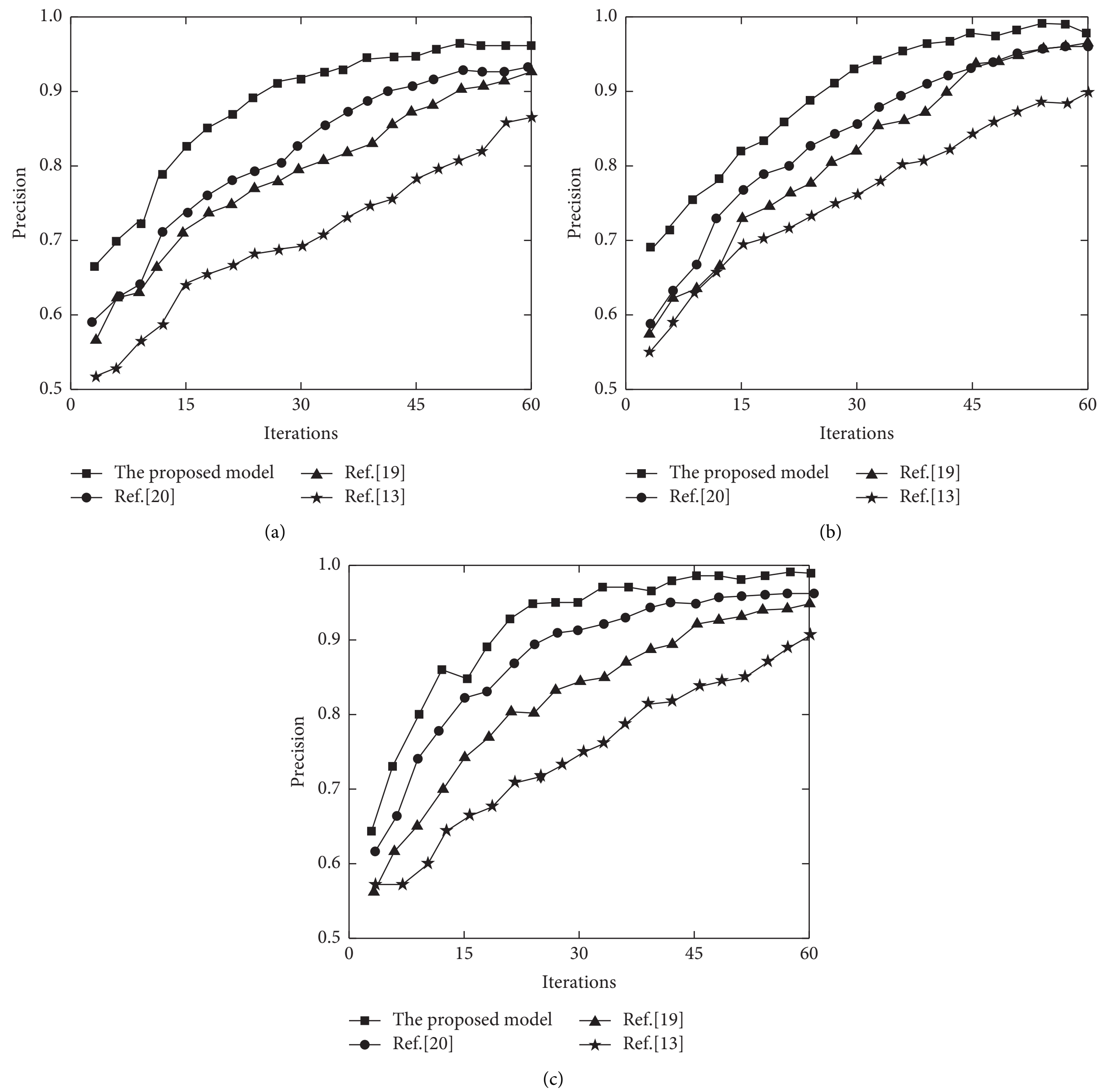


Figure 5: Accuracy changes of different models. (a) The number of input images is 128. (b) The number of input images is 64. (c) The number of input images is 32.

each time. By comparing the number of input images, it is found that, compared with the other three models, the proposed model has smaller change range, the lowest loss rate, and higher stability. From the beginning of the iteration to the 15th iteration, the loss value of [13, 19] changes greatly, which indicates that the two models have a high risk of identification error in the early stage, which leads to the instability of model identification.

The change of accuracy and loss function in the process of comprehensive training can be concluded as follows. During the model training process, changing the number of input images will directly affect the model identification accuracy, model identification risk, and the stability of model identification performance. However, the proposed model has the most stable performance compared to other models and its identification accuracy and loss function have the smallest change range, which are both optimal for any number of images.

5.3. Comparison of Identification Results of Different Network Models. The proposed model and the models in [13, 19, 20] are used to crosstrain the training set, respectively. The recognition accuracy of the four models for three different pest images is shown in Table 3.

It can be seen from Table 3 that the proposed model has a significantly higher identification accuracy for the three types of sample images than other comparison models, and its average identification accuracy is 96.26%, which is higher 7.93%, 6.96%, and 4.37% than that in [13, 19, 20],

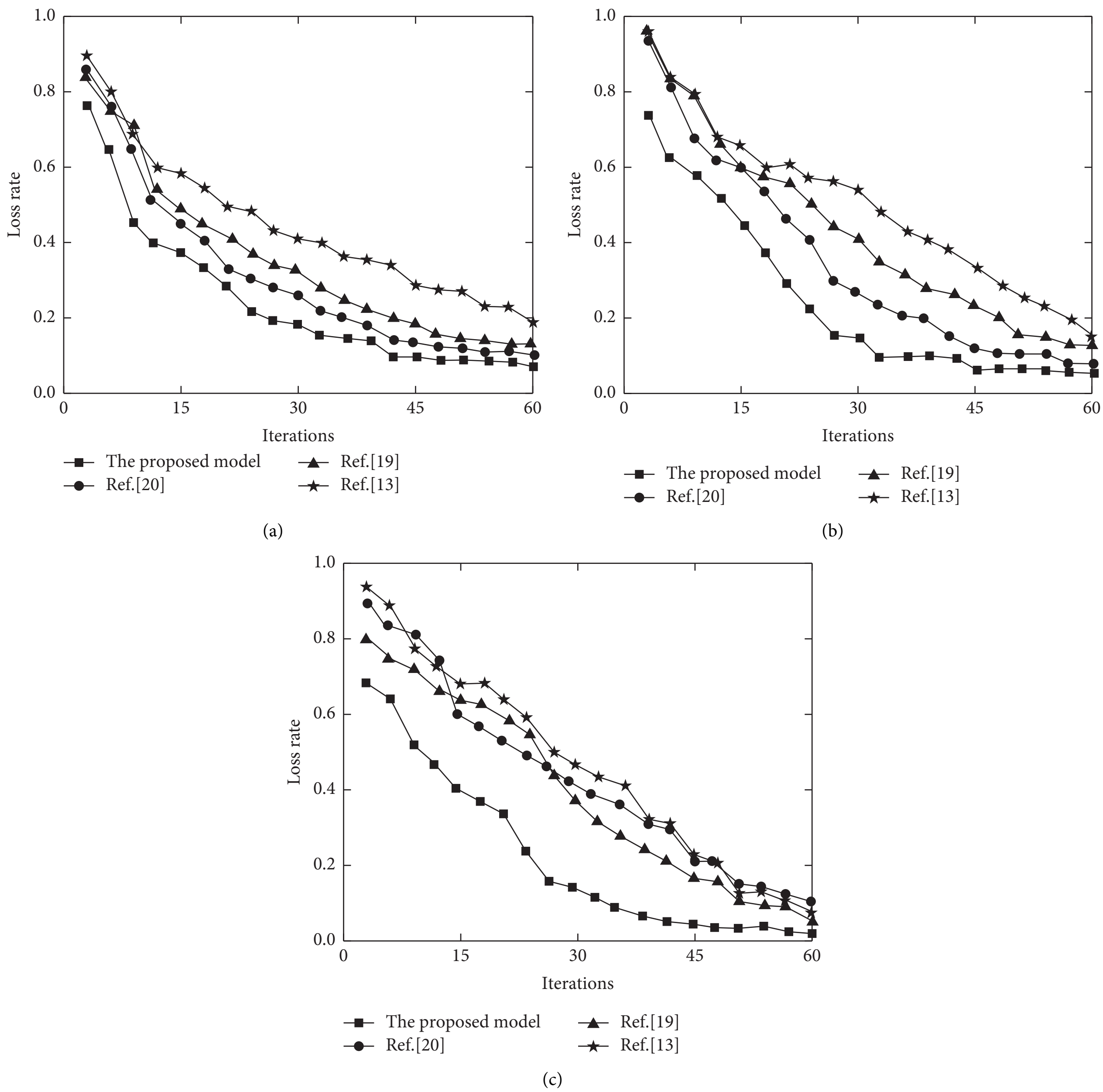


Figure 6: Change of loss function in different models. (a) The number of input images is 128. (b) The number of input images is 64. (c) The number of input images is 32.

respectively. Because the image of beetle pests is easy to recognize, the overall identification accuracy is relatively high, while the other two pests are similar in color to the leaves and have smaller targets, so the overall identification accuracy is low. Reference [13] uses convolutional neural network for local fuzzy image processing to realize crop pests and diseases identification. The model of this paper is more traditional, and the performance advantage is not obvious, so the recognition accuracy is only 89.19%. And the normalization segmentation algorithm based on spectral graph theory is more complex and time-consuming. Reference [19] builds a video detection model based on the faster-RCNN network, which can effectively identify plant diseases and insect pests. But it lacks reliable data preprocessing, affecting the identification accuracy. The recognition performance of the disease and insect pests is improved by combining the image processing technology and machine learning technology in [20]. However, the performance advantage of machine learning is not obvious, the recognition accuracy is 92.23%, and the time consumption is 369 ms. The proposed model uses an improved AlexNet network to identify pests and diseases. The simplified network shortens the identification time to 321 ms and combines with effective image preprocessing technology at the same time guaranteeing the identification accuracy.

Table 3: Experimental results of identification of pear diseases and insect pests images by different models.

Model	Image type	V_{AP} (%)	Average recognition rate (%)	Recognition time (ms)
Reference [13]	Scarab	91.28	89.19	435
	Pear gall midge	89.72		
	Pear leaf sucker	86.58		
Reference [19]	Scarab	92.63	90.00	308
	Pear gall midge	90.35		
	Pear leaf sucker	87.01		
Reference [20]	Scarab	94.18	92.23	369
	Pear gall midge	92.54		
	Pear leaf sucker	89.96		
The proposed model	Scarab	98.25	96.26	321
	Pear gall midge	95.81		
	Pear leaf sucker	94.73		

Table 4: Experimental results of the proposed model on different data sets.

Data set	Training loss	Recognition accuracy (%)
Rice leaf	0.026	96.75
Corn leaf	0.319	91.88
Potato leaves	0.042	95.31
Yellow peach leaves	0.257	92.64

5.4. Analysis of the Test Results of the Model on Other Data Sets. In order to demonstrate the generalization ability of the proposed model, it is analyzed on other data sets. The results are shown in Table 4.

It can be seen from Table 4 that, compared with the 91.88% and 92.64% accuracy rates of the corn and yellow peach leaf data sets, the proposed model obtains 96.75% and 95.31% recognition accuracy rates on the rice and potato leaf data sets, respectively.

The task of leaf classification is to classify the crops by the characteristics of leaves after they are infected by diseases and pests. Image recognition of the same crop leaves is still a fine-grained classification task. The AlexNet model is trained without using maize and yellow peach leaf data sets, and the model achieves higher classification accuracy on other crop data sets, which indicates that the proposed model has good migration for some fine-grained classification tasks of crop leaf data sets.

6. Conclusion

The traditional methods of artificial identification and machine learning for crop diseases and insect pests identification have complex data preprocessing, and the fitting degree of the model fluctuates greatly due to the advantages and disadvantages of the features, so the recognition effect is poor. Therefore, this paper proposes a recognition model of crop diseases and insect pests based on deep learning from the perspective of ecological environment protection. This paper improves the full connection layer of AlexNet network and uses the improved network to analyze the preprocessed crop image set, so as to realize the recognition of crop diseases and pests. The experimental results show that the proposed model performs best when the number of input images changes, and its average recognition accuracy and recognition time for pear diseases and pests are 96.26% and 321 ms, respectively, which are better than other comparison models. At the same time, when the proposed model is applied to other data sets, the recognition accuracy is not less than 91%, and the loss rate is not more than 0.320, which can provide some technical support for the decision-making of crop pest control.

In the research of crop pest identification, there are still many areas worthy of further research, such as how to quickly calculate the effective area of disease and judge the severity of disease and insect pests in a region, so as to carry out effective treatment and prevent large-scale economic losses. These problems are still urgent problems to be solved in the pest management work, which is also the next key research content.

Data Availability

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

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

References

[1] T. Yang and C. Liu, "Recognition system for leaf diseases of ophiopogon japonicus based on PCA-SVM," *Plant Diseases and Pests*, vol. 11, no. 2, pp. 11–15, 2020.

[2] D. Ananey-Obiri and E. Sarku, "Predicting the presence of heart diseases using comparative data mining and machine learning algorithms," *International Journal of Computer Application*, vol. 176, no. 11, pp. 975–8887, 2020.

[3] M. Long, C. Ouyang, H. Liu, and Q. Fu, "Image recognition of Camellia oleifera diseases based on convolutional neural network & transfer learning," *Nongye Gongcheng Xuebao/ Transactions of the Chinese Society of Agricultural Engineering*, vol. 34, no. 18, pp. 194–201, 2018.

[4] M. Ranjith, D. R. Bajya, T. Manoharan, and R. S. Ramya, "Biodiversity of insect pests and natural enemies affiliated with wheat (*Triticum aestivum*) ecosystem in Haryana,"

Indian Journal of Agricultural Sciences, vol. 88, no. 1, pp. 157-158, 2018.

[5] R. Srinivasan, S. Paola, M.-y. Lin et al., "Development and validation of an integrated pest management strategy for the control of major insect pests on yard-long bean in Cambodia," *Crop Protection*, vol. 116, no. 2, pp. 82–91, 2019.

[6] D. Morankar, D. M. Shinde, and S. R. Pawar, "Identification of pests and diseases using alex-net," *SSRN Electronic Journal*, vol. 7, no. 4, pp. 53–61, 2020.

[7] S. A. Rather and I. Deo, "Inheritance pattern and gene action of brown planthopper (*Nilaparvata lugens* Stäl.) resistance in newly identified donors of rice (*Oryza sativa* L.)," *Cereal Research Communications*, vol. 46, no. 4, pp. 679–685, 2018.

[8] S. Moses, D. R. Kishor, A. K. Misra, and M. A. Ahmad, "Identification and quantification of major insect pests of rice and their natural enemies," *Current Journal of Applied Science and Technology*, vol. 32, no. 2, pp. 1–10, 2019.

[9] J. O. Toyinbo, C. Fatokun, O. Boukar, and M. A. B. Fakorede, "Genetic variability and trait association under thrips (Megalurothrips sjostedti Trybom) infestation in cowpea (*Vigna unguiculata* [L.] Walp.)," *Euphytica*, vol. 217, no. 6, pp. 1–9, 2021.

[10] L. Yang, L. Yang, L. Li, R. S. Du, and H. Dong, "Integrated prevention and control technology of major diseases and insect pests of strawberry," *Plant Diseases and Pests*, vol. 11, no. 2, pp. 33–36, 2020.

[11] A. S. Samsuddin, S. Y. Lee, S. P. Ong, and R. Mohamed, "Damaging insect pests and diseases and their threats to agarwood tree plantations," *Sains Malaysiana*, vol. 48, no. 3, pp. 497–507, 2019.

[12] M. Keiichiro, "Factors leading insect pest outbreaks and preventive pest management: a review of recent outbreaks of forage crop pests in Japan," *Japanese Journal of Applied Entomology and Zoology*, vol. 62, no. 3, pp. 171–187, 2018.

[13] T. Fan and J. Xu, "Image classification of crop diseases and pests based on deep learning and fuzzy system," *International Journal of Data Warehousing and Mining*, vol. 16, no. 2, pp. 34–47, 2020.

[14] A. Ferreira, S. C. Felipussi, R. Pires et al., "Eyes in the skies: a data-driven fusion approach to identifying drug crops from remote sensing images," *Ieee Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 12, no. 12, pp. 4773–4786, 2019.

[15] Z. Liu, X. Xiang, J. Qin, Y. YunTan, Q. Zhang, and N. Xiong, "Image recognition of citrus diseases based on deep learning," *Computers, Materials & Continua*, vol. 66, no. 1, pp. 457–466, 2020.

[16] C. Crr, A. Psa, A. Mea et al., "Identification and recognition of rice diseases and pests using convolutional neural networks - sciencedirect," *Biosystems Engineering*, vol. 194, no. 5, pp. 112–120, 2020.

[17] R. K. Gaur, M. Kumar, S. Sharma, and B. S. Yadav, "Survey studies on insects and non insect pest associated with ber crop in South West Haryana," *Journal of Entomology And Zoology Studies*, vol. 8, no. 2, pp. 856–863, 2020.

[18] Y. Ai, C. Sun, J. Tie, and X. Cai, "Research on recognition model of crop diseases and insect pests based on deep learning in harsh environments," *IEEE Access*, vol. 8, no. 3, pp. 171686–171693, 2020.

[19] D. Li, R. Wang, C. Xie et al., "A recognition method for rice plant diseases and pests video detection based on deep convolutional neural network," *Sensors*, vol. 20, no. 3, pp. 578–591, 2020.

[20] R. K. Singh and J. Minj, "Detection of bacterial and fungal leaf diseases using image processing and machine learning techniques," *International Journal of Computer Science and Engineering*, vol. 7, no. 3, pp. 1126–1129, 2019.

[21] W. Huang, J. Lu, J. Lu et al., "Quantitative identification of crop disease and nitrogen-water stress in winter wheat using continuous wavelet analysis," *International Journal of Agricultural and Biological Engineering*, vol. 11, no. 2, pp. 145–152, 2018.

[22] G. Jayme, V. K. Luciano, H. V. Bernardo et al., "Annotated plant pathology databases for image-based detection and recognition of diseases," *IEEE Latin America Transactions*, vol. 16, no. 6, pp. 1749–1757, 2018.

[23] F. P. Boogaard, K. S. A. H. Rongen, and G. W. Kootstra, "Robust node detection and tracking in fruit-vegetable crops using deep learning and multi-view imaging," *Biosystems Engineering*, vol. 192, no. 2, pp. 117–132, 2020.

[24] P. Bosilj, E. Aptoula, T. Duckett, and G. Cielniak, "Transfer learning between crop types for semantic segmentation of crops versus weeds in precision agriculture," *Journal of Field Robotics*, vol. 37, no. 1, pp. 7–19, 2020.

[25] P. Lariya and M. Shrivastava, "Review paper on crops disease diagnosing using image-based deep learning mechanism," *International Journal Of Computer Sciences And Engineering*, vol. 7, no. 4, pp. 306–312, 2019.

[26] U. B. Patayon and R. V. Crisostomo, "Automatic identification of abaca bunchy top disease using deep learning models," *Procedia Computer Science*, vol. 179, no. 1, pp. 321–329, 2021.

[27] S. Yu, R. L. Hong, and J. H. Baek, "Deep learning-based rice seed segmentation for phynotyping," *Journal of the Korea Industrial Information Systems Research*, vol. 25, no. 5, pp. 23–29, 2020.

Hindawi
Scientific Programming
Volume 2022, Article ID 4169340, 12 pages
https://doi.org/10.1155/2022/4169340

Research Article

Information Sharing and Privacy Protection of Electronic Nursing Record Management System

Qiong Li,[1] Hui Yu,[2] and Wei Li[3]

[1]*Nursing Department, Jiangxi Health Vocational College, Nanchang 330052, China*
[2]*Quality Management Office, Jiangxi Health Vocational College, Nanchang 330052, China*
[3]*School of Mathematics and Statistics, Jiangxi Normal University, Nanchang 330022, China*

Correspondence should be addressed to Wei Li; liwei@jxnu.edu.cn

Received 23 October 2021; Revised 7 December 2021; Accepted 13 December 2021; Published 5 January 2022

Academic Editor: Ahmed Farouk

The traditional centralized storage of traditional electronic medical records (EMRs) faces problems like data leakage, data loss, and EMR misplacement. The current protection measures for patients' privacy in EMRs cannot withstand the fast-developing password cracking technologies and frequency cyberattacks. This paper intends to innovate the information sharing and privacy protection of electronic nursing records (ENRs) management system. Specifically, the signature interception technology was introduced to EMRs, the different phases of certificateless signature interception scheme were depicted, and the validation procedures of the scheme were designed. Then, the six phases of ENR information sharing protocol based on alliance blockchain were described in detail. Finally, an end-to-end memory neural network was constructed for ENR classification. The proposed management scheme was proved effective through experiments.

1. Introduction

With the development of medical technology, major hospitals have begun to record patients' personal health information in electronic medical records (EMRs) and connect the EMRs to the Internet. The EMRs store a lot of private information about patients' personal health, such as diagnosis and medication, and face a high risk of information leakage. Traditionally, the EMRs are stored in a centralized manner. The centralized storage makes it hard to share patients' personal health information and increases the proneness to cyberattacks. The resulting problems include data leakage, data loss, and EMR misplacement [1–3]. A series of security threats arise for EMR information. Therefore, the security of EMR usage is an urgent problem to be solved in the sharing and storage of medical information. In recent years, blockchain and cloud storage gradually enter the medical field. Many EMR storage systems no longer give patients the full control of health information [4, 5]. However, there are still some malicious behaviors in cloud servers, and the security management of EMRs in cloud storage poses an urgent problem to be solved.

Traditional EMR sharing platforms lack effective privacy protection schemes [6–8]. Xanthidis and Xanthidou [9] designed an error-correcting code hash function and constructed an anonymization algorithm for privacy protection, which effectively controls the access rights of other users, while ensuring the safe sharing of data between patients and doctors. Ma et al. [10] proposed an authentication mechanism and authorized access mechanism for the users who make access requests and effectively solved the patients' control of EMR data and the authorized access to EMR data.

EMRs need to be shared and transmitted in different formats from traditional structured data, because they contain lots of contents about the health and privacy of patients [11–13]. Responding to the classification and protection requirements of privacy-sensitive information in EMRs, Blondon and Ehrler [14] proposed a recognition and classification algorithm for medical terms that represent patient health-sensitive information in EMR texts and performed selective encryption and confidential search of the recognized words. Kim et al. [15] constructed an EMR management system based on the browser/server (B/S) architecture. The system realizes various functions: batch entry of massive medical records, multicondition query of complex EMRs, standard full-text query, and classified statistical analysis on EMRs of different years and types, providing support to the information sharing of EMRs.

The design of the consensus mechanism is the key to ensure the security of medical data in the EMR management system [16–18]. Kawser and Nyeem [19] proposed a dynamic mode Byzantine fault-tolerant (DMBFT) consensus mechanism, which applies aggregate signatures to the consensus process and optimizes the single mode of the consensus mechanism to a dynamic mode. In this way, the efficiency of signature verification is effectively improved.

The previous studies have presented solutions to the access control, storage system design, and information sharing from different angles [20–26]. However, their protection measures for patient privacy cannot cope with the fast-developing password cracking technologies and frequent cyberattacks. To solve the problems, this paper takes electronic nursing records (ENRs), which involves many people, for example, and tries to innovate the information sharing and privacy protection of ENR management system. The main contents of this research are as follows:

(1) The signature interception technology was introduced to EMRs, the different phases of certificateless signature interception scheme were depicted, and the validation procedures of the scheme were designed.

(2) The six phases of ENR information sharing protocol based on alliance blockchain were described in detail.

(3) An end-to-end memory neural network was constructed for ENR classification, which satisfies the classified protection of private information in the records. The proposed management scheme was proved effective through experiments.

2. Certificateless Signature Interception Scheme for ENRs

As an important part of medical big data, EMRs involve a lot of private information of patients, which should be protected according to laws. Compared with EMRs, ENRs involve a lot of people, including the responsible doctors, as well as the responsible nurses in different shifts. To conceal the sensitive parts of EMRs and protect the privacy of patients (e.g., basic information, type of disease, and state of disease), this paper applies the signature interception scheme to the information confirmation in the ENR scenario in Figure 1, laying the basis for blockchain-based ENR information sharing and security management.

2.1. Phase Description. Based on the certificateless public key cryptosystem, this paper designs an efficient certificateless signature interception scheme, which consists of eight phases:

Phase 1: management system initialization. Let ST_i be the serial number ST_i of identity authentication for patient V_i. The management system can be initialized in the following steps:

Step 1: the key generation center randomly selects an l-bit prime number w, creating a set $\{G\,w, R/G\,w, H_1, O\}$, where $G\,w$ is a finite field; $R/G\,w$ is an elliptic curve on $G\,w$; H_1 is the additive group; w is the order; O is the generator.
Step 2: randomly select $e \in \mathbb{R}^{C*}\ w$ as the primary key, and compute the public key of the system by formula $O_{SPK} = e \cdot O$.
Step 3: select five independent collision-proof hash functions F_0, F_1, F_2, F_3 and F_4:

$$\begin{aligned}
&F0\colon \{0,1\}* \times H1 \times H1 \rightarrow C*w;\\
&F1\colon \{0,1\}* \rightarrow \{0,l\}l;\\
&F2\colon \{0,1\}* \rightarrow \{0,l\},\\
&F3\colon \{0,1\}* \times \{0,1\}* \times H1 \times H1 \rightarrow C*w;\\
&F4\colon \{0,1\}* \times \{0,1\}* \times H1 \times H1 \rightarrow C*w.
\end{aligned} \tag{1}$$

Step 4: the key generation center publicizes system parameter $SP = \{G\,w, R/G\,w, H_1, O, O_{SPK}, F_0, F_1, F_2, F_3, F_4\}$, and stores it secretly to prevent anyone from illegally acquiring the master key e.

Phase 2: setting secret value. Select a random number $a_i \in \mathbb{R}^{C*}\ w$ as the secret value of V_i. Make $O_i = a_i O$ the public key of V_i, and transmit it to the key generation center.

Phase 3: partial generation of keys. This phase mainly includes the following two steps:

Step 1: the key generation center randomly selects $s_i \in \mathbb{R}^{C*} w$, and computes part of the public key $S_i = s_i O$
Step 2: the key generation center computes $f_0 = F_0\ (ST_i, S_i, O_i)$, and $c_i = s_i + s \cdot h_{0i}$, and secretly transmits part of the private key $C_i = (c_i, S_i)$ to patient V_i

Phase 4: setting private key. Upon receiving the ${}_iC_i$ from the key generation center, patient V_i firstly verifies the equation $c_i \cdot O = S_i + F_0(ST_i, S_i, O_i)O_{SPK}$. If the equation holds, V_i configures the entire private key $PR_i = (C_i, a_i)$. If the equation does not hold, terminate the algorithm.

Phase 5: setting public key. Patient V_i configures his/her entire public key $GR_i = (S_i, O_i)$.

Phase 6: signature generation. To sign his/her name on ENR information $N = \{n_1, n_2, \ldots, n_m\}$, patient V_i needs to go through the following four steps:

Step 1: first, calculate the hash value $f_{i1} = F_1(n_i || CIA)$ of each subsegment n_i ($i \in [1, nm]$) in N of the content interception and access (CIA) structure. Then, cascade f_{i1} subsegments by the serial number i from 1 to m, producing the hashed value $N' = F_2 \cdot (F_1\ (n_1 || CIA) \cdot F_1\ (n_2 || CIA), \ldots, F_1\ (n_m || CIA))$.
Step 2: randomly select $b_i \in \mathbb{R}^{C*} w$, and compute $B_i = b_i O$.

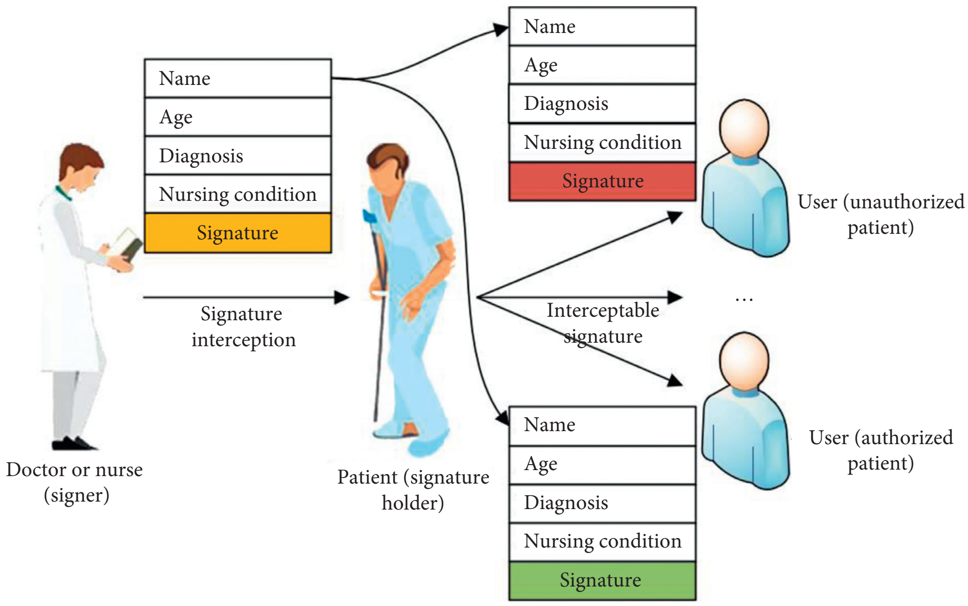


FIGURE 1: Application of signature interception in ENR scenario.

Step 3: compute $g_i = F_3\ (N', ST_i, B_i, S_i)$, and $\tau_i = F_4\ (N', ST_i, B_i, O_i)$.
Step 4: compute $\varepsilon_i = b_i - (\tau_i{\cdot}a_i + g_i{\cdot}c_i)\ mod\ w$. If $\varepsilon_i = 0$, return to Step 1; otherwise, generate the global signature $\varepsilon_G = (CIA, \varepsilon_i, B_i)$.

Phase 7: signature interception. The interceptor should intercept the global signature ε_G after the signature passes the validity test. Through signature generation, compute the total hashed value N', hash value $g_i = F_3\ (N', ST_i, B_i, S_i)$, and $\tau_i = F_4(N', ST_i, B_i, O_i)$. Next, verify if $\varepsilon_i O = B_i\text{-}\tau_i{\cdot}O_i\text{-}g_i(S_i + F_0(ST_i, S_i, O_i)O_{SPK})$ holds. If not, terminate the operation; if yes, move on to the following operations:

Step 1: intercept subset $SUB_{CIA}(N^*)$ according to the CIA structure.
Step 2: generate the intercepted information $N^* = \{n_1^*, n_2^*, \ldots, n_m^*\}$ based on $N = \{n_1, n_2, \ldots, n_m\}$ and $SUB_{CIA}(N^*)$. For each intercepted subsegment $i \in SUB_{CIA}(N^*)$, make $n_i^* = n_i$; for each un-intercepted subsegment, replace it with $n_i^* = F_1(n_i||CIA)$.
Step 3: segment signature $\varepsilon_I = (CIA, SUB_{CIA}(N^*), \varepsilon_i, B_i)$ for N^*.

Phase 8: signature verification. The verifier should verify the intercepted signature ε_I in the following three steps:

Step 1: judge if CIA belongs to $SUB_{CIA}(N^*)$. If not, terminate the algorithm; if yes, move on to the next operation.
Step 2: restore the total hash value N' from the segmented subset $SUB_{CIA}(N^*)$ and segmented information N^*. If i belongs to $SUB_{CIA}(N^*)$, then restore n_i^* with hash value $F_1(n_i||CIA)$, where $n_i = n_i^*$; otherwise, keep the original location n_i^*. After that compute $N' = F_2{\cdot}(F_1(n_1||CIA){\cdot}F_1(n_2||CIA), \ldots, F_1(n_m||CIA))$.
Step 3: calculate $g_i = F_3(N', ST_i, B_i, S_i)$ and $\tau_i = F_4(N', ST_i, B_i, O_i)$ by interceptable signature generation algorithm, and check if $\varepsilon_i O = B_i\text{-}\tau_i O_i - g_i\ (S_i + F_0(ST_i, S_i, O_i)O_{SPK})$ is valid. If yes, ε_I is valid; otherwise, ε_I is invalid.

2.2. Scheme Verification.

2.2. Scheme Verification. This paper verifies the correctness of the proposed certificateless signature interception scheme. The first is to ensure the consistency between the hashed value N' produced in signature generation and the value N' restored in signature verification. Each subsegment of signature generation information N can be replaced by

$$n_i^* = \begin{cases} n_i, & i \in \mathrm{SUB}_{\mathrm{CIA}}(N^*), \\ F_1(n_i \| \mathrm{CIA}), & i \notin \mathrm{SUB}_{\mathrm{CIA}}(N^*). \end{cases} \tag{2}$$

Each subsegment of signature verification information N^* can be restored by

$$n_i^* = \begin{cases} F_1(n_i \| \mathrm{CIA}), & i \in \mathrm{SUB}_{\mathrm{CIA}}(N^*), \\ n_i^*, & i \notin \mathrm{SUB}_{\mathrm{CIA}}(N^*). \end{cases} \tag{3}$$

Formulas (2) and (3) show that the subsegment values of both N and N^* are $F_1(n_i||CIA)$. Therefore, signature verification and signature generation should have the same total hashed value N'.

The next is to verify the correctness of the equation. Since $g_i = F_3(N', ST_i, B_i, S_i)$, $\tau_i = F_4(N', ST_i, B_i, O_i)$, $B_i = b_iO$, $O_i = a_iO$, $S_i = s_iO$, and $O_{SPK} = eO$, the equation can be verified through the following derivation:

$$\begin{aligned}\varepsilon_i O &= [b_i - (\tau_i \cdot a_i + g_i \cdot c_i)]O \\ &= b_i \cdot O - (\tau_i \cdot a_i + g_i \cdot c_i)O \\ &= B_i - \tau_i \cdot a_i \cdot O - g_i(s_i + eF_0(\mathrm{ST}_i, S_i, O_i))O \\ &= B_i - \tau_i \cdot O_i - g_i(s_i \cdot O + F_0(\mathrm{ST}_i, S_i, O_i)e \cdot O) \\ &= B_i - \tau_i \cdot O_i - g_i(S_i + F_0(\mathrm{ST}_i, S_i, O_i)O_{\mathrm{SPK}}).\end{aligned} \tag{4}$$

The proposed certificateless signature interception scheme was proved correct through the above two steps.

3. Blockchain-Based Information Sharing and Privacy Protection

Figure 2 shows the structure of the ENR management system, which includes MMSAC, different types of users, cloud storage, consensus node, and blockchain ledger. Traditionally, the data sharing of ENR management system depends too much on the centralized mechanism. To solve the problem, this paper proposes an ENR information sharing protocol based on alliance blockchain. The protocol contains a total of six phases.

Phase 1: system initialization. Similar to the preceding section, the system administrator needs to initialize the system in the following steps:

Step 1: let w be a large prime number. The system administrator chooses an elliptic curve on a finite field. The order formed by the points on the curve is denoted as w, and the additive group with the generator O is denoted as H_1.
Step 2: the system administrator selects $e \in \mathbb{R}^{C*}w$ as the master key MK, and computes $O_{SPK} = e \cdot O$ as the public key of the system.
Step 3: the system administrator chooses hash functions F_0, F_1, F_2, F_3, and F_4:

$$\begin{aligned}&F0: \{0,1\}* \times H1 \times H1 \longrightarrow C*w; \\ &F1: \{0,1\}* \longrightarrow \{0,l\}l; \\ &F2: \{0,1\}* \longrightarrow \{0,l\}l; \\ &F3: \{0,1\}* \times \{0,1\}* \times H1 \times H1 \longrightarrow C*w; \\ &F4: \{0,1\}* \times \{0,1\}* \times H1 \times H1 \longrightarrow C*w.\end{aligned} \tag{5}$$

Step 4: the system administrator publicizes system parameter $SP = \{G\,w, R/G\,w, H_1, O, O_{SPK}, F_0, F_1, F_2, F_3, F_4\}$, and stores the master key e secretly.

Phase 2: system registration. The system is registered in three steps:

Step 1: the ENR creator registers at the system administrator:

(a) The ENR creator (doctor or nurse) selects a random number $a_c \in \mathbb{R}^{C*}w$ as its secret value, computes $O_c = a_c \cdot O$, and transmits its identity ST_c and part of the public key O_c to the system administrator, as a preparatory work of registration.
(b) Upon receiving the ST_c and O_c from the ENR creator, the system administrator randomly selects $e_c \in \mathbb{R}^{C*}w$, computes $S_c = s_c \cdot O f_c = F_0(ST_i, S_i, O_i)$, and $c_i = s_i + e \cdot f_c$, and securely transmits part of the private key $CR_c = (c_c, S_c)$ to the ENR creator.
(c) The ENR creator verifies if $c_cO = S_c + F_0(ST_c, S_c, O_c)O_{SPK}$ is valid. If yes, configure the private key $PU_c = (CR_c, a_c)$ and the public key $GU_c = (S_c, O_c)$.

Step 2: the patient registers at the system administrator. The patient selects a random number $a\ v \in \mathbb{R}^{C*}w$, configures the private key $PU\ v = a\ v$, and computes the public key $GU\ v = a\ v\ O$. Then, he/she transmits his/her identity $ST\ v$ and public key $GU\ v$ to MMSAC via safe channels.
Step 3: the patient registers at MMSAC. MMSAC authenticates the identity and role of the patient and issues a real-name registration certificate to the patient $RNRC\ v = (ST\ v, GU\ v, SI_{PU})$, where SI_{PU} is the signature set by MMSAC for the public key $ST\ v$ of the patient, using its own private key. Figure 3 shows the registration flow of the ENR management system.

Phase 3: ENR creation. This paper signs ENRs following the certificateless signature interception scheme. The ENR creator needs to execute the following operations:

Step 1: compute the hash values $F_1(n_i||CIA)$ of the ten subsegments $n_i(i \in [1, 11])$ of the patient (e.g., name, gender, age, contact number, identity card number, condition description, medical history, diagnosis, treatment and medication, imaging data, and nursing conditions). Then, cascade the n_i subsegments by the serial number i from 1 to m, producing the hashed value

$$N' = F2 \cdot (F1(n1\|\mathrm{CIA}) \cdot F1(n2\|\mathrm{CIA}) \& F1(nm\|\mathrm{CIA})). \tag{6}$$

Step 2: randomly select $b_c \in \mathbb{R}^{C*w}$, and compute $B_c = b_c \cdot O$.
Step 3: compute $g_i = F_3(N', ST_i, B_i, S_i)$, and $\tau_i = F_4(N', ST_i, B_i, O_i)$.

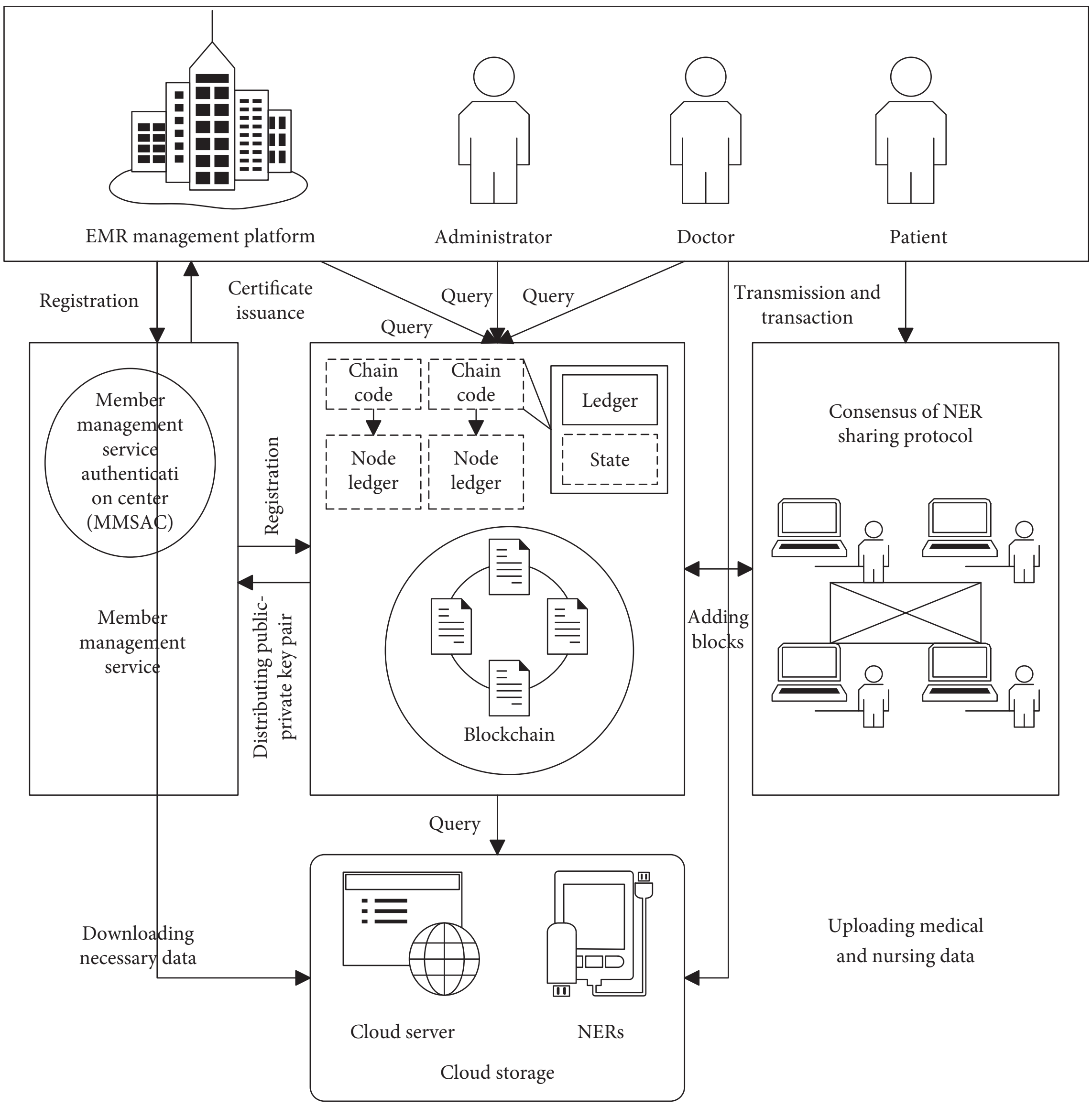


Figure 2: Structure of ENR management system.

Step 4: compute $\varepsilon_c = b_c - (\tau_c \cdot a_c + g_c \cdot c_c) \bmod w$. If $\varepsilon_c = 0$, return to Step 1; otherwise, generate the global signature $\varepsilon_G = (CIA, \varepsilon_c, B_c)$.

The ENR creator selects a random number $l \in \mathbb{R}^{C*w}$ as his/her symmetric key $SL_c = l$, and uses $SL_c = l$ to encrypt the original EMR N, identity information ST_c, hash value $f_N = F_1(n_i \| CIA)$, the global signature ε_G of N, CIA, and timestamp τ. Then, the patient's public key GU_o is used to encrypt SL_c. Finally, the patient will receive ciphertexts:

$$\begin{aligned} \mathrm{CR} \longrightarrow V\colon \text{info} = \Big\{ & R_{L_c}\big(N \| \mathrm{ST}_c \| f_N \| \varepsilon_G \| \mathrm{CIA} \| \tau\big), \\ & R_{\mathrm{GU}_o}(L_c)\Big\}. \end{aligned} \tag{7}$$

Phase 4: ENR storage. After receiving the *info* from the ENR creator, the patient decrypts the ciphertext $R_{GU}{}^{o}(L_c)$ with the private key PU_o to obtain SL_c. Then, the patient solves EMR information N based on SL_c. Finally, the patient verifies the ENR signature. There are two specific steps in this phase:

Step 1: compute $f_{N*} = F_1(n_i \| CIA)$, and verify if f_{N*} is consistent with f_N. If yes, ENR N is highly secure and not tampered.

Step 2: compute N', g_c and τ_c through the signature generation operations in ENR creation phase, and verify if $\varepsilon_c O = B_c - \tau_c O_c - g_c(S_c + F_0(ST_c, S_c, O_c) O_{SPK})$ holds. If yes, global signature ε_G is the valid signature of the recognized doctor or nurse.

If the signature fails one of the two steps, the patient will communicate with the doctor and nurse participating in nursing care. If the signature passes both steps, the patient will hide his/her sensitive

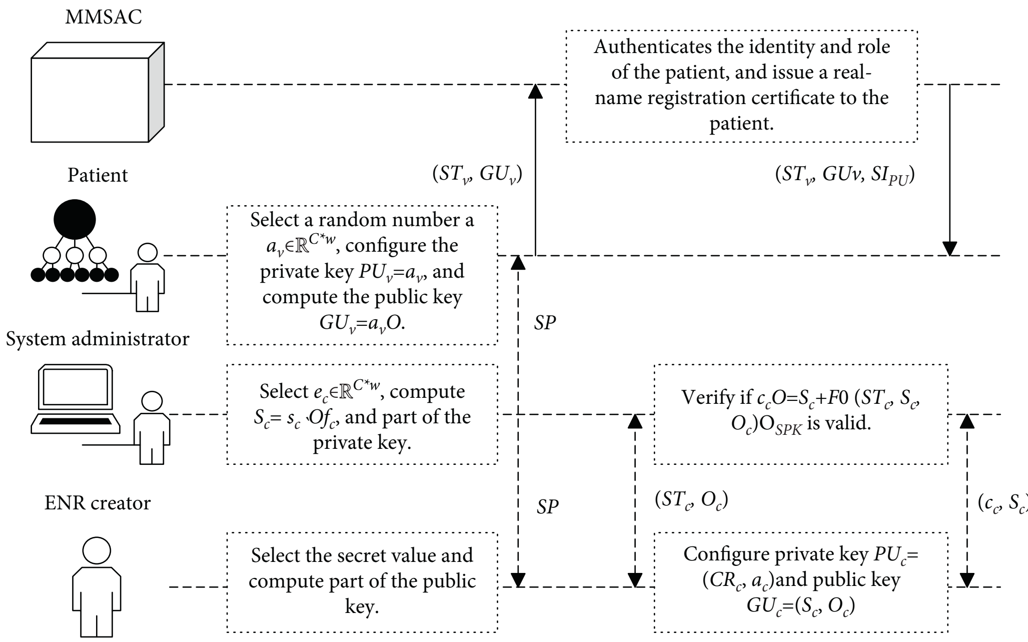


Figure 3: Registration flow of the ENR management system.

information in his/her ENR, according to his/her use needs, and the CIA structure provided by the doctor and nurse.

The huge amount of intercepted data, intercepted signatures, and hash values of ENRs are encrypted by formula (8) and then stored in the cloud:

$$\mathrm{CD} = \left(N^* \| \mathrm{ST}_c \| \mathrm{ST}_o \| f_N \| \varepsilon_G \| \mathrm{SUB}_{\mathrm{CIA}}\left(N^*\right) \| \mathrm{CIA} \| \tau\right), \tag{8}$$

where

$$f_N^* = F_1\left(N^* | \mathrm{ST}_o\right). \tag{9}$$

Figure 4 explains the creation and storage flow of ENR.

Phase 5: ENR issuance. Let CT and τ be the position and timestamp of the encrypted ENR data of the patient being stored in the cloud, respectively. The cyphertexts of CT and τ and other transaction data TD (e.g., hash values and signatures) are attached to the deployed chain code, which contains the access control list (ACL) and algebraic logic function (ALF), and the chain code is then broadcasted across the network. Let TP_{oi} be the patient's alias for transaction, and let HD be the anonymous transaction certificate. The issuance process can be described by

$$V \longrightarrow T: \begin{cases} \mathrm{TD}_i = \langle R_{GU_{TP_{o_i}}}(\mathrm{YD}) \| F(\mathrm{YD}) \| \mathrm{SL}_i \| f_N^* \| \mathrm{HP}_{TP_{o_i}} \| \tau \rangle, \\ CC_{o_i} = \langle \mathrm{ACL}, \mathrm{ALF} \rangle, \end{cases} \tag{10}$$

where

$$\begin{aligned} \mathrm{YD} &= (\mathrm{CT} \| \tau), \\ \mathrm{SL}_i &= \mathrm{SL}_{\mathrm{PU}_{TP_{o_i}}}\left(R_{\mathrm{GU}_{TP_{o_i}}}(\mathrm{YD})\right). \end{aligned} \tag{11}$$

In the blockchain, each transaction initiated by a node carries a signature, which the node signs to verify the validity of the transaction. With the growing transaction volume, the consensus efficiency will be dragged down, if each transaction is verified one by one. To speed up transaction authentication, this paper applies the consensus algorithm in Figure 5 to consensus-making and adopts a more suitable aggregate signature scheme.

Phase 6: ENR sharing. In a channel, if another user V wants to access the ENR of patient O, the access control and effective sharing of the relevant data can be realized by calling the transaction chain code deployed by consensus node for patient O. This phase requires three operations:

Step 1: the other user sends a nursing data access request AC, including the object ST, purpose VP, and visit time VT, to the management system:

$$V \rightarrow \mathrm{All}\colon\ \mathrm{AC} = \langle \mathrm{ST}_o \| \mathrm{VP} \| \mathrm{ST}_v \| \mathrm{GU}_v \| \mathrm{HP}_v \| \tau \rangle. \tag{12}$$

Step 2: after consensus node receives the access request, the chain code CC_o verifies whether the identity $ST\ g$ of the requestor exists in the ACL preset by

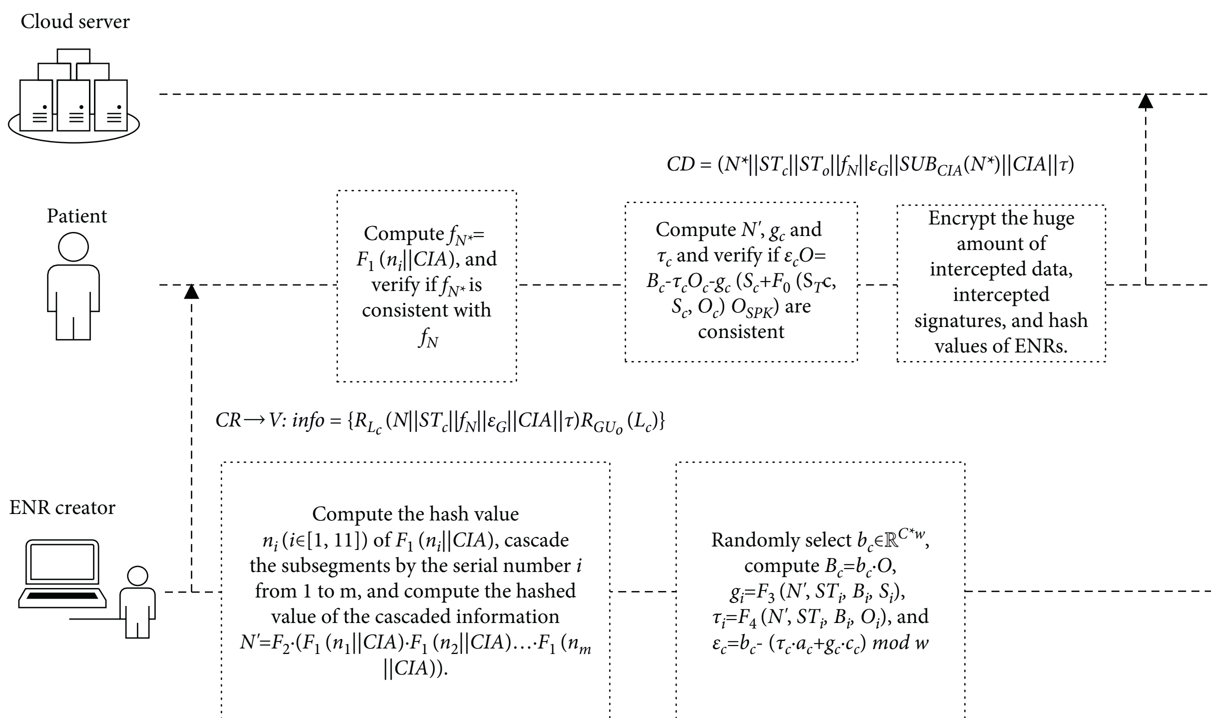


Figure 4: Flow of ENR creation and storage.

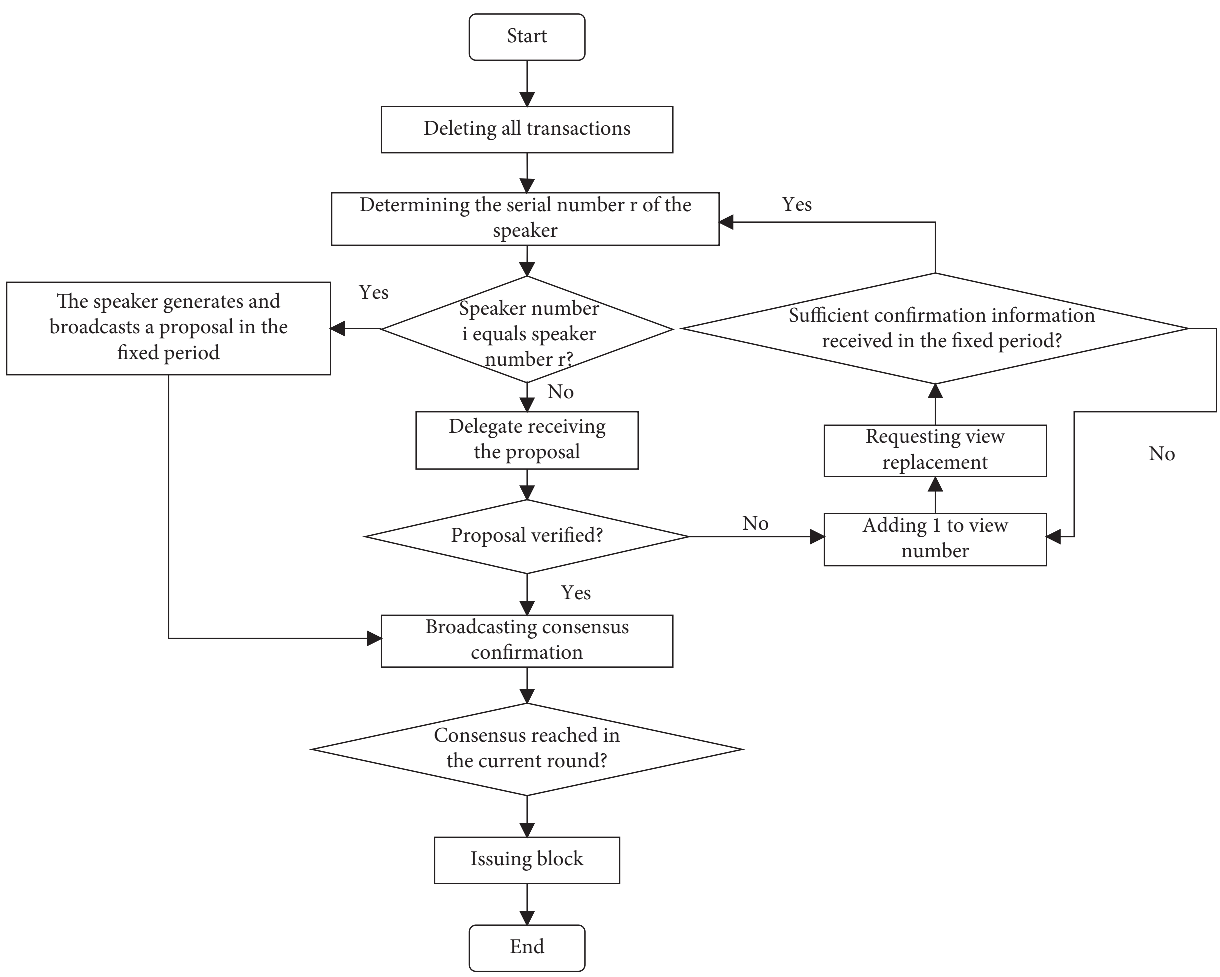


Figure 5: Flow of consensus algorithm.

patient ST_o. If not, the requestor is not authenticated by the patient. Then, CC_o refuse to execute any operation and send a rejection notice to the requestor. If yes, CC_o will start to execute the corresponding ALF. First, compute the storage location index CT of the shareable metadata of patient O according to his/her alias private key $PU_{TP}{}^{o}$. Then, encrypt the CT based on the public key $GU\ v$ of the requestor V. Finally, return the ciphertext (13) to the requestor V:

$$N = R_{\mathrm{GU}_v}\left(\mathrm{CT}\middle\|f_N\middle\|\tau\right). \tag{13}$$

Step 3: upon receiving the ciphertext, the requestor V decrypts the information with his/her private key, producing the storage location index CT of the ENR in the cloud, and further acquires the relevant data. Through ENT sharing, the requestor V can obtain the data object CD by inputting the storage location index CT. To judge if the EMR of patient O is complete and effective, it is necessary to verify the consistency between f_{N*} and f_N in CD and then examine if f_{N*} equals the hash value of the intercepted EMR N'. Figure 6 explains the flow of ENR sharing.

4. ENR Classification Based on End-to-End Memory Neural Network

This paper mainly deals with the information sharing and privacy protection of ENRs. Some ENRs involve multiple reviewers and signers. If these ENRs are classified reasonably, the ENR management system will be more efficient. To this end, this paper introduces an end-to-end memory neural network and selects the MemN2N architecture for the learning model. The network can accept semistructured and nonstructured data, including medical terms and medical texts and classify ENR information through correlation analysis.

The end-to-end memory neural network receives the basic information entry $A = \{a_1, a_2, \ldots, a_m\}$ of the ENR to be classified. Passing through word vector matrices Q and W, A can be transformed into an input memory unit (13) and an output memory unit (14):

$$\begin{aligned} \beta_i &= Q\phi(a_i), \\ \alpha_i &= W\phi(a_i). \end{aligned} \tag{14}$$

Let X and Y be the number of medical terms and the dimension of the corresponding word vectors in the entire ENR dataset, respectively. Then, Q and W are $X * Y$-dimensional matrices obeying Gaussian distribution. During neural network training, the vector of each class approximates the effective representation of the medical terms in that class, along with the gradual update of gradient descent algorithm. In this process, the basic information of each ENR class being inputted can be expressed as a matrix of memory units.

For embedded representation of the ENR, a word vector matrix $P \in \mathbb{R}^{X*Y}$ was defined, which also obeys Gaussian distribution. Every medical term in the ENR was mapped into a word vector. Then, the word vectors were added up directly into a sentence vector:

$$\gamma = P\phi(t). \tag{15}$$

Based on the input memory unit $\{\beta_i\}$ of each ENR class and the embedded representation γ of the ENR, the correlation between each ENR class and ENR can be computed by the Softmax function:

$$\omega_i = \operatorname{soft\,max}\left(\gamma^T \beta_i\right). \tag{16}$$

The Softmax function can be defined as

$$\operatorname{soft\,max}\left(\beta_i\right) = \frac{e^{\beta_i}}{\sum_{j \in [1,m]} e^{\beta_j}}. \tag{17}$$

The output memory unit $\{\alpha_i\}$ corresponding to each ENR class was adopted to compute the weighted embedded representation of each ENR based on ω_i:

$$\xi = \sum_i \omega_i \gamma_i. \tag{18}$$

Let E be the dimension of the word vector for each medical term, i.e., the dimension of the final vector for each ENR class; let Z be the number of labels in the ENR sample set. To obtain the class label of the current samples, it is necessary to map the class of each sample into a $1 * Z$-dimensional vector, using the parameter matrix $K \in \mathbb{R}^{E*Z}$. The final class of ENR outputted by the network can be expressed as

$$\widehat{b} = \operatorname{soft\,max}(K(\xi + \gamma)). \tag{19}$$

Let b be the ground-truth label of the current ENR sample; let b^* be the corresponding label outputted by the neural network. For ENR classification problem, this paper adopts binary cross entropy as the loss function of the network:

$$\mathrm{LOSS} = -\sum_{i=1}^{M} b^{(i)} \log\left(b^{*(i)}\right) + \left(1 - b^{(i)}\right)\log\left(1 - b^{*(i)}\right). \tag{20}$$

The neural network was trained by minimizing the loss. The gradient descent algorithm was adopted to update the weights and thresholds of the neural network.

5. Experiments and Results Analysis

After simulating different signature interception schemes, this paper records the runtime of each phase of these schemes in Figure 7. The bar graphs in Figure 7 visually compare the time consumptions of our scheme and the other three existing schemes in the phases of signature generation, signature interception, and signature verification. Our scheme had a small advantage over scheme [21] in signature generation and verification phases but achieved a marked superiority in signature interception phase and total time. Hence, the proposed certificateless signature interception scheme generally outperforms the contrastive schemes.

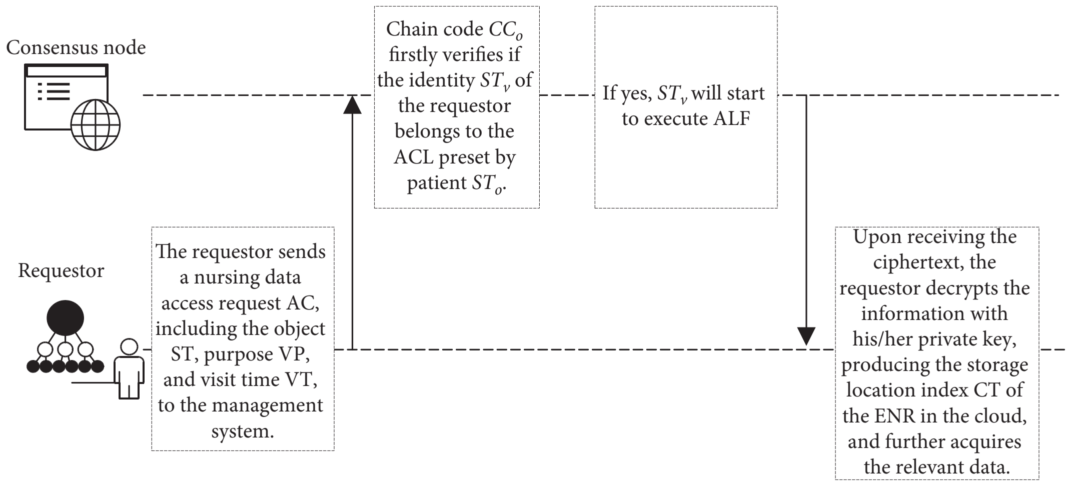


Figure 6: Flow of ENR sharing.

The throughput of a management system is generally measured by the transactions handled in each second. Figure 8 compares the time consumptions of one-by-one verification and aggregate verification. Aggregate verification consumed less than 10 s to handle 2,000 access requests. The throughput was 250–350 transactions per second. The multicenter structure of the selected alliance chain can realize the fast connection, rapid sync, and effective sharing between distributed ENR nodes, because the proposed alliance blockchain-based ENR information sharing protocol adopts the Fabric chain, which determines the node number and equipment configuration in advance. Besides, the selected consensus algorithm boasts a streamlined consensus process and a short response time. Capable of handling 5,000–10,000 transactions, the algorithm facilitates the dynamic expansion of ENR management system.

The performance of the proposed EMR information sharing scheme was compared with that of three existing information sharing schemes through comparative analysis. Scheme [21] adopts the delegated proof of stake (DPoS) consensus mechanism that alleviates the pressure on the main chain. This scheme is inferior in terms of system stability, the reliance on trustworthy third-parties, and patient control of ENR. Scheme [22] employs model chain to protect the privacy and ensure the safe storage of patient ENR information. But this scheme needs to bear some pressure of the main chain. Scheme [23] is defected in the safe storage of information. Meanwhile, our scheme effectively reduces the utilization rate of computer resources and guarantees system stability. The ENR accesses are restricted by the alliance blockchain and improved hash algorithm, laying the basis for privacy protection. Before storing the ENR, the anonymization algorithm for privacy protection is introduced to process the sensitive information in the ENR, which the patient wants to hide, thereby realizing safe storage. Table 1 compares the performance of different ENR information sharing schemes.

In our ENR information sharing scheme, the confirmation time of data block transaction was set to 10 min.

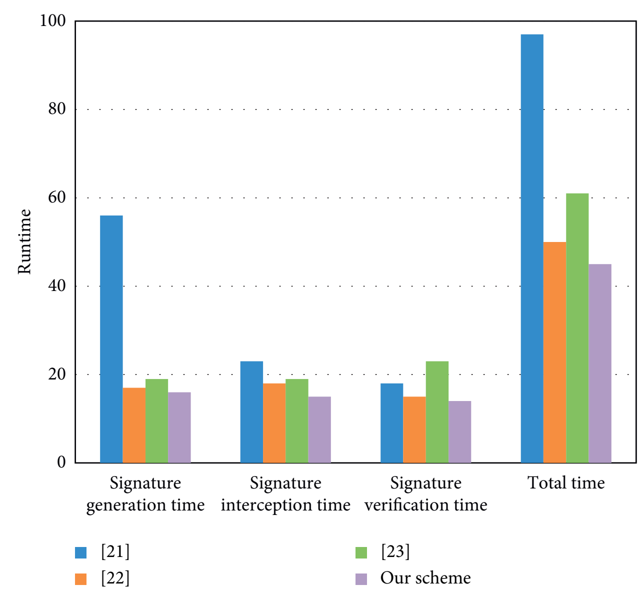


Figure 7: Runtime of each phase of different signature interception schemes.

On the consensus-making of blocks, this paper adopts the certificateless signature interception scheme. Therefore, the consensus algorithm needs no peer-to-peer communication between nodes. As a result, fewer consensus nodes are necessary. Since the consensus is reached between the patient and the doctor/nurse, the proposed EMR information sharing scheme saved more than 5 times the time in confirming data blocks, and transmitted data with 79.45% higher efficiency than the traditional blockchain (Figure 9). With the number of blocks to be confirmed, the confirmation times of our method and traditional blockchain were both on the rise. However, our method consumed less computing power and improved system throughput, due to the control of the number of nodes.

Furthermore, the original and improved consensus algorithms were compared through experiments. The

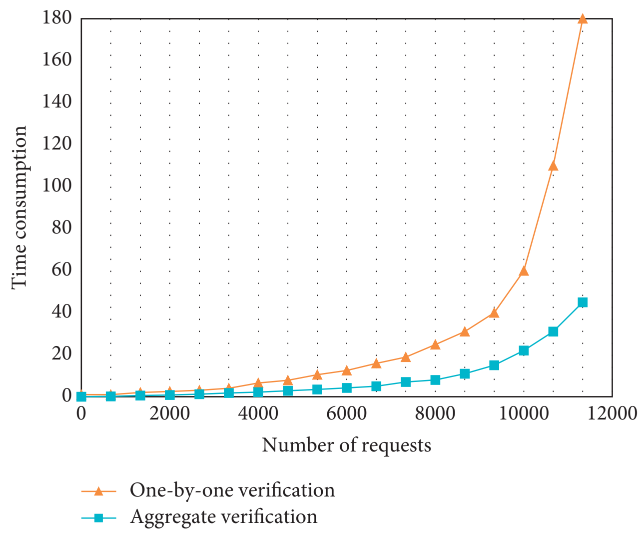


FIGURE 8: Time consumptions of one-by-one verification and aggregate verification.

TABLE 1: Performance of different ENR information sharing schemes.

	[21]	[22]	[23]	Our scheme
Capable of alleviating the pressure on the main chain?	Yes	No	No	Yes
Number of nodes needed by the alliance blockchain	Many	Many	Many	Few
Relying on trustworthy third-parties?	Yes	Yes	Yes	No
Capable of protecting privacy?	Yes	Yes	Yes	Yes
Capable of safe storage?	Yes	No	Yes	Yes
Degree of EMR control	Incomplete control	Incomplete control	Complete control	Complete control

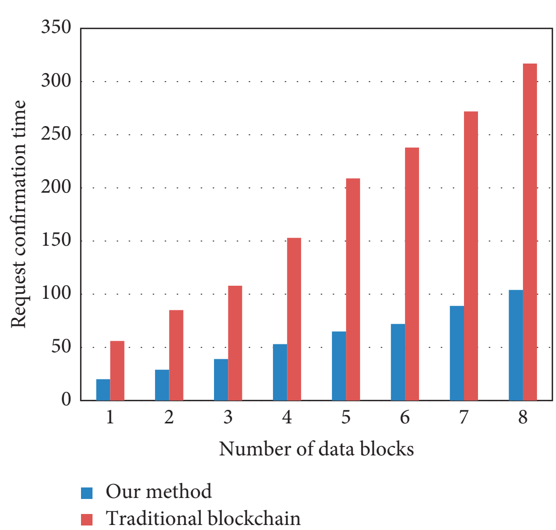


FIGURE 9: Comparison of request confirmation time of ENR information sharing scheme.

improved algorithm is more suitable to ENR management system. Figure 10 shows the CPU occupancies of the adopted consensus mechanism. From the CPU occupancy curves, it can be observed that, with the elapse of time, the CPU occupancy of the improved consensus algorithm was much smaller than that of the original algorithm. Hence, our consensus algorithm can respond to access requests more rapidly.

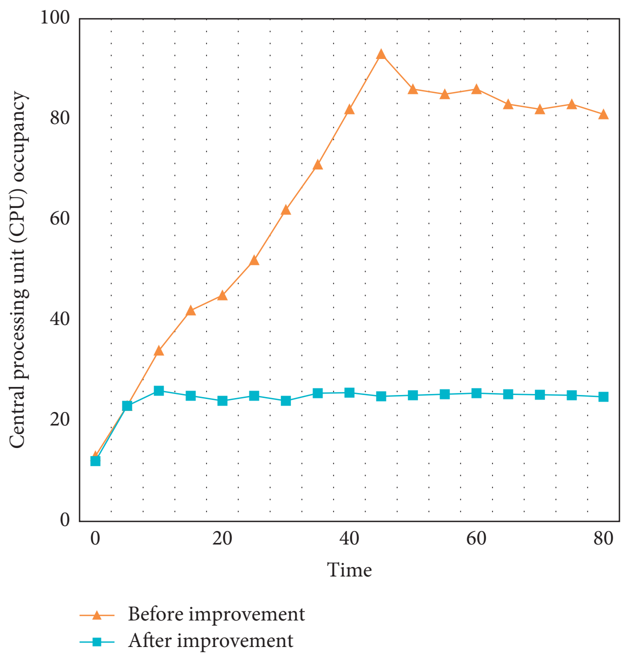


Figure 10: CPU occupancies of original and improved consensus algorithms.

6. Conclusions

This paper innovatively studies the information sharing and privacy protection of ENR management system. Specifically, the certificateless signature interception scheme was depicted phase by phase, and the validation procedures of the scheme were designed. Next, the six phases of ENR information sharing protocol based on alliance blockchain were described in detail. Afterwards, end-to-end memory neural network was constructed for ENR classification. The proposed management scheme was proved superior through experimental results on the runtime of each phase. Besides, the time consumption of one-by-one verification was compared with that of aggregate verification, suggesting that our consensus algorithm has a streamlined consensus process and supports the fast connection, rapid synchronization, and effectives haring between ENR nodes. In addition, our EMR information sharing scheme was compared with three existing information sharing schemes. The comparative analysis confirms the superiority of our scheme in functional completeness, computing power, and CPU occupancy.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] E. M. Tillman, S. L. Suppes, K. Feldman, and J. L. Goldman, “Enhancing pediatric adverse drug reaction documentation in the electronic medical record,” *The Journal of Clinical Pharmacology*, vol. 61, no. 2, pp. 181–186, 2021.

[2] S. Chabbi, R. Boudour, and F. Semchedine, “A secure cloud password and secure authentication protocol for electronic NFC payment between ATM and smartphone,” *Ingénierie des Systèmes d’Information*, vol. 25, no. 2, pp. 139–152, 2020.

[3] K. Li, G. Zhang, N. Li, and H. Yang, “A novel public information system for mobile geriatric medical services,” *Revue d’Intelligence Artificielle*, vol. 33, no. 3, pp. 197–202, 2019.

[4] S. Hashemi and F. Burstein, “A framework for managing cognitive load in electronic medical record systems training,” in *Proceedings of the Twenty fifth Americas Conference on Information Systems*, Cancún, Mexico, August 2019.

[5] M. Z. Ahmed and C. Mahesh, “A weight based labeled classifier using machine learning technique for classification of medical data,” *Revue d’Intelligence Artificielle*, vol. 35, no. 1, pp. 39–46, 2021.

[6] M. Kushima, T. Yamazaki, and K. Araki, “Text data mining of the nursing care life log from electronic medical record,” *Lecture Notes in Engineering and Computer Science*, vol. 2239, pp. 257–261, 2019.

[7] Y. Zhao, M. Cui, L. Zheng et al., “Research on electronic medical record access control based on blockchain,” *International Journal of Distributed Sensor Networks*, vol. 15, no. 11, 2019.

[8] N. Masana and G. M. Muriithi, “Adoption of an integrated cloud-based electronic medical record system at public healthcare facilities in Free-State, South Africa,” in *Proceedings of the 2019 Conference on Information Communications Technology and Society*, Durban, South Africa, March 2019.

[9] D. Xanthidis and O. K. Xanthidou, “A proposed framework for developing an electronic medical record system,” *Journal of Global Information Management*, vol. 29, no. 4, pp. 78–92, 2021.

[10] Q. S. Ma, X. X. Cen, J. Y. Yuan, and X. M. Hou, “Word embedding bootstrapped deep active learning method to information extraction on Chinese electronic medical record,” *Journal of Shanghai Jiaotong University*, vol. 26, no. 4, pp. 494–502, 2021.

[11] A. Sarkar and M. Sarkar, “Tree parity machine guided patients’ privileged based secure sharing of electronic medical record: cybersecurity for telehealth during COVID-19,” *Multimedia Tools and Applications*, vol. 80, no. 14, Article ID 21899, 2021.

[12] R. V. Deolekar and S. B. Wankhade, “A study of electronic health record to unfold its significance for medical reforms,” *Advances in Intelligent Systems and Computing*, vol. 1200, pp. 113–123, 2021.

[13] G. Bingham, E. Tong, S. Poole, P. Ross, and M. Dooley, “A longitudinal time and motion study quantifying how implementation of an electronic medical record influences hospital nurses’ care delivery,” *International Journal of Medical Informatics*, vol. 153, Article ID 104537, 2021.

[14] K. Blondon and F. Ehrler, “Integrating patient-generated health data in an electronic medical record: stakeholders’ perspectives,” *Studies in Health Technology and Informatics*, vol. 275, pp. 12–16, 2020.

[15] D. H. Kim, J. E. Lee, Y. G. Kim et al., “High-throughput algorithm for discovering new drug indications by utilizing

large-scale electronic medical record data," *Clinical Pharmacology & Therapeutics*, vol. 108, no. 6, pp. 1299–1307, 2020.

[16] M. Naeem and I. Alqasimi, "Unfolding and addressing the issues of electronic medical record implementation," *Information Resources Management Journal*, vol. 33, no. 3, pp. 59–80, 2020.

[17] H. Ma, R. Zhang, G. Yang, Z. Song, K. He, and Y. Xiao, "Efficient fine-grained data sharing mechanism for electronic medical record systems with mobile devices," *IEEE Transactions on Dependable and Secure Computing*, vol. 17, no. 5, pp. 1026–1038, 2020.

[18] M. G. Kathi and J. H. Shaik, "An approach of detecting the age of a human by extracting the face parts and applying the hierarchical methods," *Traitement du Signal*, vol. 38, no. 3, pp. 681–688, 2021.

[19] M. A. Kawser and H. Nyeem, "High fidelity embedding of electronic patient record in medical images," in *Proceedings of the 2020 IEEE Region Tenth Symposium*, pp. 1844–1847, Dhaka, Bangladesh, June 2020.

[20] J. Austin, M. Barras, and C. Sullivan, "Interventions designed to improve the safety and quality of therapeutic anticoagulation in an inpatient electronic medical record," *International Journal of Medical Informatics*, vol. 135, Article ID 104066, 2020.

[21] T. Galluzzi, M. Ridao, and S. Esteban, "Strategy for the analysis and visualization of electronic medical record data for public hospitals in the city of Buenos Aires," *Studies in Health Technology and Informatics*, vol. 270, pp. 1397-1398, 2020.

[22] M. Volpi, S. Esteban, and S. Terrasa, "Safety and drugs: how do we record medication consumption and prescription in electronic medical records? A look on aspirin," *Digital Personalized Health and Medicine*, vol. 270, pp. 1383-1384, 2020.

[23] R. Madhusudhan and C. S. Nayak, "An improved user authentication scheme for electronic medical record systems," *Multimedia Tools and Applications*, vol. 79, no. 29-30, Article ID 22007, 2020.

[24] N. Flores, M. Enteria, M. Pefianco, and M. N. Young, "Electronic medical record database with accessible online summary and statistics," in *Proceedings of the 2020 The Sixth International Conference on Industrial and Business Engineerin*, pp. 86–90, Macau Macao, China, September 2020.

[25] S. Li, "A decision model for bike sharing based on big data analysis," *Journal Européen des Systèmes Automatisés*, vol. 53, no. 2, pp. 283–288, 2020.

[26] P. Guttikonda and N. Mundukur, "Secret sharing with reduced share size and data integrity," *Ingénierie des Systèmes d'Information*, vol. 25, no. 2, pp. 227–237, 2020.

Hindawi
Scientific Programming
Volume 2021, Article ID 7162779, 9 pages
https://doi.org/10.1155/2021/7162779

Research Article

Accurate Quaternion Polar Harmonic Transform for Color Image Analysis

Lina Zhang,[1] **Yu Sang**,[2] **and Donghai Dai**[1]

[1]*Teaching Supervision Department, Zhejiang College of Security Technology, Wenzhou 325016, China*
[2]*School of Electronic and Information Engineering, Liaoning Technical University, Huludao 125105, China*

Correspondence should be addressed to Lina Zhang; zhangln19802020@163.com

Received 2 November 2021; Accepted 29 November 2021; Published 29 December 2021

Academic Editor: Ahmed Farouk

Polar harmonic transforms (PHTs) have been applied in pattern recognition and image analysis. But the current computational framework of PHTs has two main demerits. First, some significant color information may be lost during color image processing in conventional methods because they are based on RGB decomposition or graying. Second, PHTs are influenced by geometric errors and numerical integration errors, which can be seen from image reconstruction errors. This paper presents a novel computational framework of quaternion polar harmonic transforms (QPHTs), namely, accurate QPHTs (AQPHTs). First, to holistically handle color images, quaternion-based PHTs are introduced by using the algebra of quaternions. Second, the Gaussian numerical integration is adopted for geometric and numerical error reduction. When compared with CNNs (convolutional neural networks)-based methods (i.e., VGG16) on the Oxford5K dataset, our AQPHT achieves better performance of scaling invariant representation. Moreover, when evaluated on standard image retrieval benchmarks, our AQPHT using smaller dimension of feature vector achieves comparable results with CNNs-based methods and outperforms the hand craft-based methods by 9.6% w.r.t mAP on the Holidays dataset.

1. Introduction

Rotation-invariant moments (RIMs) are extensively used in image representation and pattern recognition [1–3] because of their outstanding description capability and invariance property. Moreover, RIMs not only provide hand craft features for image representation but also can reconstruct original image from these hand craft features, making them suitable for image watermarking [4–6]. There exist two kinds of RIMs: orthogonal and nonorthogonal. Since the orthogonal RIMs (ORIMs) possess minimum information redundancy and hence better information compactness, they are effective in performance. There are several low order moments and transforms can sufficiently extract the essential features of images. The most popular among these ORIMs [7, 8] are Zernike moments (ZMs) and pseudo ZMs (PZMs). Yap et al. [9] recently introduced a few ORITs, collectively known as PHTs, including the polar sine transforms (PSTs), polar cosine transforms (PCTs), and polar complex exponential transforms (PCETs). ORIMs are different from ORITs in the radial parts of kernel functions, which are polynomials and sinusoidal functions in ORIMs and ORITs, respectively. Compared with ORIMs, PHTs are more efficient in computation [10]. Besides, the high order transforms of PHTs are numerically stable, whereas those of ORIMs are numerically unstable. Therefore, PHTs are preferred to ORIMs and have recently been utilized in numerous image processing applications.

Especially for small size images, the current computational framework of PHTs is disadvantaged by geometric errors and numerical integration errors, which can be seen from image reconstruction errors, which are visible near the circular disk center, and even low orders of transform are numerically unstable. Mapping a square image into a unit circular disk can cause geometric errors, and approximating the integration with zeroth-order summation will lead to numerical integration errors. Accurate PHTs are extremely essential in tremendous image processing applications, primarily in template matching and optical character recognition problems using small size images. In addition to the problem of computation accuracy, another problem is that ORIMs and ORITs mainly focus on grayscale images, yet with the continuous improvement of computer performance, color images are drawing more and more attention from researchers in the related fields, because color images can provide much more abundant information compared with grayscale images. Most of the current research on color image moments depends on the intensity or a single channel within the color space of color images, where the information and relationship between color components in a specific color space are discarded. Several traditional orthogonal and nonorthogonal moments have been developed into quaternion moments, e.g., quaternion Zernike moments (QZMs) [2], quaternion radial harmonic Fourier moments (QRHFM) [11], quaternion polar harmonic Fourier moments (QPHFMs) [12], and quaternion polar harmonic transforms (QPHTs) [13, 14], Although various quaternion image orthogonal moments have been proposed by researchers, most of them give unsatisfied image reconstruction performance. In the present work, accurate quaternion orthogonal transforms, i.e., accurate QPHTs (AQPHTs), are proposed. In summary, the innovations of the proposed AQPHTs include the following: firstly, by using the algebra of quaternions, we extend the PHTs to color images. Secondly, a computational framework, which reduces geometric errors and numerical integration errors, is developed to construct an approach to accurately calculate PHTs. Experiments are conducted to comparatively study the performance in image reconstruction and image retrieval of AQPHT and other ORIMs, and the results present that AQPHT has the best image reconstruction performance and superb behavior in invariant image representation with and without noises.

The paper is organized as follows. Section 2 introduces the quaternion algebra and PHTs. Section 3 describes the computational framework of our AQPHTs. In Section 4, the effectiveness of the proposed AQPHTs is evaluated. Section 5 concludes this study.

2. Preliminaries

2.1. Quaternion Algebra. A quaternion can be regarded as a generalized complex number. The formula of a quaternion is as follows:

$$q = a + bi + cj + dk, \tag{1}$$

where q denotes the quaternion, a and $bi + cj + dk$ denote the real and the imaginary part; a, b, c, and d are real numbers, and i, j, and k are complex operators that satisfy these conditions:

$$\begin{aligned} i^2 = j^2 = k^2 = ijk &= -1, \\ ij &= k, \\ jk &= i, \\ ki &= j, \\ ji &= -k, \\ kj &= -i, \\ ik &= -j. \end{aligned} \tag{2}$$

The conjugate of μ is $\overline{\mu} = a - bi - cj - dk$, and the magnitude equals $|\mu| = \sqrt{a^2 + b^2 + c^2 + d^2}$. A quaternion $\mu = s(\mu) + v(\mu)$ can be considered as the combination of a scalar part $s(\mu) = a$ and a vector part $v(\mu) = bi + cj + dk$.

2.2. Polar Harmonic Transform. The two-dimensional polar harmonic transforms $M_{n,l}$ of an n-order image function $f(r,\theta)$, with repetition $l\,(|l| \geq 0)$ defined by

$$M_{n,l} = \Omega_n \int_0^{2\pi} \int_0^1 H_{n,l}^* f(r,\theta) r \mathrm{d}r \mathrm{d}\theta, \tag{3}$$

where Ω_n denotes a normalization factor, and $H_{n,l}^*(r,\theta)$ denotes the complex conjugate of the basis function $H_{n,l}(r,\theta)$. For PCET, $\Omega_n = 1/\pi$ and $H_{n,l}(r,\theta)$ are given by

$$H_{n,l}^{\mathrm{PCET}}(r,\theta) = e^{i2\pi n r^2} e^{il\theta}, \tag{4}$$

where $i = \sqrt{-1}$. While in PCT and PST,

$$\Omega_n = \begin{cases} \dfrac{1}{\pi}, & n = 0, \\ \dfrac{2}{\pi}, & n \neq 0. \end{cases} \tag{5}$$

The basis functions of PST and PCT are defined, respectively, as

$$\begin{aligned} H_{n,l}^{\mathrm{PST}}(r,\theta) &= \sin(\pi n r^2) e^{il\theta}, \\ H_{n,l}^{\mathrm{PCT}}(r,\theta) &= \cos(\pi n r^2) e^{il\theta}. \end{aligned} \tag{6}$$

The total number of PCET for $n = n_{\max}$ and $l = l_{\max}$ is $(1 + 2n_{\max})(1 + 2l_{\max})$ where $n_{\max} = l_{\max}$. However, PST and PCT have a smaller number of features, which are $n_{\max}(1 + 2l_{\max})$ and $(1 + n_{\max})(1 + 2l_{\max})$, respectively.

For an $N \times N$ image, there is no analytical solution to the integration in equation (3), therefore its zeroth-order approximation is commonly used and given by

$$M_{n,l} = \Omega_n \sum_{j}^{N-1} \sum_{k}^{N-1} f(x_j, y_k) H_{n,l}^*(x_j, y_k) \triangle x_j y_k, \quad x_j^2 + y_k^2 \leq 1, \tag{7}$$

where

$$x_j = \frac{2j+1-N}{N},$$
$$y_k = \frac{2k+1-N}{N}, \quad j,k = 0,1,\ldots,N-1. \tag{8}$$

We perform inverse transforms to reconstruct the image function. It is expressed by

$$\hat{f}(x_j, y_k) = \sum_{n=n_{\min}}^{n_{\max}} \sum_{l=l_{\min}}^{l_{\max}} M_{n,l} H_{n,l}(x_j, y_k), \quad j,k = 0,1,\ldots,N-1, \tag{9}$$

where $n_{\max}$, $n_{\min}$, $l_{\max}$, and $l_{\min}$ are the maximum and minimum orders and repetitions of PHTs, respectively, as specified in equation (3).

3. Accurate QPHTs

3.1. QPHTs. In traditional processing methods, color images are usually divided into 3 components and each component is separately handled by a follow-up process without taking into account the association within components. But, quaternion-based theory treats a color image as an integral vector, by which the relationships between each component are reflected. Let $f_R(r,\theta)$, $f_G(r,\theta)$, and $f_B(r,\theta)$ denote the color components of red, green, and blue, respectively, then we encode a color pixel $f(r,\theta)$. The pixel can be encoded as a pure quaternion:

$$f(r,\theta) = f_R(r,\theta)i + f_G(r,\theta)j + f_B(r,\theta)k. \tag{10}$$

Therefore, PHTs can be defined in the quaternion field. The multidimension feature of color images can be addressed by the transforms wherein each color pixel is treated as a whole. Due to the noncommutative multiplication of quaternions, each quaternion transform has two different forms. The left-side quaternion PCET is defined as follows:

$$\begin{aligned} M_{n,l}^L &= \frac{1}{\pi}\int_0^{2\pi}\int_0^1 H_{n,l}^* f(r,\theta) r\mathrm{d}r\mathrm{d}\theta \\ &= \frac{1}{\pi}\int_0^{2\pi}\int_0^1 e^{-\mu l\theta} e^{-\mu 2\pi n r^2} f(r,\theta) r\mathrm{d}r\mathrm{d}\theta, \end{aligned} \tag{11}$$

where μ denotes a pure unit quaternion and $f(r,\theta)$ denotes the quaternion representation of a color pixel. $\mu = (i+j+k)/\sqrt{3}$, i.e., the gray line in the RGB space is chosen in this work. By reversing the orders of images and transform kernels in equation (11), we can obtain the right-side QPCET:

$$M_{n,l}^R = \frac{1}{\pi}\int_0^{2\pi}\int_0^1 f(r,\theta) e^{-\mu l\theta} e^{-\mu 2\pi n r^2} r\mathrm{d}r\mathrm{d}\theta. \tag{12}$$

The reconstruction of a color image by using the QPCET coefficients of the left and right sides can be written as equations (13) and (14), respectively:

$$f(r,\theta) = \sum_{n=0}^{n_{\max}} \sum_{l=-l_{\max}}^{l_{\max}} e^{\mu 2\pi n r^2} e^{\mu l\theta} M_{n,l}^L, \tag{13}$$

$$f(r,\theta) = \sum_{n=0}^{n_{\max}} \sum_{l=-l_{\max}}^{l_{\max}} M_{n,l}^R e^{\mu 2\pi n r^2} e^{\mu l\theta}. \tag{14}$$

Analogous to QPCET, the left and right-side QPCT can be defined as equations (15) and (16), respectively,

$$M_{n,l}^L = \Omega_n \int_0^{2\pi}\int_0^1 \cos(\pi n r^2) e^{-\mu l\theta} f(r,\theta) r\mathrm{d}r\mathrm{d}\theta, \tag{15}$$

$$M_{n,l}^R = \Omega_n \int_0^{2\pi}\int_0^1 f(r,\theta)\cos(\pi n r^2) e^{-\mu l\theta} r\mathrm{d}r\mathrm{d}\theta, \tag{16}$$

where all factors are defined as in equation (5). Replace the radial components in Equations (15) and (16) with $f_B(r,\theta)$, and we can obtain the QPST. The construction of color images can also be achieved by using QPCT and QPST coefficients.

We note that the QPHT in this paper refers to the left-side QPCET $M_{n,l}^L$ as defined in equation (11), unless otherwise specified.

3.2. Computation of Accurate QPHT. This subsection provides a computational framework for calculating QPHTs, which can reduce geometric errors and numerical integration errors. Using our method, only the part inside the unit disk of the pixel is considered. For numerical integration, we rewrite equation (11) as

$$M_{n,l}^L = \frac{1}{\pi}\sum_{j=0}^{N-1}\sum_{k=0}^{N-1} f(x_j, y_k) h_{nl,jk}, \quad x_j^2 + y_k^2 \le 1. \tag{17}$$

We assume the image function $f_B(r,\theta)$ is constant in one grid. The calculation accuracy of QPHTs can be increased through computing the numerical integration of basis function $h_{nl,jk}$ for each grid, that is,

$$h_{nl,jk} = \int_{a_j}^{a_{j+1}}\int_{b_k}^{b_{k+1}} H_{nl}^*(x,y)\mathrm{d}x\mathrm{d}y, \quad a_j^2 + b_k^2 \le 1, \tag{18}$$

where

$$a_j = \frac{2j-N}{N},$$
$$b_k = \frac{2k-N}{N}, \quad j,k = 0,1,\ldots,N. \tag{19}$$

Since equation (18) is evaluated by using a $g\times g$ point Gaussian numerical integration method, it can be simplified into

$$h_{nl,jk} \cong \frac{1}{N^2}\sum_{l=0}^{g-1}\sum_{m=0}^{g-1}\omega_l\omega_m \times H_{nl}^*\left(\frac{t_l+2j+1-N}{N},\frac{t_m+2k+1-N}{N}\right) \cdot \left(\frac{t_l+2j+1-N}{N}\right)^2+\left(\frac{t_m+2k+1-N}{N}\right)\leq 1. \tag{20}$$

The values of ω and t for a given g can be obtained by using standard procedures [15]. For a quick reference, we provide these values in Table 1 for $g=1$ through 8. The constraint in equation (21) is an improvement over the constraint $x_j^2+y_k^2\leq 1$ in the zeroth-order approximation.

If the center of a grid falls outside the unit circle, this grid will be completely ignored in computation in zeroth-order approximation. But in the new constraint, a grid will be considered in the calculation if its sampling point falls within the unit disk even if its centers fall outside the unit disk. An improvement of the approximation of the unit disk has been observed with this new constraint. This is a great contribution of the numerical integration method for reducing geometric errors and numerical integration errors simultaneously by ensuring that none of the sampling points fall outside the unit disk. We find that the performance of image reconstruction improves as we increase the number of g, but the gain starts to saturate at $g=6$. Therefore, the accurate computation experiment of QPHTs uses 5×5 sampling points (i.e., $g=5$), which we take as a tradeoff accuracy and speed for color images.

3.3. Geometric Invariance of AQPHT

3.3. Geometric Invariance of AQPHT. Here, we will derive and analyze the rotation and scaling invariant property of AQPHTs.

3.3.1. Rotation Invariance. Let $\hat{f}(r,\theta)=f(r,\theta+\alpha)$ denote the image $f(r,\theta)$ rotated by the angle α. Accordingly, the left-side AQPHT of $\hat{f}(r,\theta)$ is

$$\begin{aligned}\hat{M}_{n,l}^L &= \frac{1}{2\pi}\int_0^{2\pi}\int_0^1 \hat{f}(r,\theta)\exp\left(-\mu 2\pi n r^2\right)\exp(-\mu l\theta)r\mathrm{d}r\mathrm{d}\theta\\ &= \frac{1}{2\pi}\int_0^{2\pi}\int_0^1 f(r,\theta+\alpha)\exp\left(-\mu 2\pi n r^2\right)\exp(-\mu l\theta)r\mathrm{d}r\mathrm{d}\theta\frac{1}{2\pi}\\ &= \int_0^{2\pi}\int_0^1 f(r,\theta)\exp\left(-\mu 2\pi n r^2\right)\exp(-\mu l\theta)r\mathrm{d}r\mathrm{d}\theta\times\exp(\mu l\theta)\\ &= M_{n,\times\exp(\mu n\theta),l},\end{aligned} \tag{21}$$

where $M_{n,l}$ and $\hat{M}_{n,l}$ are the AQPHTs of $f(r,\theta)$ and $\hat{f}(r,\theta)$, respectively.

Accordingly to equation (21), we know that a rotation of the color image by an angle α induces a phase shift $e^{\mu l\theta}$ of the $M_{n,l}^L(f)$. Taking the norm on both sides of equation (17), we have

Table 1: Weights and locations of sampling points for $g\times g$ point integration.

g	ω	t	g	ω	t
1	2.0	0.0	7	0.12948497	±0.94910791
2	1.0	±0.57735027		0.27970539	±0.74153119
3	0.55555556	±0.77459667		0.38183005	±0.40584515
	0.88888889	0.0		0.41795918	0.0
4	0.34785485	±0.86113631			
	0.65214515	±0.33998104			
5	0.23692688	±0.90617985	8	0.10122853	±0.96028987
	0.47862867	±0.53846931		0.22238103	±0.79666648
	0.56888889	0.0		0.31370665	±0.52553241
6	0.17132449	±0.93246951		0.36268378	±0.18343464
	0.36076157	±0.66120939			
	0.46791393	±0.23861919			

$$\begin{aligned}\left|\hat{M}_{n,l}\right| &= \left|M_{n,l}\exp(\mu l\theta)\right|\\ &= \left|M_{n,l}\right|\left|\exp(\mu l\theta)\right|\\ &= \left|M_{n,l}\right|.\end{aligned} \tag{22}$$

Therefore, the rotation invariant can be achieved by taking the norm of APHTs. In other words, the AQPHTs modulus coefficients $|M_{n,l}^L(f)|$ are invariant with respect to image rotation.

3.3.2. Scaling Invariance. Theoretically, AQPHTs are not invariant to image scaling, but scaling invariance can be obtained by normalizing the image into a unit circle. If an image $f(r,\theta)$ with $N\times N$ pixels is mapped to a unit circle $(x_j,y_k)\in[-1,1]\times[-1,1]$ with $x_j=2j-N+1/N$, $y_k=N-1-2k/N$, $(j,k=0,1,\ldots,N-1)$ and a unit circle is made to cover the same contents of the image, the AQPHTs are variant to image scaling.

4. Experiments and Analysis

This section is intended to validate the effectiveness of AQPHT invariants for color images. The experiments are performed using MATLAB version 8.6 on a 2.9 GHz processor, 8 GB RAM computer, and Microsoft Windows 10 Ultimate operating system.

4.1. Experiment on Scaling Invariance. Numerous great classification models, e.g., VGG [16] and ResNet [17], have been developed on the basis of the powerful deep learning framework Their recognition accuracy is amazing and even higher than that of human beings. However, the performance is achieved only for large size images having rich object structure and high quality appearance. The resolution of images with small size is low, which limits the learning of discriminative representations, thus leading to identification failure [18]. In this experiment, the impact of down-scaling operation on image representations can be evaluated on Oxford5K dataset [19] by our AQPHT and the widespread deep model of VGG16. For convenience, only the neural activation in the 36-th layers of the VGG16 model is studied as an example of deep models in this work. The ability of representation is measured by the mean Euclidean distance which is calculated between the features extracted from an image at various resolutions. Figure 1 separately presents the experimental results of mean Euclidean distance at various down-sampling scales for the VGG16 model and AQPHT. From Figure 1(a), although the VGG16 model is carefully trained with some extra useful training tricks on the Oxford5K dataset, the mean Euclidean distance is growing larger with the decrease of image resolution, indicating that the ability of deep representation reduces with decreasing image resolution. From Figure 1(b), the mean Euclidean distance of the AQPHT is almost constant, demonstrating the superb performance of the AQPHT invariants under scaling transform.

4.2. Experiment on Image Reconstruction. The capability of image representation of image moments can be measured by image reconstruction performance. This subsection compares the performance of image reconstruction between AQPHT and QZM [2], QPHT [14], QPHFM [12], and QRHFM [11]. Following the standard [11, 12], we set the relevant parameters in our experiments. The mean square reconstruction error (MSRE) is used to measure the reconstruction performance [11, 12]; lower MSREs equate to better reconstruction performance. Suppose $f(x, y)$ and $\hat{f}(x, y)$ indicate the original image and reconstructed image, respectively; the MSRE is defined as

$$\mathrm{MSRE} = \frac{\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}|f(x,y) - \hat{f}(x,y)|^2}{\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f^2(x,y)}. \tag{23}$$

In Figure 2, we plot the curves of average MSREs versus the data amount of coefficients. The coefficients in image reconstruction can be represented by real values, and the total number of required real values is defined as data amount. For instance, four real values are needed to represent one AQPHT coefficient, while representing the coefficients of three components of APHT-RGB require six real values [9]. It can be seen from Figure 2 that our AQPHT achieves higher MSREs than APHT-RGB. By dealing with various color channels in a holistic way, AQPHTs can obtain the essence of color images from the inter- and intrachannel directions, demonstrating better compactness.

Next, we use two additional metrics, i.e., PSNR and SSIM, to evaluate the reconstruction performance. The PSNR between the reconstructed image $\hat{Y}$ and original image Y of size is calculated as

$$\mathrm{PSNR}(\hat{Y}, Y) = 10\log_{10}\frac{\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}\mathrm{MAX}_I^2}{\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}(\hat{Y}(x,y) - Y(x,y))^2}, \tag{24}$$

where MAX_I is the maximum possible pixel intensity value. The SSIM is designed to better match the human perception compared to PSNR; the SSIM is defined as

$$\mathrm{SSIM}(\hat{Y}, Y) = \frac{\left(2\mu_Y\mu_{\hat{Y}} + c_1\right)\left(2\sigma_{\hat{Y}Y} + c_2\right)}{\left(\mu_Y^2 + \mu_{\hat{Y}}^2 + c_1\right) + \left(\sigma_Y^2 + \sigma_{\hat{Y}}^2 + c_2\right)}, \tag{25}$$

where μ and σ are respectively the average and variance of the pixel values, $\sigma_{\hat{Y}Y}$ is the covariance of $\hat{Y}$ and Y; c_1 and c_2 are constants. Following previous methods [20, 21], we set $c_1 = 0.01$ and $c_2 = 0.03$ in this paper. Higher values for PSNR and SSIM indicate better performance.

The "Lena" of size of 128×128 is reconstructed using our AQPHT and the compared methods with a maximum order ranging from 4 to 28. As shown in Figure 3, we can find that the reconstructed images of our AQPHT are far better than other moments. When the number of moments exceeds a certain value, the reconstruction performance of QZM [2] and QPHT [14] even degrades, whereas the reconstruction performance of our proposed AQPHT keeps getting better.

4.3. Experiment on Image Retrieval. Here, a series of extensive experiments are conducted to compare our method with other leading edge ones, namely, traditional hand craft-based methods [22–25] and CNN-based methods [26–30]. To evaluate the performance, we use the average precision (AP) measure computed as the area under the precision-recall curve for a query. We compute an average precision score for each of the 5 queries for a landmark, averaging these to obtain a mean average precision (mAP) score. The average of these mAP scores is used as a single number to evaluate the overall performance. For a fair comparison, postprocessing methods, e.g., query expansion are excluded in the work, and only mAP in representation with relevant feature dimensions is reported. The results of retrieval accuracy (mAP) [31] of the UK-bench [32], Holidays [33], and Oxford5k [19] are presented in Table 2, in which the bold indicates the best results. From Table 2, the performance of our method is much better than all hand craft-based methods but marginally worse than some CNN-based methods [28–30]. However, the length of a feature vector largely determines its retrieval efficiency. We note that

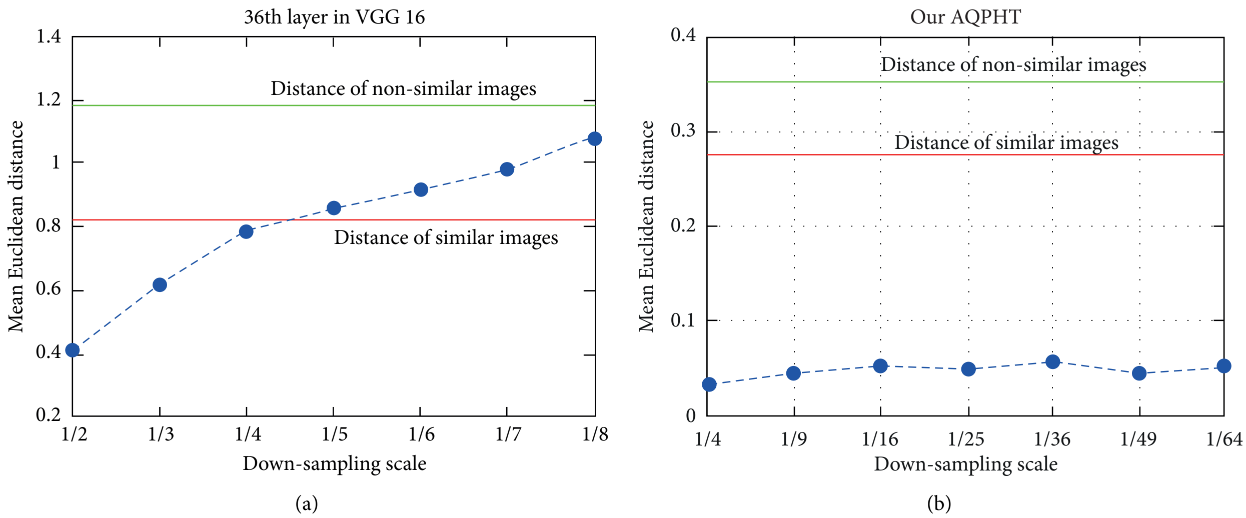


Figure 1: Mean Euclidean distance at various low resolutions on Oxford5K dataset. (a) VGG16 and (b) the proposed AQPHT.

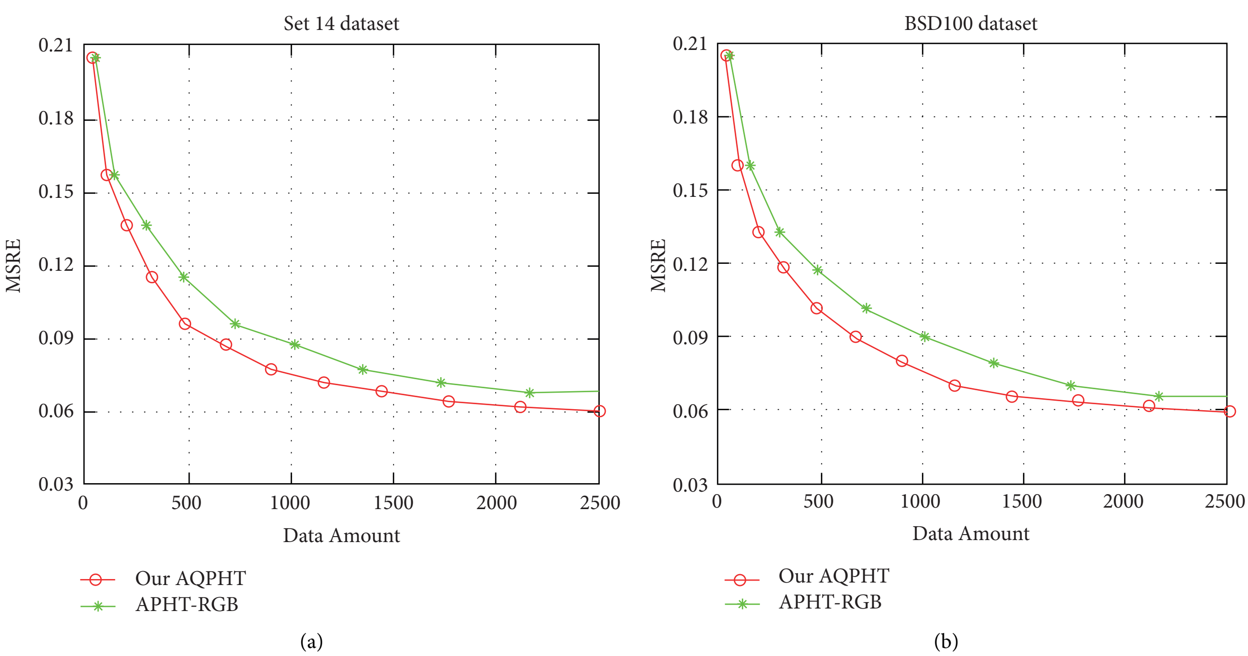


Figure 2: The MSREs curves of APH-RGB and our AQPHT on (a) Set 14 and (b) BSD 100.

our method uses feature vectors with significantly low dimensions comparing with CNN-based methods. In other words, the retrieval efficiency of our method is increased under the same experimental conditions in spite of the slight decrease of its accuracy, which means our method is a more effective compromising method for color image retrieval. Besides, the proposed AQPHT performs better than the QPHT [31] on 3 datasets by a

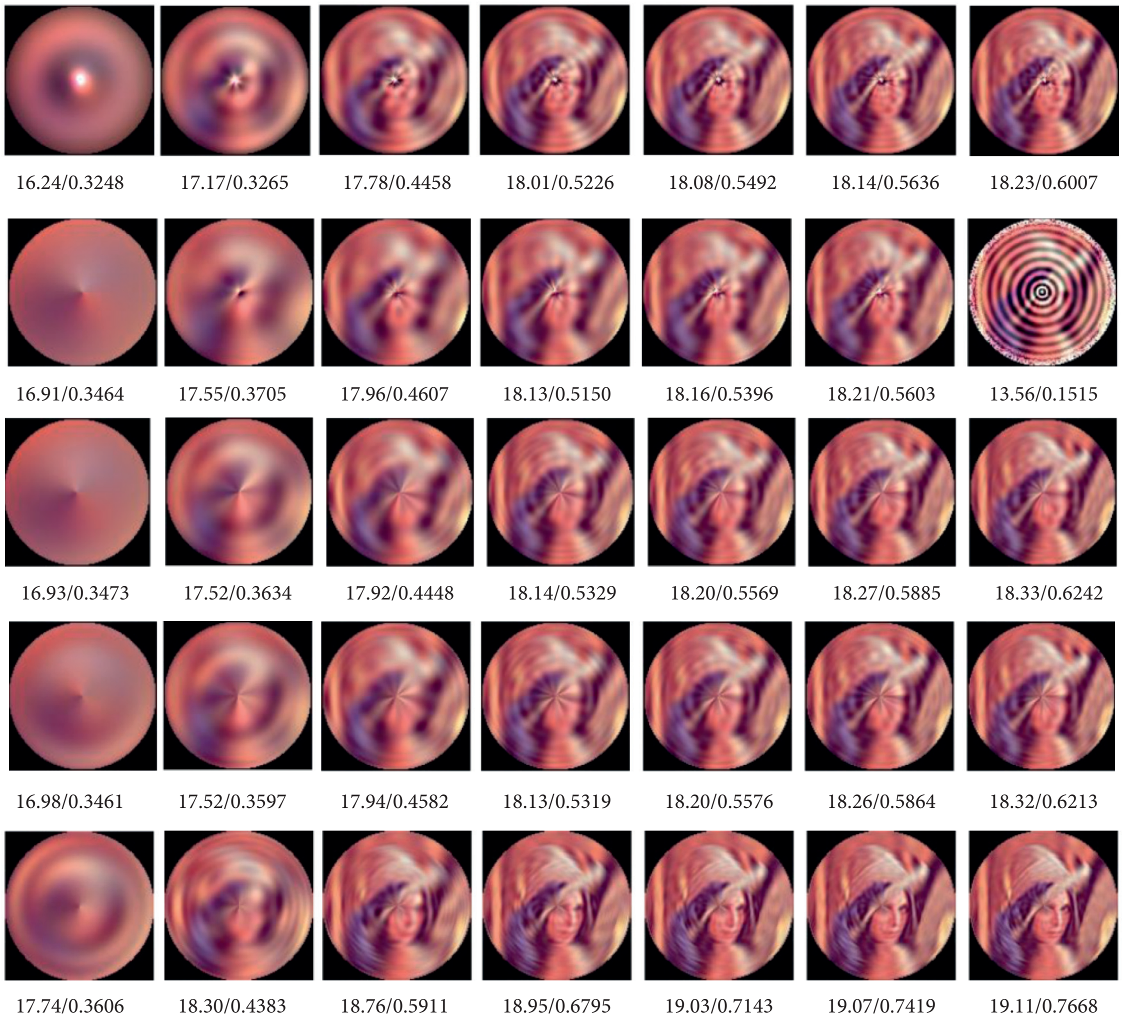


FIGURE 3: Comparison of reconstructed images for Lena, w.r.t. PSNR and SSIM. From top to down are QZM, QPHT, QPHFM, QRHFM, and our AQPHT, respectively.

TABLE 2: Comparison of retrieval performance in terms of mean average precision (mAP).

Method		Feature vector length	Oxford5K	Holidays	UK-bench
Hand craft-based methods	LCS + RN [22]		0.517	0.658	0.324
	Improved BOW [23]		0.546	0.747	0.352
	LTF [24]		—	0.689	0.355
	LBP + color [25]		0.664	0.735	0.347
CNN-based methods	Neural codes [26]	128	0.557	0.789	0.356
	CRB-M [27]	512	0.582	0.809	0.340
	VGG + GeM [28]	512	0.820	0.831	—
	AWF [29]	512	0.811	0.826	0.360
	Triplet network [30]	512	0.820	0.842	0.362
QPHT [31]		95	0.696	0.812	0.356
Our AQPHT		95	**0.742**	**0.831**	**0.363**

The bold values represent results of our proposed method, which denote the best results among the methods in Table 2.

large margin, which demonstrates the image representation ability of AQPHT which is stronger than that of QPHT.

5. Conclusion

This paper presents a novel computational framework of quaternion-based polar harmonic transform, namely, accuracy quaternion polar harmonic transforms (AQPHTs). Firstly, to holistically deal with color images, AQPHTs are introduced based on the algebra of quaternions. Secondly, geometric errors and numerical errors are reduced by using the Gaussian numerical integration. Many comparative experiments are conducted to analyze the performance of AQPHTs and other ORIMs. Experimental results verify the superb performance of AQPHTs in image reconstruction and invariant image representation. For future work, AQPHTs would be tested in other color image processing domains, e.g., watermarking, segmentation, and retrieval. Besides, more accurate algorithms will be put forward and the computational method of quaternion moments will be improved.

Data Availability

The data included in this paper are available without any restriction from the corresponding author.

Conflicts of Interest

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

Acknowledgments

This work was supported in part by the National Science Foundation of China (NSFC) under Grant no. 61602226 and in part by the PhD Startup Foundation of Liaoning Technical University of China under Grant no. 18-1021.

References

[1] B. Aneta, K. Przemyslaw, and S. Dariusz, "Constant-time calculation of Zernike moments for detection with rotational invariance," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 41, no. 3, pp. 537–551, 2019.

[2] H. Y. Yang, S. R. Qi, C. Wang, S. B. Yang, and X. Y. Wang, "Image analysis by log-polar exponent-fourier moments," *Pattern Recognition*, vol. 101, Article ID 107177, 2020.

[3] K. Arindam, P. Sourav, C. Arghya, B. Debotosh, S. L. H. Edmond, and P. H. S. Hubert, "LMZMPM: local modified Zernike moment per-unit mass for robust human face recognition," *IEEE Transactions on Information Forensics and Security*, vol. 16, pp. 495–509, 2021.

[4] C. Wang, X. Wang, Z. Xia, and C. Zhang, "Ternary radial harmonic fourier moments based robust stereo image zero-watermarking algorithm," *Information Sciences*, vol. 470, pp. 109–120, 2019.

[5] Z. Xia, X. Wang, W. Zhou, R. Li, C. Wang, and C. Zhang, "Color medical image lossless watermarking using chaotic system and accurate quaternion polar harmonic transforms," *Signal Processing*, vol. 157, pp. 108–118, 2019.

[6] Z. Xia, X. Wang, C. Wang, B. Ma, M. Wang, and Y. Q. Shi, "Local quaternion polar harmonic Fourier moments-based multiple zero-watermarking scheme for color medical images," *Knowledge-Based Systems*, vol. 216, Article ID 106568, 2021.

[7] A. W. Deng, C. H. Wei, and C. Y. Gwo, "Stable, fast computation of high-order Zernike moments using a recursive method," *Pattern Recognition*, vol. 56, pp. 16–25, 2016.

[8] Y. D. Zhang, Y. Jiang, W. Zhu, S. Lu, and G. Zhao, "Exploring a smart pathological brain detection method on pseudo Zernike moment," *Multimedia Tools and Applications*, vol. 77, no. 17, pp. 22589–22604, 2018.

[9] P. T. Yap, X. Jiang, and A. C. Kot, "Two-dimensional polar harmonic transforms for invariant image representation," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 32, no. 7, pp. 1259–1270, 2010.

[10] K. M. Hosny and M. M. Darwish, "Highly accurate and numerically stable higher order QPCET moments for color image representation," *Pattern Recognition Letters*, vol. 97, pp. 29–36, 2017.

[11] Y. Liu, S. Zhang, G. Li, H. Wang, and J. Yang, "Accurate quaternion radial harmonic fourier moments for color image reconstruction and object recognition," *Pattern Analysis & Applications*, vol. 23, no. 4, pp. 1551–1567, 2020.

[12] C. Wang, X. Wang, Y. Li, Z. Xia, and C. Zhang, "Quaternion polar harmonic fourier moments for color images," *Information Sciences*, vol. 450, pp. 141–156, 2018.

[13] Y. N. Li, "Quaternion polar harmonic transforms for color images," *IEEE Signal Processing Letters*, vol. 20, no. 8, pp. 803–806, 2013.

[14] Y. Liu, S. Zhang, and J. Yang, "Color image watermark decoder by modeling quaternion polar harmonic transform with BKF distribution," *Signal Processing: Image Communication*, vol. 88, Article ID 115946, 2020.

[15] C. Singh, S. Pooja, and R. Upneja, "On image reconstruction, numerical stability, and invariance of orthogonal radial moments and radial harmonic transforms," *Pattern Recognition and Image Analysis*, vol. 21, no. 4, pp. 663–676, 2011.

[16] K. Simonyan and A. Zisserman, "Very deep convolutional networks for large-scale image recognition," in *Proceedings of the International Conference on Learning Representations*, San Diego, CA, USA, May 2015.

[17] K. He, X. Zhang, S. Ren, and J. Sun, "Deep residual learning for image recognition," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 770–778, CVPR), Las Vegas, NV, USA, December 2016.

[18] W. Tan, B. Yan, and B. Bare, "Feature super-resolution: make machine see more clearly," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 3994–4002, CVPR), Salt Lake City, UT, USA, December 2018.

[19] J. Philbin, O. Chum, M. Isard, J. Sivic, and A. Zisserman, "Object retrieval with large vocabularies and fast spatial matching," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 1–8, CVPR), Minneapolis, MN, USA, July 2007.

[20] Y. Liu, S. Zhang, J. Xu, J. Yang, and Y.-W. Tai, "An accurate and lightweight method for human body image super-resolution," *IEEE Transactions on Image Processing*, vol. 30, pp. 2888–2897, 2021.

[21] Y. Liu, S. Zhang, C. Wang, and J. Xu, "Single image super-resolution via hybrid resolution NSST prediction," *Computer Vision and Image Understanding*, vol. 207, Article ID 103202, 2021.

[22] J. Delhumeau, P. H. Gosselin, H. Jégou, and P. Pérez, "Revisiting the VLAD image representation," in *Proceedings of the 21st ACM International Conference on Multimedia*, pp. 653–656, Barcelona, Spain, October 2013.

[23] H. Jégou, M. Douze, and C. Schmid, "Improving bag-of-features for large scale image search," *International Journal of Computer Vision*, vol. 87, no. 3, pp. 316–336, 2010.

[24] S. K. Kanaparthi, U. S. N. Raju, P. Shanmukhi, G. Khyathi Aneesha, and M. E. U. Rahman, "Image retrieval by integrating global correlation of color and intensity histograms with local texture features," *Multimedia Tools and Applications*, vol. 79, no. 47, pp. 34875–34911, 2020.

[25] M. O. Divya and E. R. Vimina, "Content based image retrieval with multi-channel LBP and colour features," *International Journal of Applied Pattern Recognition*, vol. 6, no. 2, pp. 177–193, 2020.

[26] A. Babenko, A. Slesarev, A. Chigorin, and V. Lempitsky, "Neural codes for image retrieval," in *Proceedings of the European Conference on Computer Vision*, pp. 584–599, ECCV), Zurich, Switzerland, September 2014.

[27] A. Alzu'bi, A. Amira, and N. Ramzan, "Content-based image retrieval with compact deep convolutional features," *Neurocomputing*, vol. 249, pp. 95–105, 2017.

[28] F. Radenović, G. Tolias, and O. Chum, "Fine-tuning CNN image retrieval with No human annotation," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 41, no. 7, pp. 1655–1688, 2018.

[29] J. Qin, J. Chen, X. Xiang, Y. Tan, W. Ma, and J. Wang, "A privacy-preserving image retrieval method based on deep learning and adaptive weighted fusion," *Journal of Real-Time Image Processing*, vol. 17, no. 1, pp. 161–173, 2020.

[30] W. Min, S. Mei, Z. Li, and S. Jiang, "A two-stage triplet network training framework for image retrieval," *IEEE Transactions on Multimedia*, vol. 22, no. 12, pp. 3128–3138, 2020.

[31] Y. N. Liu, S. S. Zhang, Y. Sang, and S. M. Wang, "Improving image retrieval by integrating shape and texture features," *Multimedia Tools and Applications*, vol. 78, no. 2, pp. 2525–2550, 2019.

[32] D. Nister and H. Stewenius, "Scalable recognition with a vocabulary tree," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 2161–2168, New York, NY, USA, October 2006.

[33] H. Jegou, M. Douze, and C. Schmid, "Hamming embedding and weak geometric consistency for large scale image search," in *Proceedings of the European Conference on Computer Vision*, pp. 304–317, Marseille, France, October 2008.

Hindawi
Scientific Programming
Volume 2021, Article ID 6203444, 12 pages
https://doi.org/10.1155/2021/6203444

Research Article

Remote Sensing Image Land Classification Based on Deep Learning

Kai Zhang[1] **Chengquan Hu**[1,2] **and Hang Yu**[3]

[1]*School of Computing, Changchun University of Finance and Economics, Jilin, Changchun 130122, China*
[2]*School of Computing, Jilin University, Jilin, Changchun 130022, China*
[3]*School of Computing, Jilin Agricultural University, Jilin, Changchun 130022, China*

Correspondence should be addressed to Hang Yu; hangy@jlau.edu.cn

Received 11 November 2021; Accepted 3 December 2021; Published 24 December 2021

Academic Editor: Ahmed Farouk

Aiming at the problems of high-resolution remote sensing images with many features and low classification accuracy using a single feature description, a remote sensing image land classification model based on deep learning from the perspective of ecological resource utilization is proposed. Firstly, the remote sensing image obtained by Gaofen-1 satellite is preprocessed, including multispectral data and panchromatic data. Then, the color, texture, shape, and local features are extracted from the image data, and the feature-level image fusion method is used to associate these features to realize the fusion of remote sensing image features. Finally, the fused image features are input into the trained depth belief network (DBN) for processing, and the land type is obtained by the Softmax classifier. Based on the Keras and TensorFlow platform, the experimental analysis of the proposed model shows that it can clearly classify all land types, and the overall accuracy, $F1$ value, and reasoning time of the classification results are 97.86%, 87.25%, and 128 ms, respectively, which are better than other comparative models.

1. Introduction

Remote sensing technology is a technology of observing ground objects by detecting remote sensing images through different working platforms and then processing remote sensing information to obtain some dynamic information, so as to obtain ground information [1]. With the increasing development of remote sensing technology, there are more and more applications of remote sensing image data in various aspects. And remote sensing image classification is of great significance for obtaining image information. It has a wide range of applications in national defense and security construction, urban planning, disaster monitoring, land use, landscape analysis, agricultural remote sensing, etc. [2, 3].

Remote sensing image classification is a hot issue in this field. In the past, artificial visual methods were mostly used for image interpretation. This not only consumes manpower and is inefficient, but also fails to improve accuracy [4, 5]. With the development of computer technology, the technology of image classification using computers combined with appropriate algorithms has replaced manual classification methods and has become the mainstream. Commonly used methods include neural networks and genetic algorithms. [6]. In recent years, remote sensing image acquisition technology has developed rapidly, and the acquired images have become more and more abundant. Such as hyperspectral images and high-resolution images that contain richer feature information [7]. However, the rich feature information also brings certain difficulties to the classification. How to reasonably use the rich feature information to achieve efficient and accurate remote sensing image land classification is an urgent problem to be solved [8, 9]. At the same time, the overall planning and application of remote sensing image data is also becoming more refined, and the monitored results and data need to be more comprehensive and accurate. Therefore, a new challenge is presented to remote sensing image land classification [10].

Aiming at the comprehensive application of remote sensing image refinement, a remote sensing image land classification model based on deep learning from the perspective of ecological resource utilization is proposed. Compared with the traditional model, its innovations are summarized as follows:

(1) Since the accuracy of single feature description and classification is not high, the proposed model extracts 9 features including color, texture, part, and shape. And based on the feature-level image fusion method for feature fusion, the effective discrimination information of the feature can be retained to the greatest extent, and the reliability of classification can be improved.

(2) In order to improve the accuracy of remote sensing image land classification, the proposed model uses DBN to process the fused image features. Combining the results of forward unsupervised classification and label data, the training network is fine-tuned according to the law of error back propagation, thus shortening the time of land classification.

2. Related Research

Remote sensing image classification methods usually include supervised classification and unsupervised classification. However, the classification accuracy of traditional remote sensing image classification methods is low, and manual interpretation is easily affected by subjective factors, which reduces the credibility of classification [11]. Traditional classification methods for nonartificial classification usually include feature-space indicator kriging (FSIK), traditional parameter maximum likelihood (ML), widely used nonparametric method support vector machine (SVM), and random forest (RF). Reference [12] proposed a stochastic simulation classification algorithm based on feature-space index simulation. It shows good performance in improving the accuracy of remote sensing image classification, but the performance of image classification under complex background needs to be improved. Reference [13] aimed at the land use in the priority areas of national forest resources, based on satellite images in three periods, used the ML method for image supervision and classification, and achieved high classification accuracy. However, the high performance of pure spectral segmentation based on a single image pixel needs to be improved. Reference [14] studied the multisensor data fusion of land classification in semiarid environment. A multispectral image classification method based on wavelet transform is proposed, which achieves high classification accuracy. Reference [15] proposed a land remote sensing image classifier based on RF, which realizes the classification of land images in complex background environments in the case of multidata fusion. However, the algorithm parameter setting is more complicated, which is difficult for practical applications.

With the increase in the resolution of remote sensing images, the images contain a variety of complex and diverse information, but traditional methods cannot make good use of various features. The increase of high-resolution remote sensing data and the development of computer technology make it possible to apply deep learning in remote sensing image classification [16]. Convolutional neural network (CNN), DBN, and autoencoder (AE) are the main models of deep learning [17]. Reference [18] compared deep learning and non-deep learning SVM methods, and CNN's classification method showed better classification performance. Reference [19] proposed a remote sensing image segmentation method based on depth learning. Shallow learning can output different classification results for a certain input, whereas deep learning can continue to learn from the shallow output to improve the accuracy of image classification. However, the performance of the algorithm depends too much on the training samples, and the transferability is poor. Reference [20] proposed a multiscale dense network (MSDN) for hyperspectral remote sensing image (HSI) classification. It makes full use of the different scale information in the network structure and combines the scale information of the entire network to achieve two-dimensional HSI feature extraction with different accuracy levels. However, it is impossible to balance the image classification performance under dominant and individual factors. Reference [21] proposes a remote sensing image segmentation method based on Fletcher–Reeves CNN for the situation that there are few optional training samples in the actual image classification process. The anti-interference and convergence performance of the proposed model is analyzed from different training sample datasets, different batch number of training samples, and iteration time, but it has poor adaptability to image classification with different rules and different scales. The abovementioned research based on CNN algorithm has achieved good results in the field of remote sensing image classification, but it is rarely involved in the use of ecological resources. Therefore, a remote sensing image land classification method based on deep learning from the perspective of ecological resource utilization is proposed, which improves the efficiency and accuracy of classification while taking into account the utilization of ecological environment resources.

3. Data Collection and Preprocessing

3.1. Data Source. The research object selected the 2-meter panchromatic/8-meter multispectral data of Sijing Gaofen No. 1 in Jinfeng District, Yinchuan in 2020, as shown in Figure 1. The main remote sensing data used are the domestic satellite Gaofen-1, with a resolution of 2 m panchromatic/8 m multispectral.

The Gaofen-1 (GF-1) satellite is a high-resolution Earth observation satellite developed by my country's China Aerospace Science and Technology Corporation and launched on April 26, 2013 at the Jiuquan Satellite Launch Center in Gansu. The satellite is equipped with two multispectral high-resolution cameras with a spatial resolution of 2 meters in full color/8 meters, and four multispectral wide-format cameras with a spatial resolution of 16 meters. The orbit of the GF-1 satellite is a sun-synchronous orbit with a height of 645.0 km. The launch of the GF-1 satellite broke through my country's difficulties in the combination of high-resolution (time and space) and multispectral technology. Not only has it played a key role in extending

Figure 1: Remote sensing image of Jinfeng District.

the lifetime of satellites, but it has also greatly accelerated the development of high-resolution satellite research in China. The parameters of the domestic GF-1 satellite are shown in Table 1.

The standard products of Gaofen-1 satellite are mainly divided into two categories: A-level and 2A-level. A-level is a preprocessing-level radiation correction impact product, including the impact data of level 0 data processed by data analysis, normalized radiation correction, denoising, image stitching, and band registration, and provides RPC files generated by satellite in-orbit data. Level 2A is the initial geometric correction impact product, including the impact product produced by the geometric correction of the 1A-level data and the map projection.

3.2. Remote Sensing Data Preprocessing

3.2.1. Multispectral Data Preprocessing

(1) Radiometric calibration. The ENVI software is used to perform radiometric calibration on the GF-1 remote sensing image, and the gray value of the image is converted into the radiance at the pupil of the sensor. ENVI software can automatically select the radiation calibration coefficients released in the corresponding time period for GF-1 remote sensing images acquired in different time periods.

(2) Atmospheric correction. Electromagnetic waves are absorbed, scattered, and scattered by the atmosphere during their transmission through the atmosphere and are disturbed to varying degrees. It is necessary to perform atmospheric correction processing on remote sensing images. Fast line of sight atmospheric analysis of Hypercubes (FLAASH) module of ENVI 5.3 is used for atmospheric correction to reduce the influence of atmosphere. The software module can automatically read the sensor height, longitude, and latitude of the center point, sensor type, pixel size, imaging time, and other information. Set the average height of the imaging area, atmospheric model, and aerosol type, and finally get the surface reflectance image.

(3) Orthorectification. First, use the RPB file that comes with the GF-1 image to perform "orthorectification" processing on the surface reflectance image based on the RPC model. The digital elevation model (DEM) used is a ZY-3 DEM with a spatial resolution of 8 m.

Secondly, take the ZY-3 digital orthophoto map (DOM) with a spatial resolution of 2 m as a reference. The automatic matching algorithm is used to perform image-to-image registration processing on the "orthorectification" result image, and 30 control points are manually collected to check the correction accuracy. Among them, the east-west error of the GF-1 remote sensing image in 2018 is 4.15 m, and the north-south error is 1.25 m. In 2020, the east-west error of the GF-1 remote sensing image is 1.65 m, and the north-south error is 2.05 m.

3.2.2. Panchromatic Data Preprocessing. Since the research needs to fuse the panchromatic data of September 2020 into the multispectral data for classification, the panchromatic band of the GF-1 image of this period needs to be preprocessed.

Firstly, perform radiometric calibration and atmospheric correction on the panchromatic image in ENVI. Secondly, orthorectify the panchromatic image after radiometric calibration. The ZY-3 DEM is also used, but the ZY-3 DEM is oversampled before correction to make its pixel size 0.8 m. Furthermore, the panchromatic image is orthorectified based on the RPC model. Then, use the automatic image registration tool in ENVI, with ZY-3 DOM as the reference image. By automatically finding control points and establishing a polynomial registration equation, the GF-1 panchromatic image after orthorectification is corrected to the geographic coordinate space of the DOM image. Finally, ENVI's fusion tool NNDiffuse Pan Sharpening is used to fuse panchromatic and multispectral images to obtain 0.8 m high spatial resolution multispectral remote sensing images.

4. DBN Remote Sensing Image Land Classification Based on Multifeature Fusion

4.1. Multifeature Fusion. Image fusion improves image clarity and information content and can accurately, reliably, and comprehensively obtain target or scene information. Fusion is mainly divided into three levels: pixel level, feature level, and decision-making level.

The most basic method among the three levels is based on pixel-level image fusion. Through pixel-level fusion, more detailed information, such as edge and texture information, can be obtained, which is helpful for image analysis and processing. The hidden target can also be revealed, which helps to judge the recognition and extraction of the hidden target point. Based on this method, more information in the original image can be saved, and the content and details of the fused image will also increase. This advantage is unique to pixel-level fusion [22]. But the pixel-level image fusion method also has drawbacks, because the method is aimed at pixel operations. An image contains a large number of pixels, which leads to a long computer calculation time, and the

Table 1: Specific parameter data of Gaofen-1.

Parameter		2 m panchromatic/8 m multispectral high-resolution camera	16 m multispectral wide-range camera
Spectral range	Panchromatic	0.45–0.9 μm	
	Multispectral	0.45–0.52 μm 0.52–0.59 μm 0.63–0.69 μm 0.77–0.89 μm	0.45–0.52 μm 0.52–0.59 μm 0.63–0.69 μm 0.77–0.89 μm
Spatial resolution	Panchromatic	2 m	16 m
	Multispectral	8 m	
Wide in width	—	60 km (combination of 2 cameras)	800 km (combination of 4 cameras)
Revisit period	—	4 days	—
Coverage period	—	41 days	41 days
Sway ability	—	±25°	
Emergency side swing	—	±35°°	

fusion result cannot be obtained quickly. If the registration is wrong, the target and details of the fused image will be blurred directly, resulting in great errors [23].

The feature-level image fusion method is to extract feature information from the original image. The feature information is based on the researcher's analysis of the research object in the image, such as vehicles, pedestrians, and numbers, and then extracts the relevant feature information that can fully express the target. Compared with the original image, the accuracy of target recognition and extraction based on the feature fusion information will be significantly improved. The compressed image information can be obtained through the feature-level fusion method, and the compressed information is reused for computer analysis and processing. Compared with the pixel-level fusion method, the memory and time consumption are reduced, and the fusion result can be obtained faster.

Decision-level image fusion is a fusion method of the highest level based on cognition [24]. The method can be operated in a targeted manner according to the specific requirements of the problem and make a decision based on the characteristics obtained at the feature level, certain criteria, and the probability of the existence of the target. In the three-level image fusion, the amount of calculation is the smallest, but it depends on the previous level. Therefore, compared with the previous two fusion methods, the image obtained is not clear, and the real implementation is also very difficult.

In summary, the feature-level image fusion algorithm is selected to associate the extracted multiple types of features. Feature-level fusion can complement the single feature information while eliminating redundant information. The image feature fusion process is shown in Figure 2. It can maximize the effective discrimination information of features and provide a basis for the classification decision of the classifier.

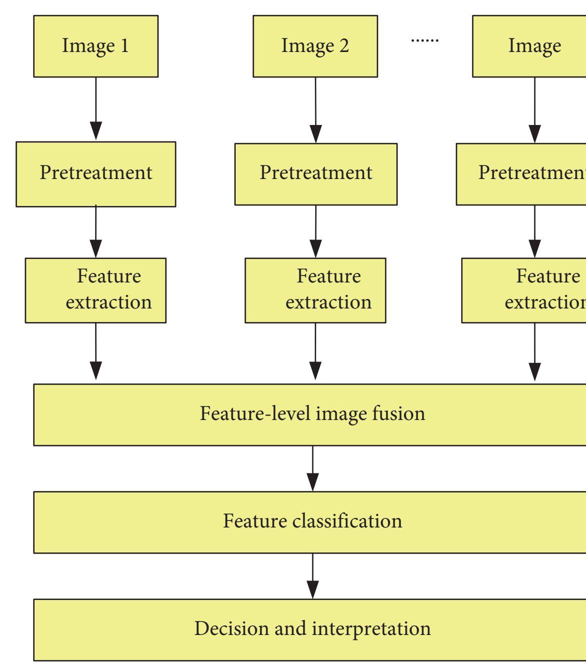


Figure 2: Process of feature-level image fusion.

4.2. Classification Model. DBN is a kind of probabilistic generative model, which establishes the joint distribution between input data and label data through the learning process [25]. Structurally, the DBN model is composed of a multilayer restricted Boltzmann machine (RBM) and the top Softmax classifier. Correctly constructing a DBN model is the key to accurately and efficiently extracting land types from remote sensing images. Reasonably designing the framework of the DBN model, such as the number of layers of the RBM network, can effectively improve the classification efficiency. Determining reasonable DBN model operating parameters, such as the learning rate, the number of positive unsupervised learning, and the number of hidden layer neurons, can greatly improve the accuracy of the classification results [26]. Considering the classification effect and training efficiency of the model, a DBN model with a network specification of 124-250-250-2 is constructed. The model structure is shown in Figure 3.

By setting up a control experiment and comparing the classification efficiency of the model, it is determined that the RBM layer stacked by the DBN model is two layers. RBM is a special generative neural network. A single RBM is a two-layer neural network composed of a visible layer and a

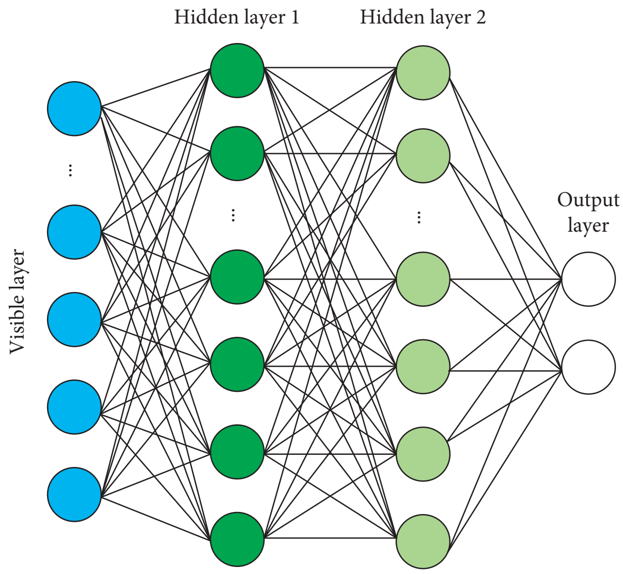


Figure 3: Network structure of DBN.

hidden layer. The neurons in each layer are not connected, and there is no self-feedback phenomenon in the layer. The neurons in the visible layer and the neurons in the hidden layer are fully connected in both directions.

The classification process of the DBN model is based on pixel-level classification. Therefore, the number of neurons in the visible layer is the same as the dimensionality of the multispectral data; that is, the visible layer is composed of 132 neurons. The essence of the forward learning process of the DBN model is the process of feature extraction. When the RBM maps the characteristic information of the neurons in the visible layer, the neurons in the hidden layer of the RBM have the same activation probability. After several trainings, the characteristics of the visible layer of neurons can be accurately expressed. Through setting experiments, the number of neurons in the hidden layer is determined to be 280. At this point, the RBM can be regarded as an autoencoder for extracting the characteristic information of neurons in the visible layer. Among them, the energy function between the visible layer and the hidden layer is expressed as follows:

$$E(v,h,\omega,b_1,b_2) = -\sum_i\sum_j \omega_{ij}v_ih_j - \sum_i b_{1i}v_i - \sum_j b_{2j}h_j, \tag{1}$$

where ω_{ij} is the weight connecting the visible layer neuron i and the hidden layer neuron j. b_1 and b_2 are the biases of the visible layer neuron and the hidden layer neuron, respectively. Among them, the joint probability distribution between neurons is calculated as follows:

$$\begin{aligned} P(v,h,\omega,b_1,b_2) &= \frac{1}{Q}e^{-E(v,h,\omega,b_1,b_2)}, \\ Q &= \sum_v\sum_h e^{-E(v,h,\omega,b_1,b_2)}. \end{aligned} \tag{2}$$

Assuming that the input value of the DBN model is X and the output value of the hidden layer is H, then the weight and bias update formula connecting the hidden layer neuron and the output layer neuron is

$$\omega_{ij} = \omega_{ij} + \varepsilon H_j\left(1-H_j\right)X(i)\sum_k \omega_{jk}\delta_k, \tag{3}$$

where δ_k is the difference between the actual output value of the DBN model and the true category of the input value. ε is the learning rate of the DBN model.

The classification process of the DBN model consists of two stages: forward unsupervised "layer-by-layer initialization" learning and reverse supervised "fine-tuning" learning. The classification process is shown in Figure 4.

The first stage of training is also called the pretraining process. The DBN model performs forward training through a layer-by-layer initialization learning method. By stacking the RBM layers, map and transfer the characteristic information of the input layer data in turn. The proposed model has a Softmax classifier on top of the top RBM. The Softmax classifier receives the output information of the top RBM as input information. The Softmax classifier outputs the classification result of the forward learning process by comparing the probability distribution. The Softmax classifier is constructed with a multinomial distribution as a model. It can be understood that the logistic regression classifier faces generalized induction of multiple classifications and can be used for multiclassification problems. The purpose is to convert the output information of RBM into a probability distribution. The mathematical representation of the Softmax classifier is as follows:

$$\text{Soft max}(y)_i = \frac{e^{y_i}}{\sum_{j=1}^{n} e^{y_i}}, \tag{4}$$

where y is the output vector of RBM.

The second stage of training is also called the fine-tuning process. Through the first stage of pretraining, the RBM network of each layer can only ensure that the weight of this layer reaches the optimal expression of the characteristic information of the layer and cannot make the mapping of the input information of the entire DBN model reach the optimal. This requires back propagation (BP) algorithm, combined with forward unsupervised classification results and label data, according to the law of error back propagation from top to bottom, fine-tuning the connection weight and bias between neurons in each layer of the whole DBN model layer by layer. The whole classification process greatly suppresses the overfitting phenomenon, which is easy to appear in a single BP neural network, thus obtaining the parameter setting, which makes the square sum of error of DBN model minimum.

4.3. Algorithm Flow

4.3.1. Multifeature Fusion Method. Feature-level fusion algorithms are mainly divided into three types: The first is feature combination; that is, all features are combined into new features according to serial and parallel methods, such as serial and parallel fusion algorithms, covariance matrix methods, and methods based on multifeature histograms. The

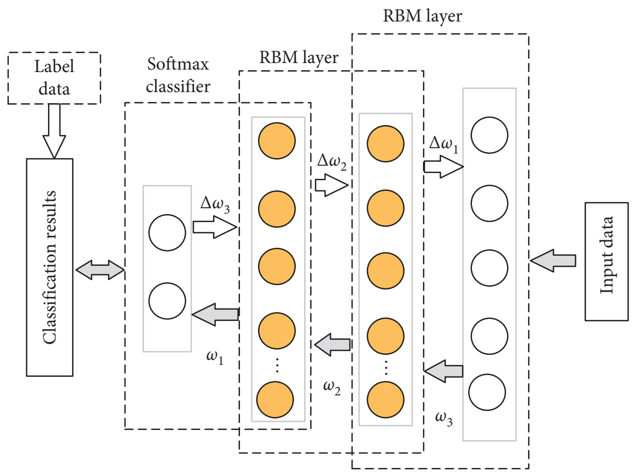


FIGURE 4: Classification process of the DBN model.

second is feature selection. The optimal calculation method is used to select the feature vector that has the best classification result from the combined features, such as the feature fusion algorithm based on genetic algorithm, artificial neural network, and fuzzy logic. The third is feature transformation, which uses mathematical methods to transform the image into a new way of expression, such as methods based on complex principal component analysis, canonical correlation analysis, and complex independent component analysis.

Since there are 7 features selected in this article, there will be multiple combinations in feature fusion, and it takes many trial and error steps to select the best feature combination. Therefore, this article adopts a simple and classic serial method for feature fusion. Combine multiple feature permutations into a new feature vector, use the deep belief network to classify based on the new feature vector, and finally determine the optimal feature combination. The specific fusion algorithm composes a new feature vector according to the end-to-end method and then uses the new feature vector for classification and recognition.

4.3.2. Algorithm Flow. The specific process of the proposed DBN classification model based on multifeature fusion is

(1) Nine features were extracted. Two texture features are extracted by gray histogram and wavelet transform algorithm. Three color features are obtained through color histogram and color moment. One shape feature is obtained by the moment invariant algorithm, and three local features are obtained by solving the census and scale-invariant feature transformation algorithm. Finally, a total of 9 characteristic values are obtained.

(2) Normalize the 9 features and convert the data to [0-1]. The selected normalization function is

$$X^* = \frac{X - X_{\min}}{X_{\max} - X_{\min}}. \tag{5}$$

In the formula, X and X^* are the data before and after normalization respectively. $X_{\max}$ and $X_{\min}$ are the maximum and minimum values of the data, respectively.

(3) The nine normalized feature vectors are serially fused to obtain new features of the image as the input of the DBN model. Fully consider the computational complexity and classification accuracy to determine the final DBN network model.

(4) The test data are input into DBN for testing using the same feature fusion method, and the Softmax method is used to complete the classification of remote sensing image land types.

The process of remote sensing image classification model based on multifeature fusion and DBN is shown in Figure 5.

Firstly, the DBN model is trained with training dataset, including feature extraction and fusion. Then, feature extraction is performed on the test data set, including color, texture, shape, and local features. It is fused into the trained DBN model to obtain the land type of the remote sensing image.

5. Experiment and Analysis

The experiment was trained on Ubuntu 16.04 system, using NVIDIA Ge Force Titan X graphics device, and the device has a total of 2 pieces, each with 12 GB of graphics memory. And the DBN model is implemented in the open-source frameworks Keras and TensorFlow.

At the same time, indicators such as overall accuracy (OA), recall (Recall), precision (Precision), and Intersection over Union (IoU) are used to evaluate the classification performance of the proposed model. Among them, OA is the proportion of correct pixels that the classification model judges. The recall rate is the proportion of positive samples that are correctly classified. The precision is the proportion of the classified positive samples to the total samples. IoU is the similarity between real and classified samples. The calculation of each indicator is as follows:

$$\begin{aligned} \text{OA} &= \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FP} + \text{FN} + \text{TN}}, \\ \text{Recall} &= \frac{\text{TP}}{\text{TP} + \text{FN}}, \\ \text{Precision} &= \frac{\text{TP}}{\text{TP} + \text{FP}}, \\ \text{IoU} &= \frac{\text{TP}}{\text{TP} + \text{FP} + \text{FN}}. \end{aligned} \tag{6}$$

In the formula, TP represents the classification of positive samples as positive sample instances; FP represents the classification of negative samples as positive sample instances; FN represents the classification of positive samples as negative sample instances; and TN represents the classification of negative samples as negative sample instances.

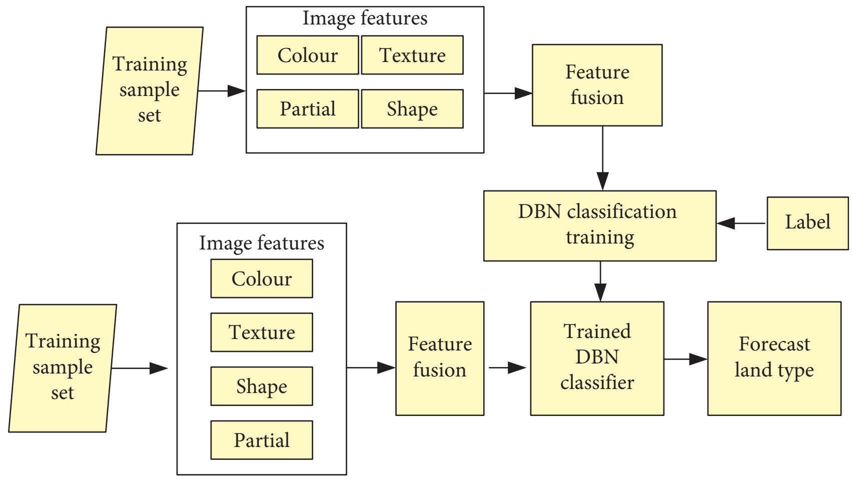


Figure 5: The process of remote sensing image classification.

5.1. Analysis of the Influence of Network Parameter Adjustment. By adjusting various operating parameters of the DBN model, such as the number of hidden layer neurons, learning rate, and the number of positive unsupervised learning, the influence of various parameters on the DBN model and classification results is analyzed.

5.1.1. Number of Hidden Layer Neurons. By adjusting the number of neurons in the hidden layer, on the basis of consistent experimental conditions, the classification accuracy when the number of neurons is 120, 160, 200, 240, 280, 320, 360, respectively, is compared, and the results are shown in Figure 6.

It can be seen from Figure 6 that the classification accuracy of the DBN model for remote sensing images fluctuates with the change of the number of neurons in the hidden layer. When the number of hidden layer neurons reaches 280, the classification effect reaches the best, which is 97.28. When the number of neurons exceeds 280, the DBN model appears overfitting, and the classification accuracy decreases as the number of hidden layer neurons increases.

The number of neurons in the hidden layer of the RBM determines the accuracy of the DBN model's description of the characteristics of the input data. If the number of neurons in the hidden layer is set too small, the characteristic information of the input data cannot be accurately expressed. Too many hidden layer neurons will increase the training time and complexity of the entire pretraining process, and even overfitting will occur.

5.1.2. Learning Rate. The DBN model is trained according to the stochastic gradient descent algorithm, and the learning rate needs to be introduced to adjust the training rhythm of the training process. By adjusting the size of the learning rate, based on the consistency of other experimental conditions, the classification accuracy when the learning rate is 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, and 0.75 is compared. The result is shown in Figure 7.

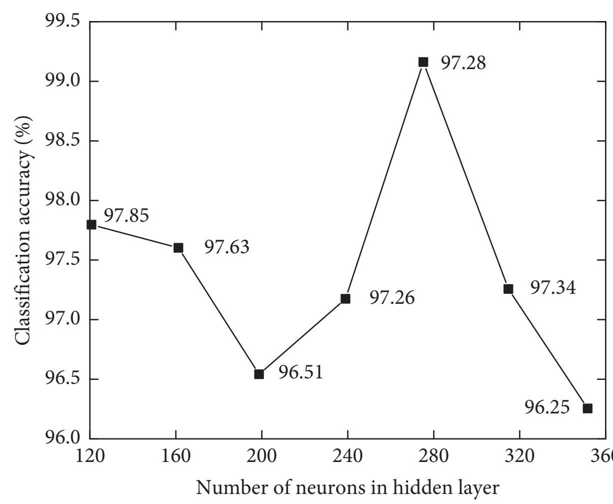


Figure 6: Relationship between the number of hidden layer neurons and classification accuracy.

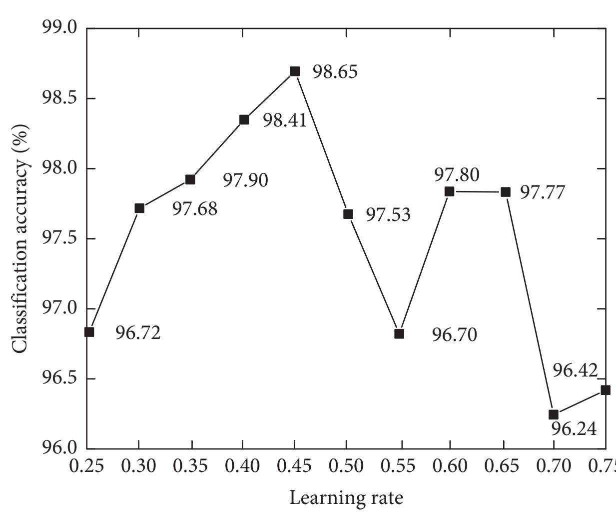


Figure 7: The relationship between learning rate and classification accuracy.

It can be seen from Figure 7 that the classification accuracy of the DBN model varies with the learning rate. When the learning rate is low, the classification accuracy of the DBN model increases as the learning rate increases. When the learning rate reaches 0.45, the classification accuracy of the DBN model reaches the best, 98.65%. When the learning rate exceeds 0.45, the DBN model has overfitting phenomenon, and the classification accuracy shows a downward trend as a whole.

The learning rate determines the step length of the weight in the direction of gradient movement. In the forward unsupervised learning process of the DBN model, the learning rate is mainly responsible for the weight update. In the reverse fine-tuning process, the learning rate is responsible for adjusting the convergence rate of the entire model. It has a vital impact on the classification accuracy of the DBN model. In addition, a lower learning rate will increase the credibility of the training results, but the training process will take a long time. A high learning rate will cause the connection weight to change too much, which may cause the training of the DBN model to fail to converge and the output result to be unstable.

5.1.3. Number of Positive Unsupervised Learning. By adjusting the number of forward unsupervised training, comparing the classification accuracy when the number of training is 30, 60, 90, 120, 150, 180, and 210, the result is shown in Figure 8.

It can be seen from Figure 8 that the classification accuracy of the DBN model fluctuates with the change of the number of forward unsupervised learning. When the number of forward learning reaches 120 times, the classification accuracy of the DBN model reaches the best, which is 97.61%. When the number of learning times exceeds 120 times, the DBN model appears overfitting, and the classification accuracy gradually decreases.

The forward training process of the DBN model is an unsupervised learning process. Each training of the DBN model is accompanied by the update of the weights and biases between neurons. Therefore, the number of forward unsupervised learning determines the number of updates of each parameter of the DBN model. Setting more positive unsupervised learning during training is beneficial to the DBN model to express the characteristic information of the input neuron more effectively. However, multiple positive learning not only affects the training efficiency of the model, but also causes the classification results of the DBN model to appear overfitting.

5.2. Qualitative Comparison of Classification Results. Using the proposed model for remote sensing image processing, the land classification results of Jinfeng District are obtained, as shown in Figure 9. Various features are presented in remote sensing images. The water body is blue, vegetation is dark green, light green is cultivated land, yellow is bare land, pink is construction land, and orange is road.

It can be seen from Figure 9 that the land types obtained by using the DBN model are very clearly presented in the

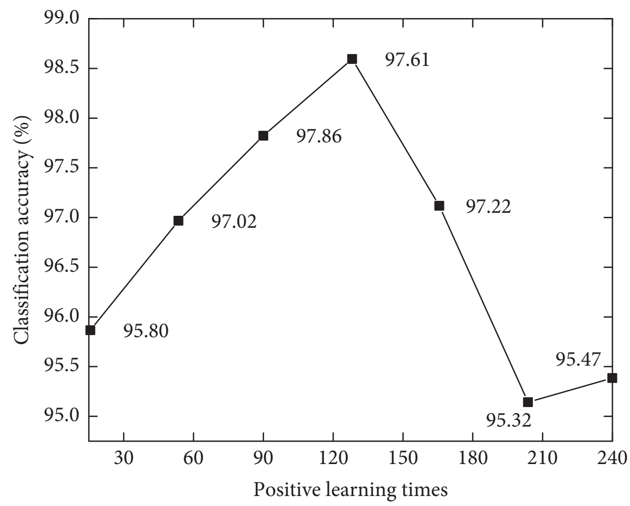


Figure 8: Relationship between positive learning times and classification accuracy.

remote sensing images, which provides ideal support for the monitoring and subsequent utilization of ecological resources. In order to demonstrate the classification performance of the proposed model, it is qualitatively analyzed with reference [14, 19], and three local areas in Jinfeng District are selected for land classification. The result is shown in Figure 10.

It can be seen from Figure 10 that the classification performance of reference [14] is not satisfactory. Due to the irregular distribution of construction land and the complicated boundaries between foreground and background, it is difficult to extract its features in such a complex remote sensing image for accurate target recognition. In reference [19] because the design of the model follows a larger receptive field, the identification pays more attention to the overall information and only correctly identifies the construction land, which is slightly insufficient in detail. The proposed model comprehensively considers the characteristics of various aspects of remote sensing images and integrates them, and at the same time uses the DBN model for classification. Therefore, the construction land area is clearly divided into the recognition result. Although there are slightly jagged edges, overall, the classification results are better than other comparison models.

5.3. Quantitative Analysis of Classification Results. In order to quantitatively analyze the performance of the proposed classification model, compare it with reference [14, 19]. The results of each evaluation index are shown in Table 2.

It can be seen from Table 2 that the visual sensory and data verification are relatively consistent. The OA of the proposed model is 97.86%, and the IoU is 95.09%, which are 2.34% and 2.55% higher than those in reference [19]. Reference [14] uses wavelet transform for image classification. The method is more traditional and difficult to apply to complex remote sensing images. Therefore, the IoU is 88.58%, and the classification effect is not ideal.

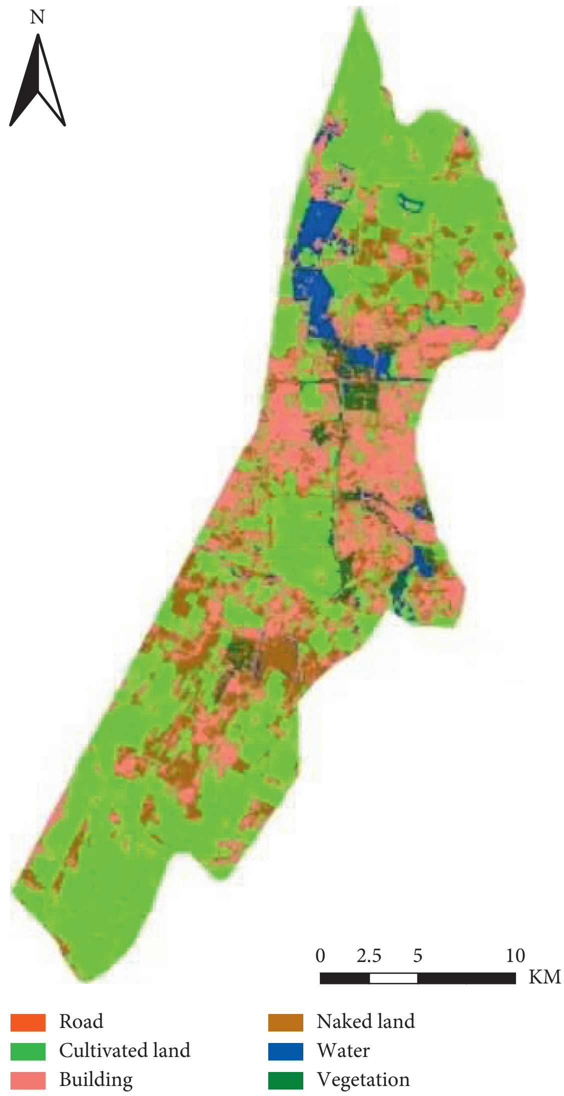
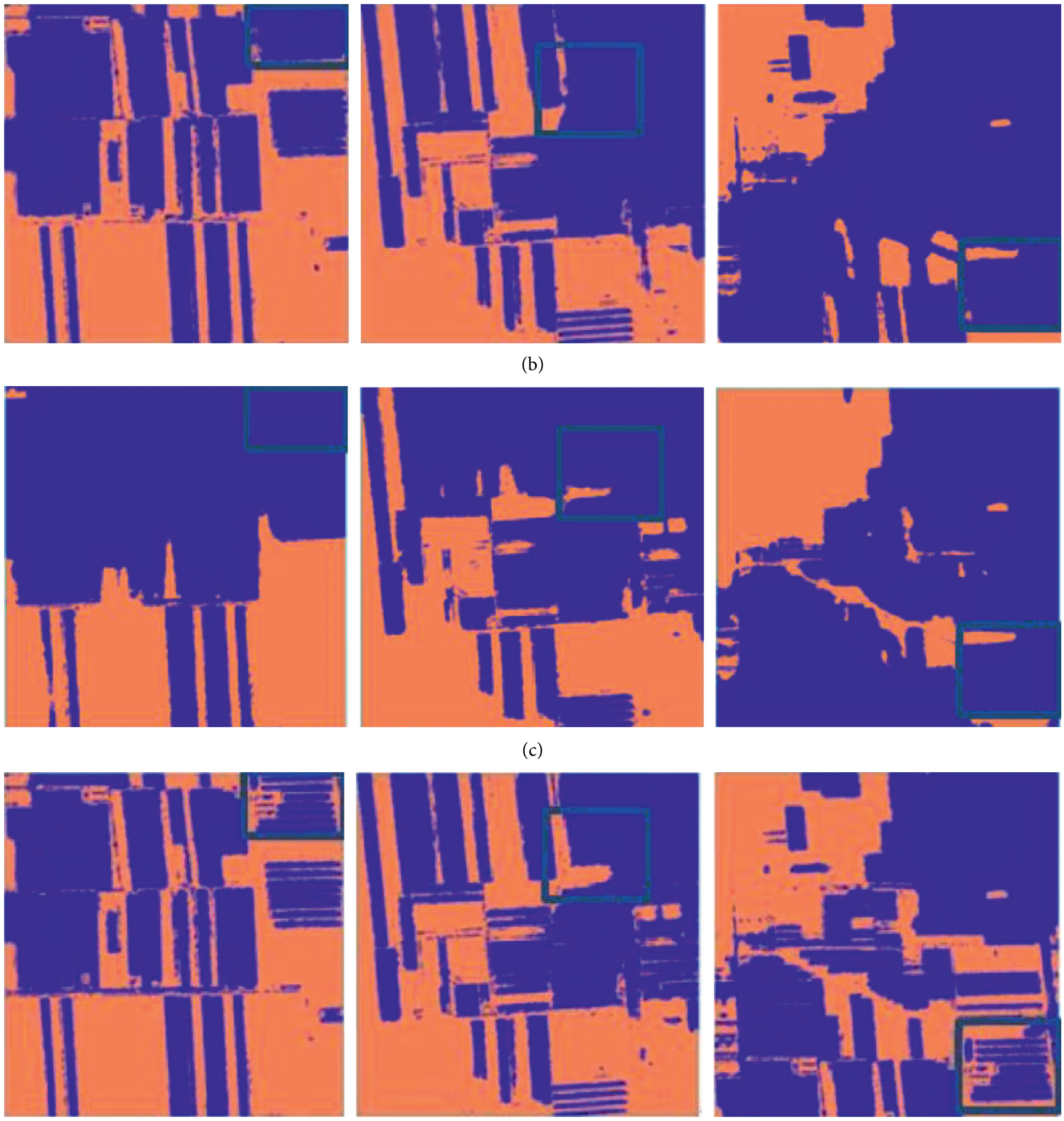


Figure 9: Land classification results of remote sensing image in Jinfeng District.

(a)

Figure 10: Continued.



(b)

(c)

(d)

Figure 10: Comparison of land classification results from remote sensing images.

Table 2: Comparison results of each classification model.

	Ref. [14]	Ref. [19]	The proposed model
OA (%)	90.84	95.62	97.86
Precision (%)	90.66	95.48	97.59
Recall (%)	90.37	94.91	97.27
IoU (%)	88.58	92.73	95.09

The relationship between time consumption and accuracy has always been the focus of deep learning research. The amount of network parameters and GPU inference time reflect the overall time consumption of the network. In order to prove the universality of the proposed model, the official $F1$ index was used to measure the accuracy in the experiment, and the parameter quantity (Params) and the inference speed of the graphic processing unit (GPU) were used to measure the time consumption. The results are shown in Table 3.

It can be seen from Table 3 that the higher accuracy of reference [19] is at the cost of time. Since it does not perform operations such as dimensionality reduction or preprocessing, the network has a huge amount of parameters of 49.83 M. The image classification time is 290 ms, which is difficult to achieve high efficiency. The wavelet transform model of reference [14] has a simple network, so the parameter is only 23.95 M. The inference time to complete the classification is only 115 ms, but the overall accuracy is not high. The proposed model adopts operations such as image

Table 3: Time consumption comparison results of each classification model.

	Ref. [14]	Ref. [19]	The proposed model
*F*1 (%)	80.48	85.36	87.25
Params (M)	23.95	49.83	36.02
Reasoning time (ms)	115	236	128

preprocessing and feature fusion, which reduces the amount of parameters to 36.02 M. While ensuring the accuracy of classification, the reasoning time is shortened, and the time consumption is 128 ms. Even if the time consumption is not the shortest, but considering the speed and accuracy, the proposed model can meet the actual needs.

6. Conclusion

Land cover type is the key and extensive research field in ecological environment observation. However, the land form is affected by the season, and the recognition effect of most classification methods is not ideal. To this end, a remote sensing image land classification model based on deep learning from the perspective of ecological resource utilization is proposed, combining feature-level image fusion methods and DBN network model processing and analysis of remote sensing image data obtained by the Gaofen-1 satellite to obtain land types efficiently and accurately. Based on the Keras and TensorFlow platform, the proposed model is experimentally demonstrated. The results show that when the number of hidden layer neurons is set to 280, the learning rate is set to 0.45, and the number of forward unsupervised learning is set to 120, the classification performance of the DBN model is the best. And the proposed model can clearly classify the types of land. The results of OA, *F*1 value, and reasoning time were 97.86%, 87.25%, and 128 ms, respectively, which are better than other comparison models, providing technical support for deep learning in the field of remote sensing.

At present, deep learning is the mainstream way to analyze remote sensing images, but the problem of poor interpretability of deep learning has always hindered the development speed of deep learning. The development of traditional remote sensing technology has gone through many years, with a sound theoretical foundation and rich practical applications. Even if the accuracy is not as good as deep learning methods, similar exponential models and time series dynamic analysis models are instructive. In the future, how to use traditional remote sensing technology to provide more effective feature input for deep learning networks will greatly improve the generalization ability and classification accuracy of deep learning.

Data Availability

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

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

[1] S. Dong, Y. Zhuang, Z. Yang, L. Pang, H. Chen, and T. Long, “Land cover classification from VHR optical remote sensing images by feature ensemble deep learning network,” *IEEE Geoscience and Remote Sensing Letters*, vol. 17, no. 8, pp. 1396–1400, 2020.

[2] S. Di, Z. L. Li, R. Tang, X. Pan, H. Liu, and Y. Niu, “Urban green space classification and water consumption analysis with remote-sensing technology: a case study in Beijing, China,” *International Journal of Remote Sensing*, vol. 40, no. 5-6, pp. 1909–1929, 2019.

[3] H. He, H. Xing, D. Hu, and X. Yu, “Novel fuzzy uncertainty modeling for land cover classification based on clustering analysis,” *Science China(Earth Sciences)*, vol. 62, no. 2, pp. 94–106, 2019.

[4] K. U. Maheswari and S. Rajesh, “A novel QIM-DCT based fusion approach for classification of remote sensing images via PSO and SVM models,” *Soft Computing*, vol. 24, no. 20, Article ID 15561, 2020.

[5] H. Shao, Y. Li, Y. Ding, Q. Zhuang, and Y. Chen, “Land use classification using high-resolution remote sensing images based on structural topic model,” *IEEE Access*, vol. 8, no. 5, Article ID 215943, 2020.

[6] M. Boell, H. R. Alves, M. Volpato, D. Ferreira, and W. Lacerda, “Exploiting feature extraction techniques for remote sensing image classification,” *IEEE Latin America Transactions*, vol. 16, no. 10, pp. 2657–2664, 2019.

[7] Z. Shan, Z. Wang, C. Gao, K. Zhen, and D. Feng, “Hyperspectral image classification with global–local discriminant analysis and spatial–spectral context,” *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 11, no. 12, pp. 5005–5018, 2019.

[8] S. Pan, H. Guan, Y. Chen et al., “Land-cover classification of multispectral LiDAR data using CNN with optimized hyper-parameters,” *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 166, no. 3, pp. 241–254, 2020.

[9] B. Ren, B. Hou, J. Chanussot, and L. Jiao, “PolSAR feature extraction via tensor embedding framework for land cover classification,” *IEEE Transactions on Geoscience and Remote Sensing*, vol. 58, no. 4, pp. 2337–2351, 2019.

[10] Y. Zhang, F. Liu, L. Jiao, S. Yang, L. Li, and M. Yang, “Discriminative sketch topic model with structural constraint for SAR image classification,” *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 13, no. 3, pp. 5730–5745, 2020.

[11] Y. Shendryk, Y. Rist, C. Ticehurst, and P. Thorburn, “Deep learning for multi-modal classification of cloud, shadow and land cover scenes in PlanetScope and Sentinel-2 imagery,” *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 157, no. 11, pp. 124–136, 2019.

[12] Q. Wang, H. Sun, R. Li, and G. Wang, “A new stochastic simulation algorithm for image-based classification: feature-space indicator simulation,” *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 152, no. 6, pp. 145–165, 2019.

[13] B. Emiru, A. Haregeweini, A. F. Ayele et al., “Land use land cover changes along topographic gradients in Hugumburda national forest priority area, Northern Ethiopia - ScienceDirect,” *Remote Sensing Applications: Society and Environment*, vol. 13, no. 4, pp. 61–68, 2019.

[14] P. Iervolino, R. Guida, D. Riccio, and R. Rea, “A novel multispectral, panchromatic and SAR data fusion for land classification,” *IEEE Journal of Selected Topics in Applied Earth*

Observations and Remote Sensing, vol. 12, no. 10, pp. 3966–3979, 2019.
[15] Q. Wu, R. Zhong, W. Zhao, K. Song, and L. M. Du, "Land-cover classification using GF-2 images and airborne lidar data based on Random Forest," *International Journal of Remote Sensing*, vol. 40, no. 5-6, pp. 2410–2426, 2019.
[16] A. Shaker, W. Y. Yan, and P. E. Larocque, "Automatic land-water classification using multispectral airborne LiDAR data for near-shore and river environments," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 152, no. 6, pp. 94–108, 2019.
[17] B. Sergio, C. Martiño, S. Neftalí, G. P. Manuel, N. Horacio, and N.. Jorge, "Fully automatic multi-temporal land cover classification using Sentinel-2 image data," *Procedia Computer Science*, vol. 159, no. 8, pp. 650–657, 2019.
[18] S. S. Heydari and G. Mountrakis, "Meta-analysis of deep neural networks in remote sensing: a comparative study of mono-temporal classification to support vector machines," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 152, no. 6, pp. 192–210, 2019.
[19] P. Dou, H. Shen, Z. Li, X. Guan, and W. Huang, "Remote sensing image classification using deep-shallow learning," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 14, no. 3, pp. 3070–3083, 2021.
[20] C. Zhang, G. Li, and S. Du, "Multi-scale dense networks for hyperspectral remote sensing image classification," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 57, no. 11, pp. 9201–9222, 2019.
[21] C. Chen, Y. Ma, and G. Ren, "A convolutional neural network with fletcher-reeves algorithm for hyperspectral image classification," *Remote Sensing*, vol. 11, no. 11, pp. 1325–1335, 2019.
[22] E. Lichtblau and C. J. Oswald, "Classification of impervious land-use features using object-based image analysis and data fusion," *Computers, Environment and Urban Systems*, vol. 75, no. 5, pp. 103–116, 2019.
[23] H. Wei, L. Z. Wang, R. Y. Feng et al., "Sample generation based on a supervised Wasserstein Generative Adversarial Network for high-resolution remote-sensing scene classification-ScienceDirect," *Information Sciences*, vol. 539, no. 8, pp. 177–194, 2020.
[24] S. A. Mohamed and M. E. E. Raey, "Land cover classification and change detection analysis of Qaroun and Wadi El-Rayyan lakes using multi-temporal remotely sensed imagery," *Environmental Monitoring and Assessment*, vol. 191, no. 4, p. 229, 2019.
[25] D. P. Shrestha, A. Saepuloh, and F. V. D. Meer, "Land cover classification in the tropics, solving the problem of cloud covered areas using topographic parameters," *International Journal of Applied Earth Observation and Geoinformation*, vol. 77, no. 3, pp. 84–93, 2019.
[26] A. Awad, A. E. Mohamed, E. Mohamed et al., "Remote sensing of 10years changes in the vegetation cover of the northwestern coastal land of Red Sea, Saudi Arabia," *Saudi Journal of Biological Sciences*, vol. 27, no. 11, pp. 3169–3179, 2020.

Hindawi
Scientific Programming
Volume 2021, Article ID 8271950, 11 pages
https://doi.org/10.1155/2021/8271950

Research Article

Water Pollution Prediction Based on Deep Belief Network in Big Data of Water Environment Monitoring

Li Liang

Chongqing Industry Polytechnic College, Chongqing 401120, China

Correspondence should be addressed to Li Liang; swaumyh@swu.edu.cn

Received 11 November 2021; Revised 30 November 2021; Accepted 2 December 2021; Published 22 December 2021

Academic Editor: Ahmed Farouk

Aiming at the problems that the traditional water quality prediction model is generally not high in prediction accuracy and robustness, a water pollution prediction using deep learning in water environment monitoring big data is proposed. *Objective*. To optimize and improve the prediction accuracy of the water quality prediction model. Firstly, in the water environment monitoring system, the Internet of Things big data technology is used to accurately sense and monitor the real-time data of sewage treatment equipment and sewage quality. Then, the deep belief network (DBN) is used to build the water pollution prediction model, and the collected sewage treatment data is analyzed to predict the water quality status. Finally, particle swarm optimization algorithm is used to dynamically optimize the number of hidden layer neural units and learning rate in the DBN prediction model, which makes the prediction results more scientific and accurate. Based on the sampling data of Shanghai Jinze Reservoir, the proposed model is experimentally analyzed. The results show that the probability of accurate location of the pollution source is not less than 70%. And under the two indicators of chemical oxygen demand and biological oxygen demand, the root mean square error and correlation coefficient are 3.073, 0.9892 and 1.958, 0.9565, respectively, which are better than other comparison models.

1. Introduction

In recent years, with the rapid development of cities and social economy, the issue of water resources has gradually become a hot social issue. In association with this, the problem of water pollution is particularly prominent, which is directly related to the long-term development of my country's economy and society [1]. As shown in Figure 1, water eutrophication caused by industrial waste water, domestic sewage, accidental pollution source leakage, and other reasons, such as serious excess of toxic and hazardous substances, and other water resources problems are common [2].

However, in real life, the detection of water resources is still done manually in a considerable part of the area and submitted to the laboratory for analysis. Although it is possible to obtain as detailed water quality information as possible, it will greatly consume manpower and material resources, and it is difficult to ensure timeliness [3]. At present, sensors are widely used to collect water quality data of the water supply pipe network in real time and transmit the data to the server through the network for centralized analysis. The method of using sensor data to detect and trace the source of water pollution is directly related to the choice of sensor type, usually including sensors for specific pollutants and general-purpose sensors. As far as a specific sensor is concerned, it has better performance in detecting specific pollutants, but its ability to detect other pollutants is weak. Usually this type of sensor is mainly aimed at pollutants such as heavy metal ions [4]. For general-purpose sensors, they are not designed for a specific type of pollution, so they have a more general detection ability for most pollution types [5]. Faced with the massive detection data generated by many sensors in the water supply network, its analysis and judgment also require updated technical support. Through the study of water resources prediction models, the use of water environment monitoring big data to predict the pollution of water sources is the key research direction [6, 7].

At present, scholars at home and abroad have done a lot of research on water quality prediction based on sensor big data. Traditional water quality prediction models mainly

Figure 1: Typical water pollution cases.

include time series models, regression analysis models, and grey system theory models [8, 9]. Reference [10] proposed a recurrent neural network water quality prediction method based on sequence-to-sequence framework. The gate loop unit model is used as the encoder and decoder, and the factorization machine is integrated in the model to solve the problem of high sparsity and high-dimensional feature interaction in the data. However, it cannot accurately predict data with large fluctuations. Reference [11] proposed a method to estimate the concentration of environmental pollutants in water based on environmental parameters. Symbolic constraints are used to express domain knowledge, and the influence of symbolic constraints on prediction performance is studied by using censored data sets. Its prediction accuracy is greatly affected by the data itself, and it is only suitable for medium- and short-term prediction. Reference [12] proposed a prediction model based on nonlinear regression for the problem of irrigation water quality. It has flexible and accurate evaluation performance for irrigation water quality. Traditional forecasting models often only pay attention to the characteristics of the data itself, without fully considering the interrelationship between the data. The prediction accuracy is generally not high, and it is difficult to accurately predict and monitor the water quality parameters of the water environment [13].

With the continuous improvement of the computing performance of smart hardware, deep learning and artificial intelligence have developed rapidly. They are continuously integrated into all aspects of national life and industrial control [14]. As an important component in the field of deep learning, cyclic neural network fully considers the long-term dependence of time series data and can handle time series data well [15]. Reference [16] proposed a water quality parameter analysis and water quality prediction method using linear regression analysis and artificial neural network. The artificial neural network has a good forecasting effect, but linear regression analysis cannot be used for nonlinear forecasting. Reference [17] proposed a seawater quality prediction method based on artificial neural network and multiple linear regression model. The seawater quality of mangroves and estuaries has been accurately predicted. However, a large amount of sample data is required for training, and the parameters set by experience can easily lead to the appearance of local extreme values. Reference [18] combines convolutional neural network and long-short-term memory model to predict water quality, which has good accuracy and predictive performance. However, the training sample should not be too large, and it is more sensitive to missing data. Reference [19] proposed a water supply and drainage health monitoring method combining fog computing and cloud computing based on the Internet of Things water supply system, which improved the prediction accuracy. However, the mining of the in-depth correlation information between data is not deep enough, and the utilization rate of monitoring big data needs to be further improved.

Aiming at the problem that traditional prediction models cannot handle massive data from multiple sensors, a water pollution prediction model using deep learning in the big data of water environment monitoring is proposed. The innovations of the proposed model are summarized as follows:

(1) Due to the lack of data in most waters and the unclear water management mechanism, the accuracy of traditional prediction models is not high. The proposed model introduces deep learning technology, which has good data nonlinear approximation, self-learning, and generalization capabilities and can achieve a more ideal water quality prediction effect.

(2) The particle swarm optimization algorithm is used to dynamically optimize the number of hidden layer neural units and the learning rate in the prediction model. In order to improve its convergence speed and generalization ability, the prediction results are more scientific and accurate.

2. Related Technology

2.1. Deep Belief Network. Deep belief network (DBN) is a directed graph model widely used at present. It can be seen as a superposition of multiple restricted Boltzmann machines (RBM). First, the effective unsupervised greedy layer-by-layer training method is used to initialize the DBN weights; that is, only two adjacent layers are trained each time, and each output is used as the input of the next training, and the training is performed layer by layer. The features are extracted from the input sample data to obtain the parameters of the global network model. Then the supervised learning method is used to fine-tune all the parameters, further optimize the network, and get the trained DBN. The DBN network structure is shown in Figure 2.

In order to reduce the complexity of the algorithm, the whole DBN is divided into several RBMs. The RBM was trained layer by layer with the fast training method of contrast divergence (CD). Although CD algorithm does not follow any function gradient and its maximum likelihood estimation is not accurate, it is very effective for training depth structure similar to DBN [20, 21]. The RBM training process optimizes the initial parameters of the network model to avoid the situation where the model falls into a local extreme value due to improper initial values. Finally, the back propagation (BP) algorithm is used to supervise and fine-tune the network parameters. This is a local space search, so the speed is faster, and it is not easy to fall into a local extreme value situation.

2.2. Particle Swarm Optimization Algorithm. Particle swarm optimization (PSO) algorithm is a swarm intelligent optimization algorithm that simulates the collective cooperation of birds to find food. It was first proposed by J. Kennedy and R. Eberhart in 1995. PSO combines the advantages of swarm intelligence optimization algorithms and the advantages of evolutionary calculations to achieve global optimal search in complex spaces.

In the PSO algorithm, in order to achieve the optimality of the behavior of the entire group, the individual is represented by particles that specify the corresponding behavior rules. The particles find the optimal position based on their own experience and group experience and constantly update themselves, and the particles find the optimal solution through cooperation and mutual assistance.

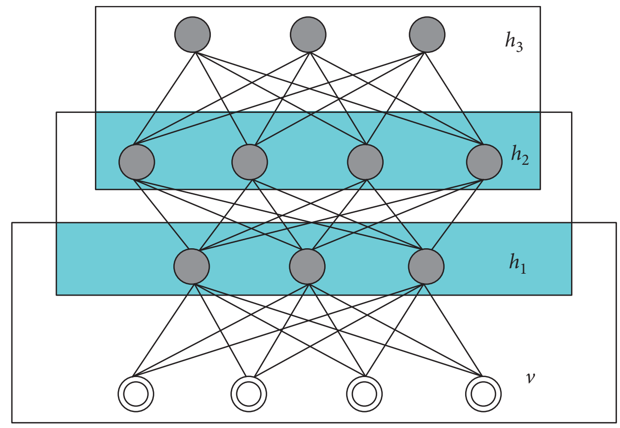


Figure 2: The structure of deep belief network.

Mathematical expression of PSO: in the D-dimensional search space, n represents the number of particles $i = 1, 2, \ldots, n$. The position of the i-th particle is denoted by $X_i = (x_{i1}; x_{i2}; \ldots; x_{i\,D})$. The historical optimal position of the i-th particle is represented by $P_i = (p_{i1}; p_{i2}; \ldots; p_{i\,D})$. The velocity of the particle is denoted by $V_i = (v_{i1}; v_{i2}; \ldots; v_{i\,D})$. The particle velocity and position update formula are as follows:

$$\begin{cases} V^{k+1} = \omega V^k + c_1\gamma_1\left(P_i^k - X^k\right) + c_2\gamma_2\left(P_g^k - X^k\right) \\ X^{k+1} = X^k + V^{k+1} \end{cases}, \quad (1)$$

where the right side of the speed update formula is inertial part, cognitive part, and social part. ω is the inertia weighting factor, which is generally between (0.2, 0.9). c_1 and c_2 are learning factors, generally take the same normal number between (0,4), and usually take 2. γ_1 and γ_2 are random positive numbers, evenly distributed between (0,1). P_g represents the historical global optimal solution. Sometimes in order to limit the speed of the particles, the upper limit $V_{\max}$ and the lower limit $V_{\min}$ of the particle speed are set according to different situations, generally set to 2.048 and -2.048.

3. System Structure

In the water quality pollution prediction system architecture based on deep learning in the water environment monitoring big data, the overall topological structure and functional structure of the system are mainly designed, and the overall design and implementation of the system are planned [22]. The system design goals mainly include two aspects: water quality data collection based on big data of the Internet of Things, water quality pollution prediction and control based on deep learning. Its overall topological structure is shown in Figure 3.

The system uses wireless sensor nodes as data sensing equipment for big data of the Internet of Things to monitor the sewage water quality of sewage treatment equipment and every intermediate link in the sewage treatment process. The monitoring results are handed over to the cloud computing storage platform. On the cloud computing storage platform,

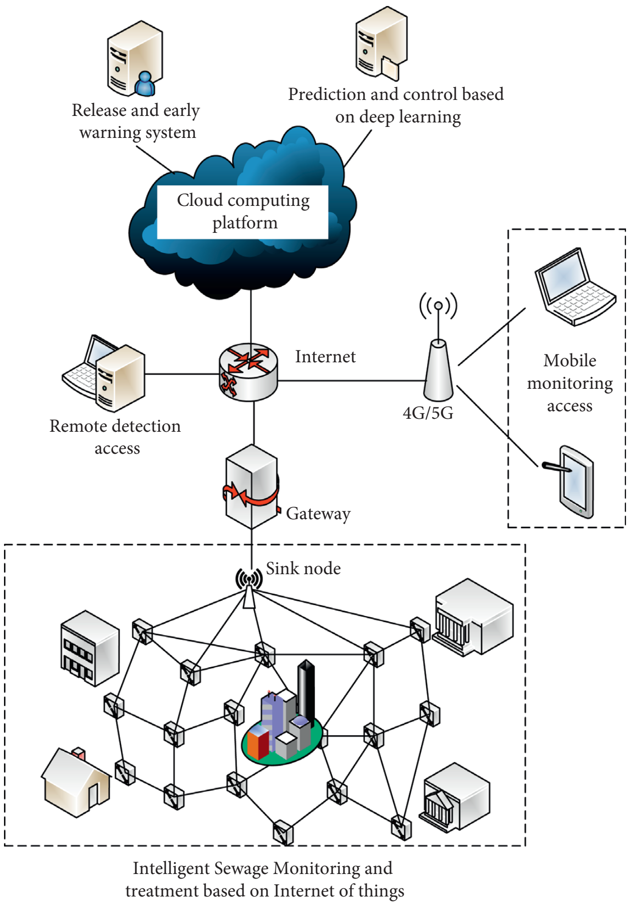


Figure 3: Overall topological structure of the system.

deep learning algorithms are used to process and analyze monitoring data, generate prediction results, and intelligently control sewage treatment equipment.

General sewage treatment is divided into four levels. The sewage treatment perception system based on big data of Internet of Things deploys wireless sensor nodes for each treatment process, each important parameter index, and important treatment equipment of sewage treatment, realizes the information perception of the whole sewage treatment process without dead angle and full coverage, and ensures the comprehensive, in-depth, and thorough perception and collection of the sewage treatment process information. Each sensor node self-organizes to build a wireless multihop network through the Zigbee protocol and reports the collected sewage treatment data to the sink node. The coordinator node will upload the data to the cloud platform through the gateway for subsequent intelligent analysis and processing.

4. Intelligent Prediction and Control Design of Sewage Treatment Process Based on Deep Learning

4.1. Algorithm Design of Prediction Model. The intelligent prediction and control of sewage treatment based on deep learning are as follows. Firstly, the water environment monitoring IOT collects the parameters of each treatment equipment and the intermediate sewage quality data in the sewage treatment process and obtains the historical original data. After data preprocessing, the training data set is obtained. Then, the unsupervised learning machine learning DBN is used to model the wastewater treatment prediction. The optimal network structure of DBN is determined by using the training data set, including the number of nodes in the input layer, the number of nodes in the hidden layer, and the number of layers in the hidden layer, and the weight is adjusted. The training data is used to train this model, and the final model is adjusted continuously.

The big data system of water environment monitoring collects the data of sewage treatment equipment parameters and intermediate sewage quality data in real time to form the current original data. At present, the original data becomes the prediction data set after data preprocessing. The DBN model and prediction data set are used to predict the results of sewage treatment and then control the operation of related equipment in the whole process of sewage treatment.

DBN overlaps multiple RBM models together, regards the visual layer of each RBM model as the input layer and the hidden layer as the output layer, and then completes the training [23]. The visual layer of the network and the hidden layer unit are interconnected (no connection within the layer), and the hidden layer unit can obtain the high-order correlation of the input visual unit. Compared with the traditional Sigmod reliability network, the learning of RBM weights is relatively easy [24]. In order to obtain generative weights, unsupervised greedy layer-by-layer implementation is used in pretraining [25, 26]. In the training process, the Gibbs sampling principle is adopted; that is, the visible vector value is mapped to the hidden layer unit. Then the visible unit is reconstructed from the hidden layer unit. These new visual units are mapped to hidden layer units again, and new hidden layer units are obtained. A typical DBN network with only one hidden layer can use the joint probability density distribution to describe the relationship between the input vector x and the hidden vector g^i. The mathematical expression is as follows:

$$\begin{aligned}\rho\left(x, h^1, h^2, \ldots, h\right) &= \rho\left(x \mid h^1\right) P\left(h^1 \mid h^2\right),\\ &\rho\left(h^2 \mid h^3\right) \ldots \rho\left(h^i \mid h^{i+1}\right) \rho\left(h \mid h\right),\end{aligned} \tag{2}$$

where $\rho\left(h^i|h^{i+1}\right)$ is the conditional probability distribution. Think of the hidden layer h^i as a random binary vector with n^i elements h^i_j:

$$\begin{aligned}\rho\left(h^i \mid h^{i+1}\right) &= \prod_{j=1}^{n^i} \rho\left(h^i_j \mid h^{i+1}\right) \rho\left(h^i_j = 1 \mid h^{i+1}\right)\\ &= \operatorname{sigm}\left(b^i_j + \sum_{k=1}^{n^{i+1}} \omega^i_{kj} h^{i+1}_k\right),\end{aligned} \tag{3}$$

where $\operatorname{sigm}(t) = 1/\left(1 + e^{-t}\right)$, b^i_j is the bias value of the j th unit in the i-th layer, and ω^i is the weight of the i-th layer.

After training, you need to fine-tune the DBN training. According to the loss function of the input data and the reconstructed data, the BP algorithm is used to fine-tune the correlation network parameters to minimize the loss function. The formula of the loss function is

$$L(x - x') = \|x - x'\|_2^2. \quad (4)$$

Among them, x is the true value of the training data, and $x\prime$ is the value of the DBN fitting function.

Considering that the final discharged water quality is the final direct indicator, the final water quality is used as the indicator of the sewage treatment result. Realize the prediction of the discharge water quality by constructing the DBN network. The construction process of the sewage treatment forecast DBN network model is shown in Figure 4.

The input of DBN water pollution prediction model includes the parameters of each process and the sewage quality after each process. And through the bottom-up combination of multiple RBMs to build a DBN network, the final output of sewage quality is obtained.

4.2. Optimization of Model Parameters for Water Quality Prediction. When designing the structure of the DBN, it is necessary to determine the number of hidden layers, the number of nodes contained in each hidden layer, the learning rate of RBM, and the learning rate of the fine-tuning process. The setting of these parameters largely affects the prediction performance of the water pollution prediction model. However, there is no relevant theory to clarify the best selection method for these parameters. Many researchers use a large number of experimental comparisons, experiences, and trial-and-error methods to determine these parameters and choose a better network structure of the water pollution prediction model. The network structure needs to be readjusted every time the impact factor related to the forecast changes. The network structure of each model is only suitable for a specific environment, resulting in poor generalization ability of the predictive model. Moreover, the accuracy of the model's prediction results is related to the model user, and experienced experts may get better results.

The proposed model uses PSO to optimize the parameters of the water pollution prediction model. PSO can not only avoid falling into local extreme values but also ensure the global search ability and can optimize the parameters of the water pollution prediction model. Regarding each parameter to be optimized as a particle, it iteratively adjusts continuously to continuously approach the global optimal solution. The convergence speed is fast, and the adaptability of the water pollution prediction model becomes stronger, and the generalization ability is improved. The process of using the PSO algorithm to dynamically optimize the water pollution prediction model based on deep learning is shown in Figure 5.

The number of hidden layer units of the DBN network is M, and the learning rates of RBM1, RBM2, and RBM3 are ε_1, ε_2, and ε_3, respectively. The particle $x(m, \varepsilon_1, \varepsilon_2, \varepsilon_3)$ is a four-dimensional vector, where $\varepsilon_1, \varepsilon_2, \varepsilon_3 \in (0, 1)$.

The pseudocode of the specific PSO algorithm is shown in Algorithm 1.

5. Experiment and Analysis

The water quality data in the experiment comes from the real monitoring data of the main water quality indicator chemical oxygen demand (COD) of Shanghai Jinze Reservoir, the main water source in Shanghai, from April 30, 2019, to November 30, 2019, and according to the collection frequency per minute to obtain 300,520 monitoring value data. The original COD data measurement value is shown in Figure 6.

5.1. Data Preprocessing

5.1.1. Missing Value Processing. In the original data set, some sensor data is missing at some moments. Therefore, it is necessary to fill in the missing data before using the data. Since the sensor data has a high probability to remain relatively stable in a short period of time, the forward filling method is adopted. That is to fill in the missing data at the current moment based on the data at the previous moment. The possible data missing in the sensor data collected at 4 consecutive times within a certain period of time and the corresponding forward filling results are shown in Table 1. The black data is the real measurement data, and the red data is the filling data.

5.1.2. Standardization. For the learning of multidimensional feature data, standardization can often facilitate data processing and speed up the convergence speed of model training. For the data set used, each piece of data has different characteristics. Therefore, it is also necessary to standardize the original data set, so as to avoid the phenomenon that the model convergence is too slow due to the large difference between the original data of different characteristics. The standardization method adopted is that, for each sensor indicator, if the mean value of the indicator in the set time window is recorded as μ, the standard deviation is recorded as δ. Then the observed value x_t of this indicator at time t becomes

$$\widehat{x}_t = \frac{x_t - \mu}{\delta}. \quad (5)$$

After this transformation, the values between different sensors are scaled to a range that can be directly compared. Moreover, using the transformed data to train the model can also speed up the convergence speed of the model training to a certain extent.

5.2. Evaluation Index. Two indicators, RMSE and correlation coefficient R, are used to evaluate the performance of the water quality prediction model.

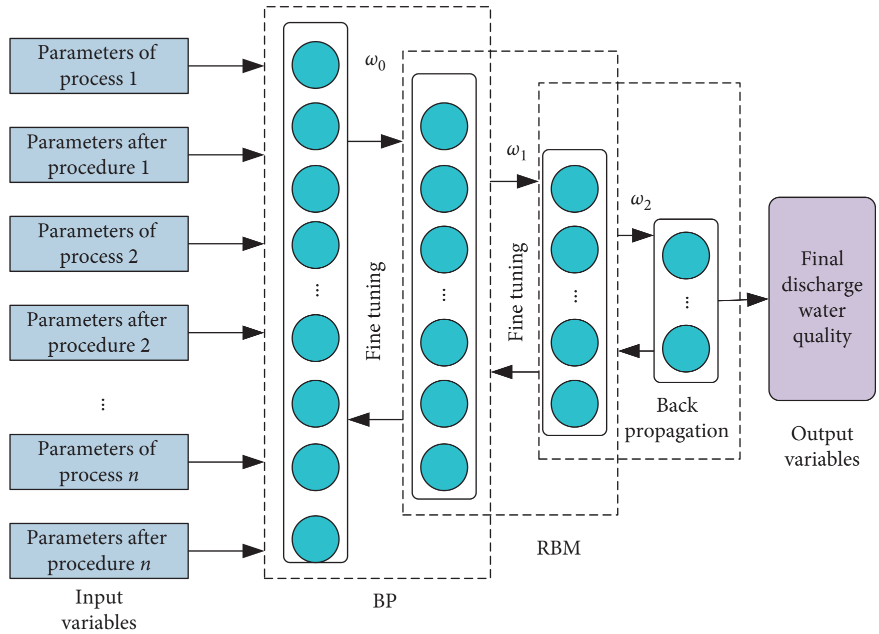


Figure 4: Training process of DBN network model for wastewater treatment prediction.

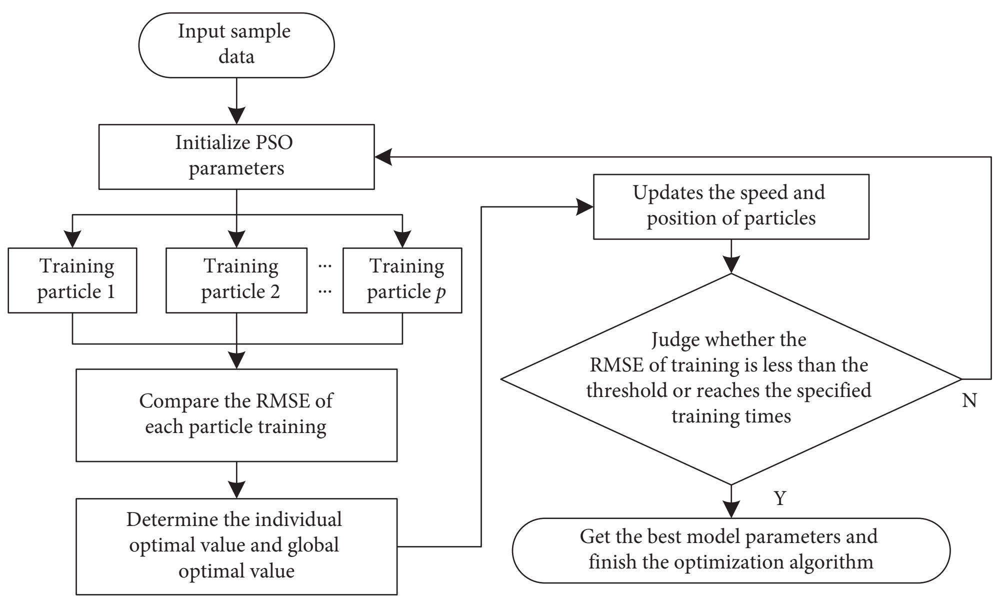


Figure 5: Optimization process of PSO algorithm.

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} \left(y_i - y_i'\right)^2}{n}},$$
$$R = \frac{\sum_{i=1}^{n} \left(y_i - \overline{y}\right)\left(y_i' - \overline{y}\prime\right)}{\sqrt{\sum_{i=1}^{n} \left(y_i - \overline{y}\right)^2 \cdot \sum_{i=1}^{n} \left(y_i' - \overline{y}'\right)^2}}. \quad (6)$$

In the formula, y_i represents the actual data of the i-th sample, and y_i' represents the predicted data of the i-th sample. $\overline{y}$ and $\overline{y}\prime$, respectively, represent the average value of n actual data and the average value of n predicted data. When using RMSE and R as indicators to evaluate the water quality prediction model, the smaller the RMSE, the better, and the closer R to 1, the better.

5.3. Pollution Source Location Based on Deep Learning Model. First, the data set obtained by monitoring is divided into two data sets to evaluate the effect of the deep learning model in the first stage of traceability in the location of pollution sources. Before that, the same segmentation is performed on the two data sets: 80% of the data is used as the training set, and 20% of the data is used as the test set. The positioning results of the

(1) Parameter: N:The population size of the particle swarm; C:The maximum number of iterations.
(2) Begin
(3) Initialize the particle's position $x^{c=0}$ and velocity $v^{c=0}$.
(4) The root mean square error (RMSE) between the predicted value and the expected value is used to find the optimal position $x^c_{i_{\text{pbest}}}$ and the global optimal position x^c_{gbest} of each particle.
(5) Update speed and position information. Calculate and update the speed and position information of the particles according to the speed update formula and the position update formula: $\begin{cases} x_i^{c+1} = x_i^c + v_i^{c+1} \\ v_i^{c+1} = \omega v_i^c + c_1\gamma_1 (x^c_{i_{\text{pbest}}} - x_i^c) + c_2\gamma_2 (x^c_{\text{gbest}} - x_i^c) \end{cases}$
(6) If RMSE convergence and $c = C$ then PSO algorithm ends;
(7) otherwise $c = c + 1$, return to step 3.
(8) End

Algorithm 1: Pseudocode of PSO algorithm.

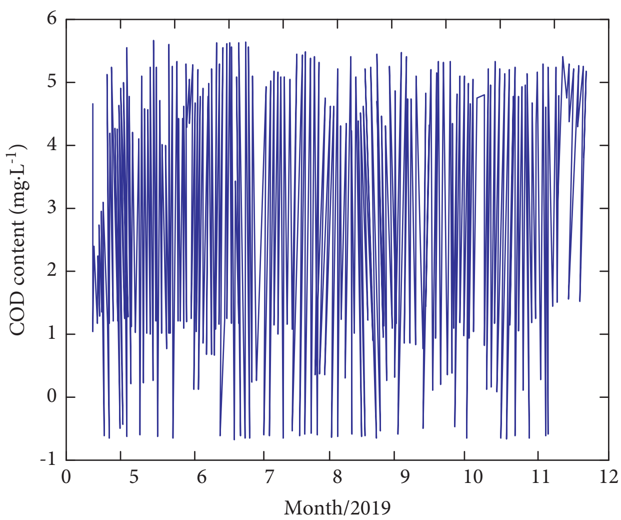


Figure 6: Measured value of original COD data.

Table 1: Forward fill results with missing data.

Time	Cl	Cl_2	pH	Tp	COD
...	...	...	...	...	...
T	A_t	B_t	C_t	D_t	E_t
$t+1$	A_{t+1}	B_t	C_{t+1}	D_t	E_{t+1}
$t+2$	A_{t+1}	B_{t+2}	C_{t+2}	D_t	E_{t+2}

proposed model on the two data sets are shown in Tables 2 and 3. It should be noted that T in the table represents the number of samples. That is, the data used in training and testing the model is the concentration data at T moments after the pollution occurs, rather than all the data during the entire simulation period. For example, when the number of sensors is 4 and that of T is 12, it means that the data used by the corresponding proposed model is the data collected at the 4 sensor nodes at 12 moments after the pollution occurred.

Since the proposed model will output multiple suspicious pollution source nodes at the same time, the evaluation of the model can be described by whether the actual pollution source node is included in several nodes predicted by the proposed model. Therefore, it can be seen from Tables 2 and 3 that, (1) under the combination of the number of various sensors and the number of samples, the 6 nodes predicted by the proposed model obtained on the two data sets have a high probability of

Table 2: The probability that the 6 nodes predicted by the proposed model in dataset A contain real pollution source nodes.

Number of sensors	$T=2$	$T=6$	$T=8$	$T=12$	$T=14$
4	0.854	0.868	0.892	0.886	0.884
6	0.795	0.807	0.856	0.875	0.863
8	0.733	0.774	0.827	0.861	0.859

Table 3: The probability that the 6 nodes predicted by the proposed model in dataset B contain real pollution source nodes.

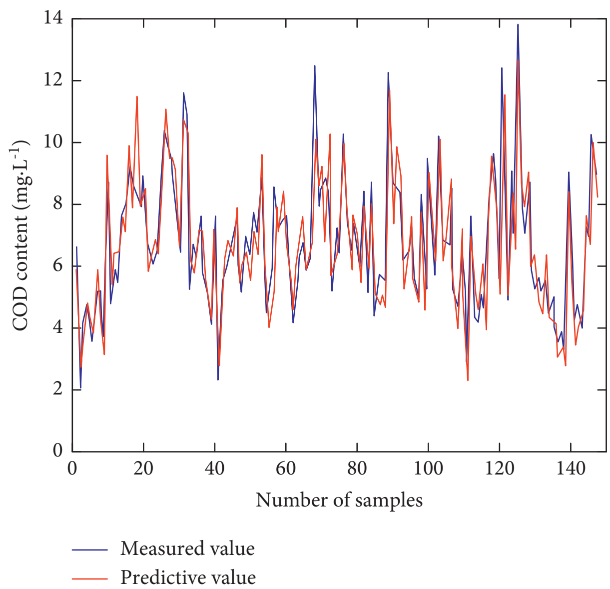
Number of sensors	$T=6$	$T=12$	$T=18$
10	0.713	0.740	0.769
20	0.752	0.785	0.791
30	0.868	0.863	0.884

containing the real pollution source nodes. In the worst case, the probability also exceeds 70%. Therefore, the constructed DBN model for locating pollution sources is effective. (2) The effect of the proposed model is still reliable even when the number of samples T is small. Therefore, the method of locating pollution sources based on the DBN model does not rely on long-term data collection. The process of locating the pollution source is a task that can be completed in a relatively short period of time.

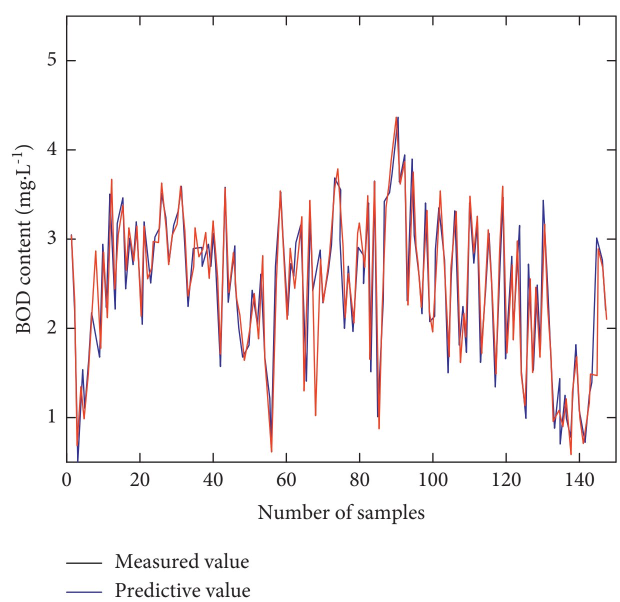
5.4. Comparison of Predicted Value and Actual Value. The water quality pollution prediction model based on deep learning is used to predict this sewage treatment plant dataset, and the result is shown in Figure 7. Among them, the predicted output value of the model includes biological oxygen demand (BOD) in addition to COD.

It can be seen from Figure 7 that whether it is COD or BOD, the predicted value can better approximate the actual value, and the two curves have a higher consistency. The predicted value of individual points differs greatly from the actual value, which may be caused by test errors or other uncertain parameters. Taken together, it can be demonstrated that the proposed model has better predictive performance.

5.5. Comparison with Other Models. In order to better demonstrate the performance of the proposed model, the prediction experiment was performed on the same set of experimental data as the model in [17]. The results of the comparative experiment are shown in Figure 8.

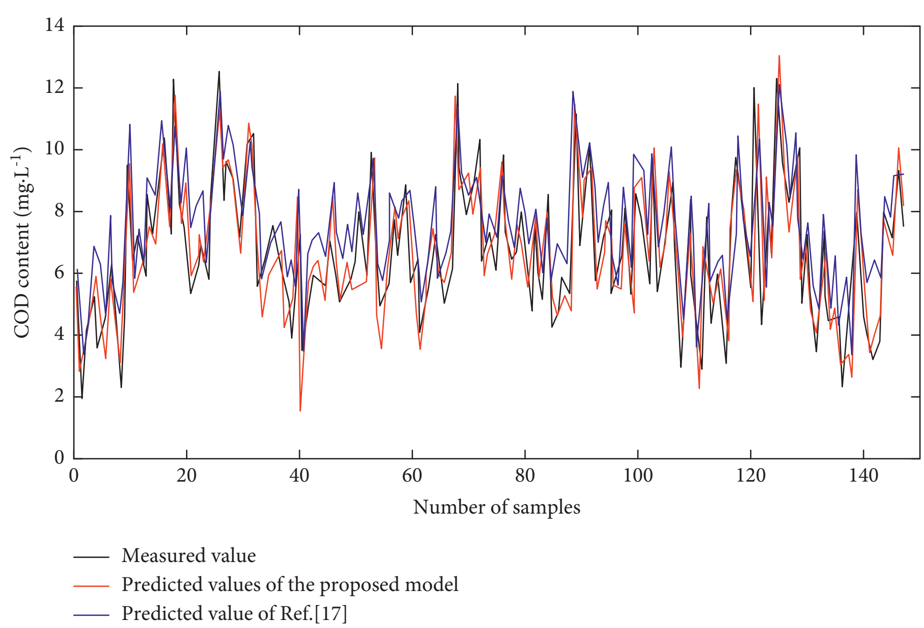


(a)



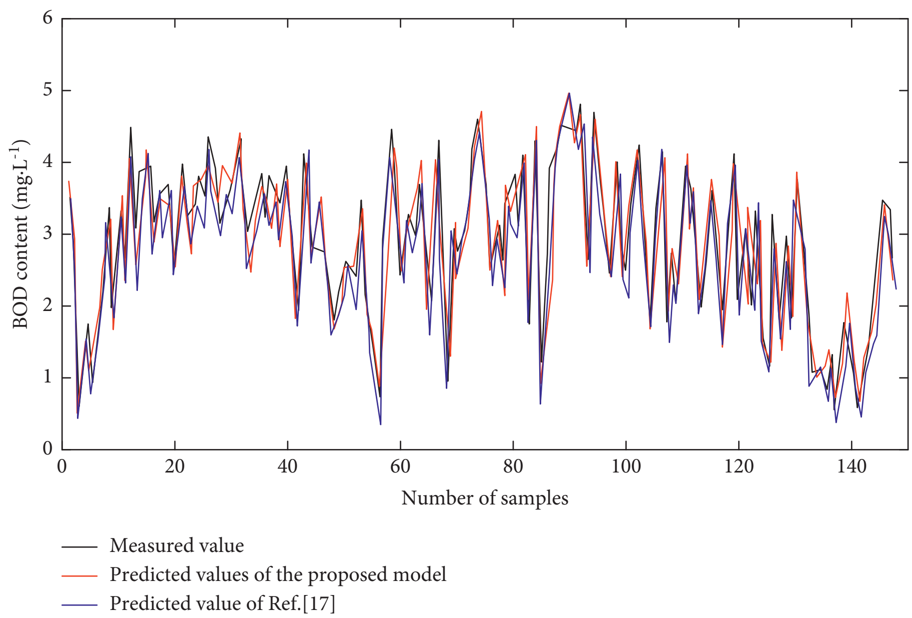
(b)

FIGURE 7: The prediction and output value of different water quality parameters by the model. (a) The predicted and actual values of COD. (b) The predicted and actual values of BOD.



(a)

FIGURE 8: Continued.



(b)

Figure 8: Comparison of predicted value and output value under different models. (a) Comparison of COD predicted value and actual value in different models. (b) Comparison of BOD predicted value and actual value in different models.

Table 4: Comparison results of evaluation indexes of two prediction models.

Model	Water quality index	RMSE	*R*
Ref. [11]	COD	5.384	0.9533
	BOD	3.190	0.9017
Ref. [17]	COD	4.521	0.9641
	BOD	2.185	0.9239
The proposed model	COD	3.073	0.9892
	BOD	1.958	0.9565

It can be seen from Figure 8 that the water quality prediction model based on the improved DBN and [17] based on the artificial neural network and the multiple linear regression model have good COD and BOD prediction effects, and the curve fits well. Their predicted and actual values are relatively consistent. However, the prediction results of the improved DBN prediction model are closer to the actual data, with smaller errors and higher accuracy.

In order to quantitatively compare and analyze the performance of the two models, RMSE and correlation *R* are used for evaluation. The results are shown in Table 4. In order to increase the persuasive power, the traditional prediction model proposed in [11] is added.

It can be seen from Table 4 that, for the prediction of COD and BOD, the RMSE and *R* of the proposed prediction model are 3.073 and 0.9892, 1.958 and 0.9565, respectively, which are better than other comparison models. Because it uses PSO to improve DBN, it can quickly obtain high-precision prediction results. The model in [11] is more traditional, and the prediction results are not ideal. Taking the correlation *R* of BOD as an example, it is only 0.9017. Reference [17] combines artificial neural network and multiple linear regression model to achieve water quality prediction, and their prediction performance has been improved to a certain extent. But the learning performance advantage of artificial neural network is not obvious, because the overall effect is lacking. The particle swarm optimization algorithm is used to dynamically optimize the number of hidden layer neural units and the learning rate in the prediction model. In order to improve its convergence speed and generalization ability, the prediction results are more scientific and accurate. Therefore, the proposed water quality prediction model based on deep learning has a relatively ideal water quality prediction effect and has certain practical application advantages.

6. Conclusion

Water quality is closely related to people's daily life. In order to improve the quality of life, a highly reliable water quality prediction model is necessary. For this reason, a water pollution prediction model using deep learning in water environment monitoring big data is proposed. In the water environment monitoring system, the Internet of Things big data technology is used to accurately sense and monitor the real-time data of sewage treatment equipment and sewage water quality. And the DBN is improved by PSO to build the water pollution prediction model, so as to get the ideal water quality prediction results. Based on the sampling data of Jinze reservoir in Shanghai, the proposed model is demonstrated experimentally. The results show that the probability of accurate pollution source location is not less than 70%, and the pollution source location can be completed in a short time. In addition, under the two indicators of COD and BOD, the RMSE of the proposed model is 3.073 and 1.958, respectively, which are better than other comparative models. And the correlation coefficient R is 0.9892 and 0.9565, which are very close to 1. The proposed model only uses a specific data set for experimentation. In reality, the benchmarks of water quality in different water supply pipe networks are not the same, and the types of sensors deployed are also different. Therefore, how to obtain data from a real water supply network and design a learning model for pollution detection still needs to be further explored.

Data Availability

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

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this study.

Acknowledgments

This work was supported by Effects of plants on soil mercury migration and its ecological effects in the water-level fluctuation zone of the Three Gorges Reservoir project of science and technology research program of Chongqing Education Commission of China (no. KJQN201803203).

References

[1] H. Yang, B. Y. Liu, and J. H. Huang, “Forecast model parameters calibration method for sudden water pollution accidents based on improved Bayesian-Markov chain Monte Carlo,” *Kongzhi yu Juece/Control and Decision*, vol. 33, no. 4, pp. 679–686, 2018.

[2] B. Liu, H. Wang, X. Lei, Z. Liu, and J. Quan, “Emergency operation rules for water-supply reservoirs under uncertainty and risk in dry seasons,” *Water Science and Technology*, vol. 18, no. 5-6, pp. 1682–1695, 2018.

[3] N. Y. Hrybova, O. I. Khyzhan, V. I. Maksin, L. O. Kavshun, and O. L. Tankha, “Determination of xenobiotic imidacloprid content in surface waters,” *Journal of Water Chemistry and Technology*, vol. 41, no. 5, pp. 313–317, 2019.

[4] M. A. Zazouli, L. R. Kalankesh, and M. Hasanpour, “Forecast optimal fluoride concentration data in drinking water according to the ambient temperature in Golestan, Iran,” *Environmental Quality Management*, vol. 28, no. 3, pp. 1–5, 2019.

[5] B. Kurbanov, A. Primov, and B. Kurbanov, “Analysis and forecast of the ecological conditions of surface water in Uzbekistan,” *InterCarto. InterGIS*, vol. 26, no. 1, pp. 242–256, 2020.

[6] Y. Xing, J. Yue, and C. Chen, “Dam deformation forecasting avoiding social and environmental impacts caused by dam break,” *Fresenius Environmental Bulletin*, vol. 28, no. 11A, pp. 8831–8838, 2019.

[7] G. Maryam, O. Kaveh, E. Saeid, and P. Singh, “Application of time series modeling to study river water quality,” *American Journal of Engineering and Applied Sciences*, vol. 11, no. 2, pp. 574–585, 2018.

[8] V. Grubinko, H. Humeniuk, V. Khomenchuk, N. Garmatiy, V. Voytiuk, and M. Barna, “Ecotoxicological status and prognosis of the state of an urbanized hydroecosystem (on the example of the reservoir “Ternopil pond”),” *Journal of Geology, Geography and Geoecology*, vol. 27, no. 2, pp. 202–212, 2018.

[9] A. P. Belousova and E. E. Rudenko, “Basic environmental-hydrogeological studies in the territory of European Russia affected by chernobyl accident,” *Water Resources*, vol. 46, no. 4, pp. 571–581, 2019.

[10] J. Xu, K. Wang, C. Lin, L. Xiao, X. Huang, and Y. Zhang, “FM-GRU: a time series prediction method for water quality based on seq2seq framework,” *Water*, vol. 13, no. 8, pp. 1031–1045, 2021.

[11] T. Kato, A. Kobayashi, W. Oishi et al., “Sign-constrained linear regression for prediction of microbe concentration based on water quality datasets,” *Journal of Water and Health*, vol. 17, no. 3, pp. 404–415, 2019.

[12] R. Jasim, M. Al-Saadi, and A. Khider, “New regression model for estimating irrigation water quality index,” *International Journal of Design & Nature and Ecodynamics*, vol. 16, no. 2, pp. 127–134, 2021.

[13] H. Chiri, A. J. Abascal, S. Castanedo, and R. Medina, “Mid-long term oil spill forecast based on logistic regression modelling of met-ocean forcings,” *Marine Pollution Bulletin*, vol. 146, no. Sep, pp. 962–976, 2019.

[14] C. Braun, “Parallel genetic algorithms for ground water pollution due to dumping of solid wastes,” *Pollution Engineering*, vol. 1, no. 3, pp. 1–3, 2020.

[15] M. R. Enikeev, M. F. Fazlytdinov, L. V. Enikeeva, and I. M. Gubaidullin, “Forecast of water-cut at wells under design by machine learning methods,” *Information Technology and Nanotechnology*, vol. 2019, no. 2416, pp. 510–520, 2019.

[16] A. S. Kalamdhad, J. Singh, and K. Dhamodharan, “Surface water quality modeling by regression analysis and artificial neural network,” *Advances in Waste Management*, vol. 10, no. 15, pp. 215–230, 2019.

[17] M. S. Samsudin, A. Azid, S. I. Khalit, M. S. A. Sani, and F. Lananan, “Comparison of prediction model using spatial discriminant analysis for marine water quality index in mangrove estuarine zones,” *Marine Pollution Bulletin*, vol. 141, no. 04, pp. 472–481, 2019.

[18] R. Barzegar, M. T. Aalami, and J. Adamowski, “Short-term water quality variable prediction using a hybrid CNN–LSTM deep learning model,” *Stochastic Environmental Research and Risk Assessment*, vol. 34, no. 8, pp. 1–19, 2020.

[19] L. K. Narayanan, S. Sankaranarayanan, and J. Rodrigues, “CCC publications water demand forecasting using deep learning in IoT enabled water distribution network,” *International Journal of Computers, Communications & Control*, vol. 15, no. 6, pp. 1–15, 2020.

[20] Z. Yang, H. Cai, W. Shao et al., “Clarifying the hydrological mechanisms and thresholds for rainfall-induced landslide: in situ monitoring of big data to unsaturated slope stability analysis,” *Bulletin of Engineering Geology and the Environment*, vol. 78, no. 4, pp. 2139–2150, 2019.

[21] M. Azrour, J. Mabrouki, A. Guezzaz, and Y. Farhaoui, “New enhanced authentication protocol for Internet of things,” *Big Data Mining and Analytics*, vol. 4, no. 1, pp. 1–9, 2021.

[22] H. Biglari, M. Tatari, M. R. Narooie, G. Ebrahimzadeh, and H. Sharafi, "Data for inactivation of free-living nematode rhabditida from water environment using ultraviolet radiation," *Data in Brief*, vol. 18, no. 4, pp. 30–34, 2018.

[23] N. M. Said, Z. M. Zin, M. N. Ismail, and T. A. Bakar, "Univariate water consumption time series prediction using deep learning in neural network (DLNN)," *International Journal of Advanced Technology and Engineering Exploration*, vol. 8, no. 76, pp. 473–483, 2021.

[24] A. Y. Ayturan, Z. C. Ayturan, and H. O. Altun, "Short-term prediction of PM2.5 pollution with deep learning methods," *Global Nest Journal*, vol. 22, no. 1, pp. 126–131, 2020.

[25] Z. Xie, Q. Liu, and Y. Cao, "Hybrid deep learning modeling for water level prediction in yangtze river," *Intelligent Automation & Soft Computing*, vol. 28, no. 1, pp. 153–166, 2021.

[26] C. Y. Hu, J. Y. Cai, Z. Zeng, X. S. Yan, W. Y. Gong, and L. Wang, "Deep reinforcement learning based valve scheduling for pollution isolation in water distribution network," *Mathematical Biosciences and Engineering: MBE*, vol. 17, no. 1, pp. 105–121, 2019.

Hindawi
Scientific Programming
Volume 2021, Article ID 3532845, 9 pages
https://doi.org/10.1155/2021/3532845

Research Article

Advances in an Event-Based Spatiotemporal Data Modeling

Xinming Zhu, Haiyan Liu, Qing Xu, Jun'nan Liu, and Xiaoyang Lihua

Institute of Surveying and Mapping, Information Engineering University, Zhengzhou 450000, Henan, China

Correspondence should be addressed to Qing Xu; geozz_xd@whu.edu.cn

Received 4 October 2021; Revised 28 October 2021; Accepted 1 November 2021; Published 14 December 2021

Academic Editor: Ahmed Farouk

Spatiotemporal data are vitally important for the national economy and defense modernization since it is not only an important component of human society and geographical information of the environment but also a key carrier of spatiotemporal information. An event-based spatiotemporal data model and its improvements are employed to model spatiotemporal objects, change history, and change relation, which is the main approach to resolve the spatiotemporal change modeling and has been comprehensively developed in modeling theory and applications. This manuscript studies the event-based spatiotemporal data modeling theory based on three aspects of the cognitive theory, which are the spatiotemporal object, the concept of the spatiotemporal dynamic object, and the spatiotemporal object relationship. Then, the implementation characteristics of the models were analyzed regarding the management of cadastral information, analog natural disaster phenomena, and reasoning. Finally, the key points and difficulties of an event-based spatiotemporal data modeling and prospective developmental trends were discussed to provide insights with spatiotemporal data modeling.

1. Introduction

With the increasing implementations of a series of new geospatial technologies, such as Mobile Internet and Internet of Things (IoT), the acquisition cycle of spatial information becomes much shorter and the amount and coverage of spatiotemporal data keep on increasing and expanding, including the appearance of typical spatiotemporal data such as trajectory and environmental detection.

Abundant spatiotemporal data are the basis for the expression of spatiotemporal phenomena and knowledge mining as they contain information about the occurrence and evolution of spatiotemporal phenomena [1]. They are of great significance to the national economy and defense modernization. The research of spatiotemporal data model has gone through three major periods [2]: (1) the temporal snapshot period focusing on recording changes in entity state; (2) the object change period focusing on the expression of the relationship before and after an entity change, and (3) the event and activity period focusing on the description of semantic relations of an entity change.

The event-based spatiotemporal data model (ESTDM) and its improvements cope with the typical representatives of the third period. By modeling spatiotemporal objects, spatiotemporal changes, and relations of a change, it acquires the characteristics of explicitly modeling causes, processes, and results of spatiotemporal changes [3]. It has unique advantages that include the formation and evolution simulations of spatiotemporal phenomena, the knowledge mining of spatiotemporal changes, and discoveries of potential historical processes of the Earth [4, 5].

However, the further improvements and applications of the model are restricted since the ESTDM and its improvements have been mainly employed at specific scientific problems and applications. This research comprehensively considered the basic process of spatiotemporal data modeling, reviewed the theoretical basis and application characteristics of the existing models, analyzed the theoretical research status of the cognitive theory of spatiotemporal object, spatiotemporal dynamic object concept, and spatiotemporal object relationship, and summarized the application characteristics of the model in cadastral management and both re-enactment and reasoning of a physical geographic phenomenon, which is expected to provide a reference with an improvement and application of the ESTDM.

The rest of the manuscript is organized as follows: Section 2 briefly introduces the theoretical research regarding the ESTDM based on the cognitive theory and its concepts. The research coverage related to implementation areas is presented in Section 3. Section 4 presents the effectiveness of the ESTDM model when spatiotemporal information, changes, and object relations exist. Besides, the issues are underlined. Section 5 concludes the research.

2. Theoretical Research on the ESTDM

Peuquet [6] proposed the ESTDM in 1995, which deals with the change of each state such as shape and attribute of the spatial region as an event, organizes events in temporal order, and expresses a process of a discrete spatiotemporal change of the spatial region from the initial state to the final change. In the real world, the relationships between entity and environment as well as interentity alter constantly. Aiming at dealing with the problem of change expression, researchers have proposed a variety of theories and methods that improve and apply the model in the realm of problems that could probably appear in the future. It is necessary to sort out and standardize the concepts of events, processes, states, and spatial regions and re-establish the concepts and relations of various elements of the ESTDM by utilizing the available achievements of the cognitive theory of a spatiotemporal object.

2.1. The Cognitive Theory of Spatiotemporal Object. Spatiotemporal objects are entities and changes that existed in spatiotemporal dynamic phenomena. They can be comprehensively recognized based on the way that they exist in the time-space domain and the characteristics of changes that they undergo. Theories analyzing the characteristics of object existence in space and time domains include both endurantism and perdurantism [7–9]. While the object of endurantism is only expanded in the space domain and a snapshot at any time is its complete form, the object of perdurantism is expanded in both time and space domains, and "change" is the uneven distribution of an object in the time domain. There are continuum and contingency theories to analyze the characteristics of objects in terms of experiencing change [10]: continuum is considered a change without an alteration in nature and can be used to describe relatively stable geographical objects, such as people, the Earth, and other geographical entities. On the other hand, contingency occurs in the time domain, having clear time boundaries, acting on the continuums, and expressing the history of the continuums.

To sum up, spatiotemporal objects can be divided into geographic objects that can change, have spatial attributes and any snapshots as a complete existence, and are dynamic objects with changes embedded in the interior and strong temporal attributes. Meanwhile, spatiotemporal objects are independent, nonseparable, and occupy a certain range of space, that is, they have properties called independence, atomicity, and scope. The characteristics of spatiotemporal objects are shown in Table 1.

2.2. The Concept of a Spatiotemporal Dynamic Object. Spatiotemporal dynamic objects are the carriers of dynamically changing semantics and events. Processes are common spatiotemporal dynamic objects. Different improved models embrace different fields and scientific problems, and the concepts of events and processes get confused and the boundaries are not clear [11]. The ESTDM puts forward the concept of an event in the field of geographic information and expresses the significant change with clearer endpoints for the first time. The events of spatiotemporal dynamic objects in this manuscript follow this concept. For the concept of a process, the characteristics, representation of a structured process, and homogenization process based on Galton's research [12] are discussed in this manuscript.

2.2.1. The Structured Process. A structural process refers to the spatiotemporal evolution process consisting of subevents organized in a certain structure and having a definite endpoint (but not yet arrived). For example, the evolution process of the ESTDM is represented by an event sequence organized in a temporal order. The representation methods of a structured process can be divided into the representation methods based on logical relations and based on temporal hierarchy when the temporal order and the different internal event organization methods are a concern.

(1) The method of the process representation based on a logical relationship

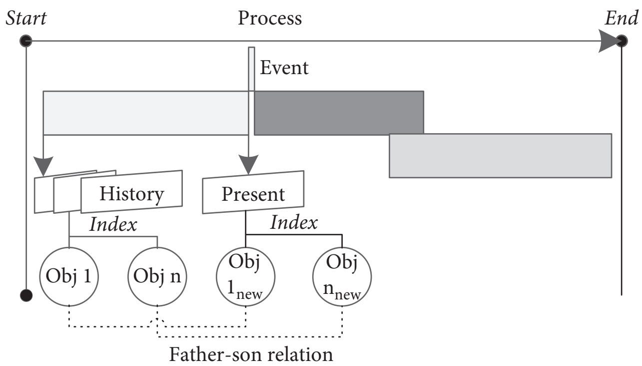
The process representation method based on logical relationship records the state change of the object, event causality, object evolution relationship, and the relationship of the event-process interaction concerning a temporal order. The changed semantics expressed by the model is richer. The model designed based on this method is shown in Table 2.

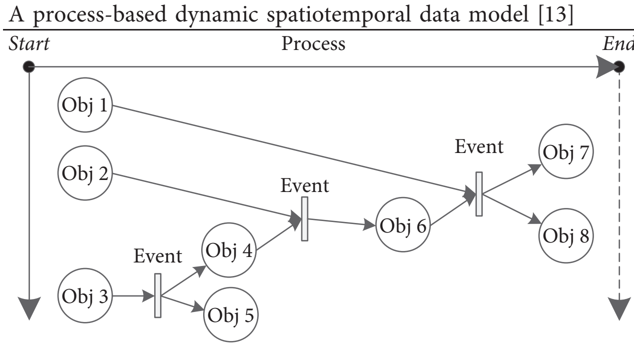
Zhang et al. [13] designed a process-based spatiotemporal data model (PBSTDM), which combines logically connected events obtained by both classification and abstraction with the object state to form a spatiotemporal change process. Then, it depicts the relationship of the parent-child change of the object at the same time by expressing the semantics of the change process. The spatiotemporal data model based on the graph theory [17] employs the causal evolution process of the state-event-state situation expressed by Petri net place, transition, and directed arc [14], which effectively expresses the temporal prepost relationships and the successful relationships such as element replacement, merging, and segmentation. Chen et al. [15, 16] proposed that process ontology can be composed of object and event ontologies and is multiple event ontologies occurring in one (multiple) object ontology in a continuous time. The process ontology can also be composed of the process ontologies. Object ontology has the participation relations of generation, support, and

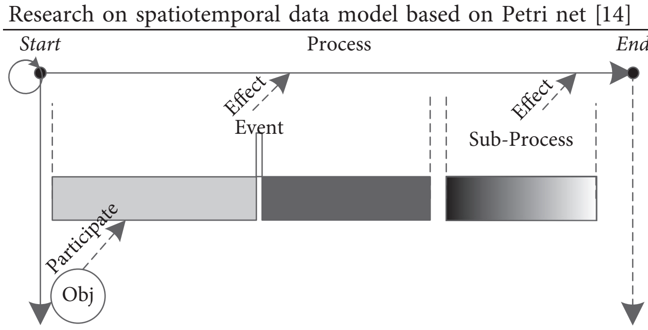
Table 1: Analyzing the characteristics of spatiotemporal objects.

	Geographic object	Dynamic object
Similarities	Independence: spatiotemporal objects are independent of each other Atomicity: the components of a spatiotemporal object are not of the same type as itself Scope: geographical objects occupy a certain range of space domains, while dynamic objects extend in the time domain	
Differences	Can go through changes Has spatial properties But no temporal properties exists intact at any point in its life cycle	Have changes embedded within the object Has a temporal part Cannot be expressed completely for a while in its life cycle

Table 2: Description of a process representation model based on a logical relationship.

<table>
<tr><th>Model diagram</th><th>Model characteristics</th></tr>
<tr><td>

A process-based dynamic spatiotemporal data model [13]</td><td>Record the changing status of objects before and after and the relationship between objects</td></tr>
<tr><td>

Research on spatiotemporal data model based on Petri net [14]</td><td>The graph model used to record and express the spatiotemporal changes with complex composition structure is effectively expressed, and the evolution process of object-event-object is recorded</td></tr>
<tr><td>

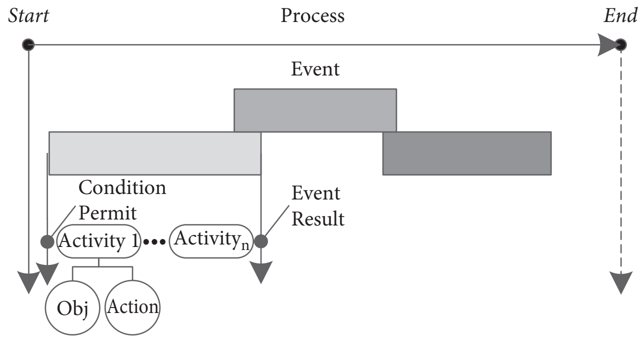
Spatiotemporal data model based on object-event-process and its application [15]
Database model based on spatiotemporal ontology [16]</td><td>Record the object-event participation relationship and the active relationship between events and processes</td></tr>
</table>

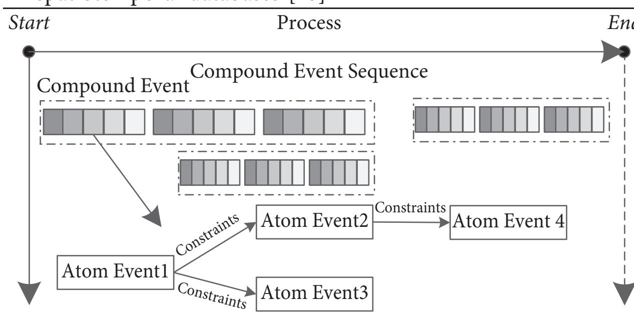
enhancement/weakening with event ontology and process ontology when ontology relations are a concern. Events act on processes, with triggering, promoting, hindering, ending, and other types of relations. Process reacts to events with birth and end of events.

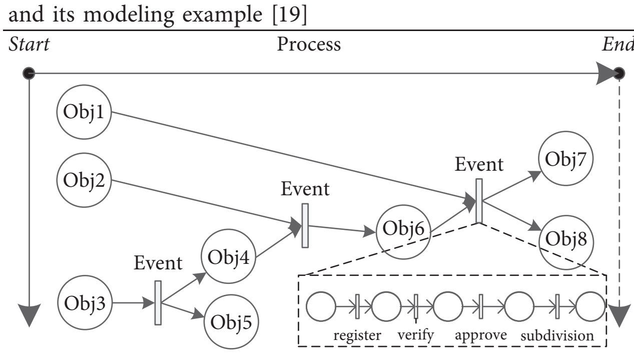
(2) Enriching the process of a temporal hierarchy method.

Based on the two-layer structure of both event and process, the method contributes to the temporal and spatial granularity of change semantics of the spatio-temporal data models through both subdivision and

Table 3: Description of the enriching process of the temporal hierarchy method.

<table>
<tr><th>Model diagram</th><th>Model characteristics</th></tr>
<tr><td>


Toward knowledge discovery about geographic dynamics in spatiotemporal databases [18]
</td><td>Space-time phenomena are expressed by activity, event, and process structure, and activity records objects and their actions</td></tr>
<tr><td>


A trapezoidal hierarchical description framework for spatiotemporal processes and its modeling example [19]
</td><td>The expression of linkage complex events is achieved by introducing constraint relations into atomic events at the lowest level of spatiotemporal change semantics</td></tr>
<tr><td>


Research on spatiotemporal data model based on Petri net [14]
</td><td>The graph model used to record and express the temporal and spatial changes with complex composition structures is effectively expressed, and the evolution process of object-event-object is recorded</td></tr>
</table>

aggregation to meet the requirements of semantic expression of complex temporal and spatial phenomena (Table 3).

The knowledge extraction framework of a spatiotemporal dynamic system [18] uses “activities” smaller than event granularity to express object behavior. Events record the conditions of change, participating objects and results, and process organization events. Events also express dynamic system states and stages. The three-level spatiotemporal structure composed of activity-event-process can effectively resolve the key problems related to the calculation of a spatial relation and the discovery of an attribute change for knowledge mining of spatiotemporal dynamic systems. Spatiotemporal process using the trapezoid multilevel description framework (STP-TRAP) [19] divides the spatiotemporal change into four levels: atom event, evolution, evolution sequence, and spatiotemporal process. The granularity of the atom event is the smallest, which represents the instances of the constraint condition and corresponding spatiotemporal changes of atomic events.

The combination of atom events constitutes evolution (compound events). The evolution sequence organizes an evolution according to the temporal order and represents the compound spatiotemporal change with a meaning of a certain semantic. The spatiotemporal process is the top-level hierarchical description unit, which expresses the semantics of the whole spatiotemporal process. By organizing four levels from top to bottom, the spatiotemporal process is explicitly modeled, and the overall change process and the constraint relationship of the microscopic change are expressed. The transformation hierarchy of the Petri net-based spatiotemporal data model is extended, and the subprocess is introduced to express the process and trigger mechanism of the transformation process. This explicit expression of the spatiotemporal process has richer semantics and improves the efficiency of the analysis [20].

2.2.2. Homogenization Process. The homogenization process refers to the process type of the same internal change and the change of the semantic generally smaller than the event. It is often used to express the spatiotemporal process with continuous gradual change as a component of significant change—“event.”

The most typical is the simulation of wildfires, storms, and other dynamic geographical phenomena, which are difficult to simulate exactly by functions due to various internal mechanisms and the characteristics of continuous gradual change in appearance. To express the semantics of the continuous gradual change, the observed sequence states are organized into “processes” according to specific semantics [21]. For the spatiotemporal evolution expression of entities such as seafront and sea ice through both classification and abstraction of homogenous change types, stage objects such as generation, expansion, stability, weakening, and extinction are defined [22, 23]. Based on sequence states, the process semantics of stage objects are refined by using spatiotemporal evolution functions. The processes are abstracted into mathematical functions, and the combinatorial relations of the simultaneous or sequential occurrence of “process algebra” are introduced to effectively simulate the complex spatiotemporal changes occurring internally in parallel settings [11]. The semantics of continuous gradual process also need to consider nonlinear continuous processes [24]. The characteristics of the intrinsic homogenous process model are shown in Table 4.

2.3. Spatiotemporal Object Relations. Traditional GIS data modeling only focuses on spatial attribute and thematic attribute information, while dynamic objects composed of events and processes interact with geographical objects to maintain the continuous development of spatiotemporal change in a spatiotemporal setting. This interaction is the key to the complete semantic representation of spatiotemporal changes and is also the feature of the ESTDM. Based on the available research results, this manuscript discusses both causality and composition.

2.3.1. Causality. Causality and change are inseparable. Because of the different mechanisms of action, the expression of causality varies greatly in different times and spaces. Therefore, this manuscript mainly discusses the predicates of causality between dynamic and geographical objects, which can be divided into a trigger, terminate, cause, permit, and maintain [25]. Dynamic objects act on geographic objects to “cause” state-change events, “trigger” new states, and “terminate” the original states. The occurrence of dynamic objects depends on geographical objects. When the accumulation of geographical object states reaches a certain extent, the occurrence of dynamic objects is “allowed.” The state is a sufficient but not a necessary condition for the occurrence of dynamic objects. A special causality is the “maintenance” relationship. For the homogenization process, its internal change semantics are consistent, and when the process continues to occur, it implies the “maintenance” relationship.

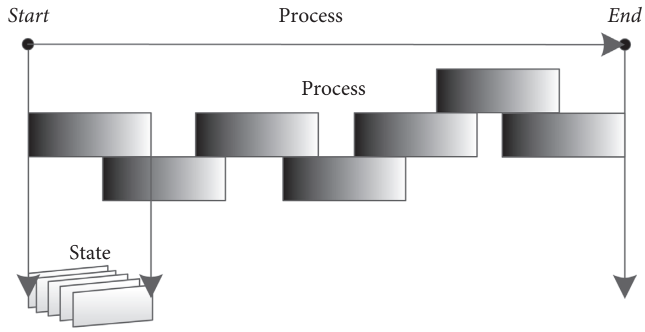
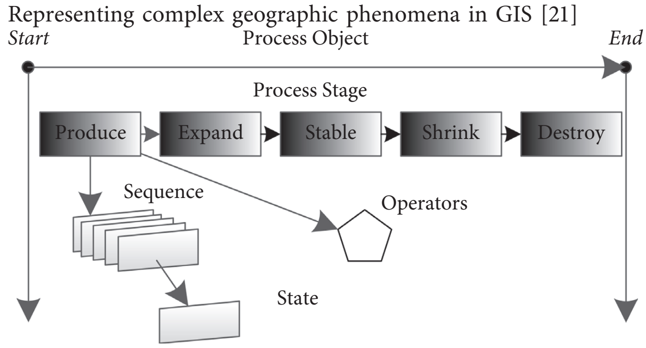
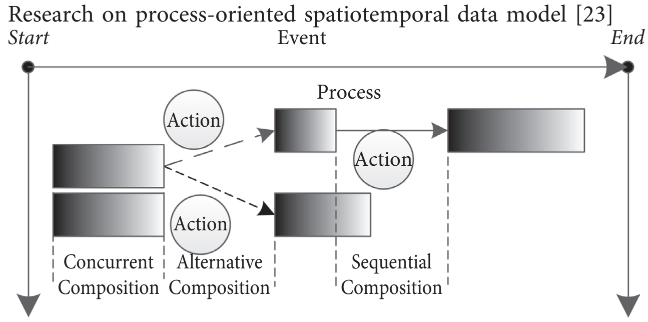
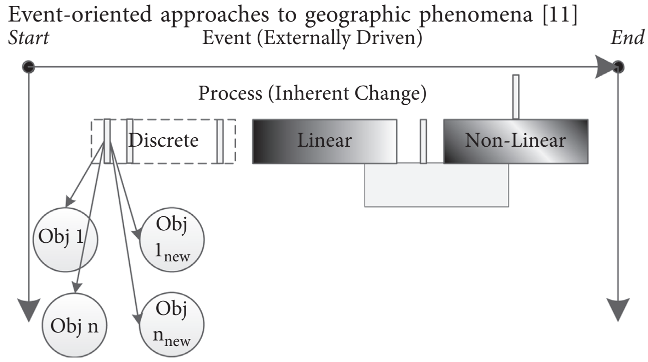
2.3.2. Composition. The process and event of a dynamic object have a composition relation due to the difference of a granularity semantic of a spatiotemporal change. Based on the previous analysis, a structured process usually expresses the semantics of a large-scale change and consists of a series of events organized in sequence. Intrinsically, homogenous processes express continuous, progressive, and fine-grained change semantics and can be composed of semantically similar sequence states and spatiotemporal evolution functions. Therefore, the composition relations between spatiotemporal objects represent spatiotemporal change semantics from different levels, which can effectively improve the efficiency of spatiotemporal information retrieval of the model in practical applications.

The relationships among the three aspects are presented in Figure 1.

3. Application Research of the ESTDM

3.1. The Management of Cadastral Information. In the applications of both land and real estate, a change of spatiotemporal objects is mainly characterized by discrete time-varying characteristics [26]. The time-varying semantics of sequences such as the change of plot scope and utilization type can be expressed through the sequence of geographical events. In addition to the expression of sequential time-varying semantics, the recording and expression of evolutionary relationships between cadastral objects are also concerned in practical applications. The spatiotemporal change table is designed based on the invariance of an object identification [3] and graph theory [17]. Petri net [14] is used to explicitly record the spatiotemporal topological relationship between entities to realize the expression of the parent-child relationship of evolution relationship. To express a change of linkage relations of objects in evolutionary relations, the identification of the cadastral object that changes simultaneously with other cadastral objects is added to the concept of events [27], and the updated constraint rules of the cadastral object are formulated based on the causality and linkage rules among cadastral objects, processes, and events [26]. In terms of the expression of the business process related to a land change, the combination of “atomic event” and “event operator” constitutes the “composite event” of land allocation, which flexibly meets the change of the business demand for the land allocation [28, 29]. The business processes of the land allocation are expressed through hierarchical expansion of the spatiotemporal data model based on the Petri net [20]. While “process” is defined as a change of a cadastral attribute, an “event” is defined as a land registration event, that is, external cause of cadastral change [24], which is organically connected to the change of the cadastral use concerning the land allocation business.

Table 4: Description of intrinsic homogenous spatiotemporal processes.

Model diagram	Model characteristics
 Representing complex geographic phenomena in GIS [21]	Establish the relationship between spatiotemporal process and observation state
 Research on marine spatiotemporal process data model and its prototype system construction [22] Research on process-oriented spatiotemporal data model [23]	Define the five-stage objects of "generation, expansion, stability, weakening, and extinction" to form the expression of process objects
 Event-oriented approaches to geographic phenomena [11]	Introduce process operation to formally describe complex spatiotemporal events, with stronger and more standardized description ability
 Research on an improved temporal model based on event-process [24]	Propose three types of processes: discrete, linear, and nonlinear

3.2. Re-Enactment and Reasoning of Physical Geographic Phenomena. The evolution of the physical geographic phenomenon is the result of various factors influencing each other and energy transfer, which has the characteristics of continuous gradual change and obvious causal relationships. In the process of modeling, it is necessary to make a lot of improvements to the ESTDM, which mainly focuses on the simulation of the evolution process and the coherence expression of spatiotemporal change semantics.

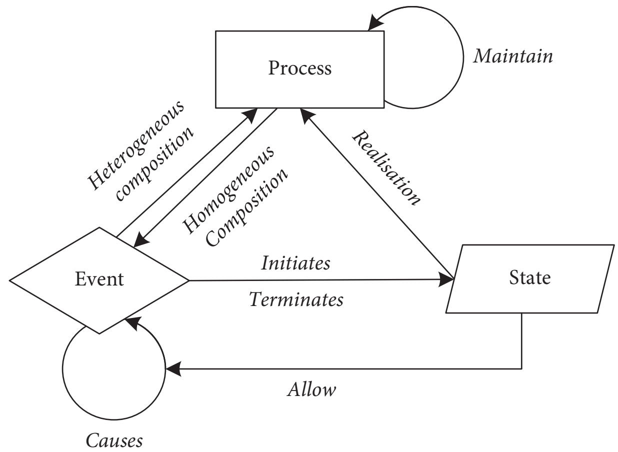


Figure 1: Relationships between events, processes, and states.

A sea ice ontology concerning sea ice objects, events, and processes was constructed utilizing ice caps, icebergs, and floating ice which are called sea ice objects, and events such as “falling off” of ice caps and “drift” of icebergs, as well as processes such called as “formation,” “rupture,” “drift,” and “agglomeration” of floating ice. The relationships such as “instance,” “composition,” “action” and “trigger,” the changes and causes of sea ice are effectively expressed [16]. Based on the idea of a continuous and progressive change of spatiotemporal process expression [30, 31], the objects of the ocean vortex process with complete evolution characteristics are classified and selected. The inference responses to comprehensive spatiotemporal query questions are realized through the decomposition of the temporal conditional statement, process object integration, and the processes of the sequence object integration [23]. Based on Region Connection Calculus (RCC) and Temporal Logic theory, the RCC Association Event (RAE) model, associated with the topological time-varying of “regional object” and “event,” is proposed, and the path law of tropical cyclone is effectively mined by using the probability model [32]. Some of the recent researches dealing with different disciplines can be found [33–36].

4. Findings

The ESTDM is a dynamic spatiotemporal information modeling method, which can effectively simulate spatiotemporal changes and reflect the intrinsic laws of changes by modeling spatiotemporal information, changes, and object relations when temporal and spatial changes need to be modeled.

This manuscript expounds on the modeling theory of the ESTDM, compares the characteristics of geographical and spatiotemporal dynamic objects, studies the concepts and modeling methods of structuration and homogenization processes, and discusses the causal and composition relationships between spatiotemporal objects.

The characteristics of both discrete and continuous change models are analyzed based on the management of the cadastral object, the re-enactment of a physical geographic phenomenon, and reasoning. It is found that the ESTDM is an effective method to deal with dynamic spatiotemporal information by modeling spatiotemporal information, changes, and object relations, which can effectively simulate spatiotemporal change and reflect the intrinsic laws of change. However, there are still several challenges due to the dynamics and complexity of space-time phenomena and the characteristics of modeling objects in various fields.

4.1. Research and Understanding of the Spatiotemporal Dynamic Semantics. The research of spatiotemporal objects has made some theoretical achievements, but it is still in its infancy. Spatiotemporal dynamic semantics are closely related to spatiotemporal granularity, which is instantiated in the mutual composition relation of events and processes, which would lead to spatiotemporal semantic crossover and data redundancy to a certain extent. A standard, clearer, and comprehensive dynamic semantic of a spatiotemporal expression model needs to be introduced.

4.2. The Knowledge Mining of the Spatiotemporal Change. The ESTDM resolves the problems of spatiotemporal data organization and expression of spatiotemporal evolution relations and can better serve the application areas when the management of the cadastral information and the re-enactment of the physical geographic phenomenon is a concern. Based on solving the problem of dynamic spatiotemporal data modeling, it is necessary to continuously introduce key technologies such as probabilistic and automatic inference machine models to realize the promotion of data management to knowledge service.

4.3. Intelligent Aggregation of the Multisource/MultivariantData. With the continuous development of emerging communication technologies such as 5G, the Internet of Things (IoT), and sensor networks, “digital twin cities” are no longer far away. Available models mainly focus on simulating the semantic changes of a single type of geographical object or natural geographic phenomenon. Therefore, for the expression of complex spatiotemporal changes involving multisource/multivariant data and interaction of multitype spatiotemporal objects, continuous exploration is still needed.

5. Conclusion

In this manuscript, we study the event-based spatiotemporal data modeling theory based on three aspects of the cognitive theory, which are the spatiotemporal object, the concept of the spatiotemporal dynamic object, and the spatiotemporal object relationship. Then, the implementation characteristics of the models were analyzed regarding the management of cadastral information, analog natural disaster phenomena, and reasoning. Finally, the key points and difficulties of an event-based spatiotemporal data modeling and prospective developmental trends were discussed to provide insights with spatiotemporal data modeling.

Data Availability

All the data are included in the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] M. Yuan and J. Mcintosh, *GIS Representation For Visualizing and Mining Geographic Dynamics*, Transactions in GIS, vol. 3, no. 2, , pp. 3–10, 2003.

[2] J. Gong, X. Li, and H. Wu, “Real-time GIS spatiotemporal data model,” *Journal of Geodesy and Geoinformation Science*, vol. 14, no. 3, pp. 226–232, 2014.

[3] Z. Xu, F. Bian, and J. Chen, “Temporal GIS model based on event semantics,” *Journal of Wuhan University (Natural Science Edition)*, vol. 27, no. 3, pp. 311–315, 2002.

[4] L. Meng, C. Zhao, Z. Lin, and C. Huang, “Research and implementation of spatiotemporal data model based on the time-varying sequence of geographical events,” *Journal of Wuhan University (Natural Science Edition)*, vol. 28, no. 2, pp. 202–207, 2003.

[5] K. E. Grossner, “Event objects for spatial history,” in *Proceedings of the Sixth International Conference on Geographic Information Science*, Zurich, Switzerland, September 2010.

[6] D. J. Peuquet and N. Duan, “An event-based spatiotemporal data model (ESTDM) for temporal analysis of geographical data,” *International Journal of Geographical Information Systems*, vol. 9, no. 1, pp. 7–24, 1995.

[7] A. Galton, “Fields and objects in space, time, and space-time,” *Spatial Cognition and Computation*, vol. 4, no. 1, pp. 39–68, 2004.

[8] A. Galton, “Experience and history: processes and their relation to events,” *Journal of Logic and Computation*, vol. 18, no. 3, pp. 323–340, 2008.

[9] A. Galton and R. Mizoguchi, “The water falls but the waterfall does not fall: new perspectives on objects, processes and events,” *Applied Ontology*, vol. 4, no. 2, pp. 71–107, 2009.

[10] G. Pierre and S. Barry, “SNAP and SPAN: towards dynamic spatial ontology,” *Spatial Cognition and Computation*, vol. 4, no. 1, pp. 69–104, 2004.

[11] M. Worboys, “Event-oriented approaches to geographic phenomena,” *International Journal of Geographical Information Science*, vol. 19, no. 1, pp. 1–28, 2005.

[12] A. Galton, “On what goes on: the ontology of processes and events: conference on formal ontology in information systems,” in *Proceedings of the Fourth International Conference*, Baltimore, MD, USA, November 2006.

[13] F. Zhang, R. Liu, N. Liu et al., “A process-based dynamic spatiotemporal data model,” *Journal of Sun Yat-sen University (Social Science Edition)*, vol. 47, no. 2, pp. 123–126, 2008.

[14] Z. Yin and L. Li, “Research on spatiotemporal data model based on Petri net,” *Journal of Wuhan University (Natural Science Edition)*, vol. 29, no. 8, pp. 740–743, 2004.

[15] X. Chen, L. Li, and M. Li, “Spatiotemporal data model based on object event process and its application,” *Geography and Geo-Information Science*, vol. 29, no. 3, pp. 14–20, 2013.

[16] X. Chen and J. Zhu, “Database model based on spatiotemporal ontology,” *Geography and Geo-Information Science*, vol. 26, no. 5, pp. 1–6, 2010.

[17] Z. C. Yin, L. Li, and Z. Ai, “Research on spatiotemporal data model based on graph theory,” *Journal of Geodesy and Geoinformation Science*, vol. 32, no. 2, pp. 168–172, 2003.

[18] Y. May, “Toward knowledge discovery about geographic dynamics in spatiotemporal databases,” in *Geographic Data Mining and Knowledge Discovery*, pp. 347–365, , CRC Press, Boca Raton, FL, USA, 2009, 2nd edn.

[19] J. Xie, R. Liu, N. Liu et al., “A Trapezoidal hierarchical description framework for spatiotemporal processes and its modeling example,” *Journal of Geodesy and Geoinformation Science*, vol. 36, no. 3, pp. 321–328, 2007.

[20] Z. Huang and X. Feng, “Spatiotemporal process modeling of land change based on Petri net,” *Journal of Geodesy and Geoinformation Science*, vol. 34, no. 3, pp. 239–245, 2005.

[21] Y. May, “Representing complex geographic phenomena in GIS,” *The American Cartographer*, vol. 28, no. 2, pp. 83–96, 2001.

[22] C. Xue and Q. Dong, “Research on marine spatiotemporal process data model and its prototype system construction,” *Marine Science Bulletin*, vol. 31, no. 6, pp. 667–674, 2012.

[23] C. Xue, C. Zhou, F. Su, Q. Dong, and J. Xie, “Research on process-oriented spatiotemporal data model,” *Journal of Geodesy and Geoinformation Science*, vol. 39, no. 1, pp. 95–101, 2010.

[24] C. Wu and G. Lu, “Research on an improved temporal model based on event-process,” *Journal of Wuhan University (Natural Science Edition): Information Science Edition*, vol. 33, no. 12, pp. 1250–1253, 2008.

[25] E. Allen, G. Edwards, and Y. Bédard, “Qualitative Causal Modeling in Temporal GIS,” in *Proceedings of the International Conference on Spatial Information Theory*, Semmering, Austria, September 1995.

[26] F. Zhang, N. Liu, R. Liu et al., “Research on object-oriented cadastral spatiotemporal process expression and data update model,” *Journal of Geodesy and Geoinformation Science*, vol. 39, no. 3, pp. 303–309, 2010.

[27] L. Meng, P. Chen, X. Tong et al., “Research on the spatiotemporal data model of cadastral objects based on the whole life cycle and improvement events,” *Geomatics World*, vol. 22, no. 4, pp. 51–56, 2015.

[28] C. J. Jiang, J. Chen, and J. Jiang, “Event-based Spatio-temporal database design,” *Acta Geodaetica et Cartographica Sinica*, vol. 29, no. 1, pp. 64–70, 2000.

[29] J. Chen and J. Jiang, "An event-based approach to spatio-temporal data modeling in land subdivision systems," *Geo-informatics*, vol. 4, no. 4, pp. 387–402, 2000.
[30] C. Claramunt, C. Parent, and M. Thériault, "Design ps-temporal processes," *Data Mining and Reverse Engineering*, pp. 455–475, 1998.
[31] F. Su and C. Zhou, "Framework foundation and prototype construction of process geographic information system," *Geographical Research*, vol. 25, no. 3, pp. 477–484, 2006.
[32] X. Chen, *Research on the Spatiotemporal Data Model and Time-Varying Analysis Model of Events and Processes*, Central South University, Changsha, China, 2011.
[33] Ş. Boghiu and D. Gîfu, "A spatial-temporal model for event detection in social media," *Procedia Computer Science*, vol. 176, pp. 541–550, 2020.
[34] W. Xiong, H. Chen, N. Guo et al., *ENSTDM: An ENtity-Based Spatial-Temporal Data Model and Case Study in Real Estate Management, Spatial Data and Intelligence*, Springer, Heidelberg, Germany, 2021.
[35] M. Yu, "A graph-based spatiotemporal data framework for 4D natural phenomena representation and quantification-an example of dust events," *Int. J. Geo-Information*, vol. 9, no. 127, pp. 1–17, 2020.
[36] M. Yu, M. Bambacus, G. Cervone et al., "Spatiotemporal event detection: a review," *International Journal of Digital Earth*, vol. 13, 2020.

Hindawi
Scientific Programming
Volume 2021, Article ID 1704995, 10 pages
https://doi.org/10.1155/2021/1704995

Research Article

Automatic Synthesis Technology of Music Teaching Melodies Based on Recurrent Neural Network

Yingxue Zhang[1] and Zhe Li[2]

[1]*Academy of Music, Hubei Engineering University, Xiaogan 432100, China*
[2]*Economic and Management, Hubei Engineering University, Xiaogan 432100, China*

Correspondence should be addressed to Zhe Li; lizhe_lz@hbeu.edu.cn

Received 27 September 2021; Revised 15 November 2021; Accepted 19 November 2021; Published 9 December 2021

Academic Editor: Ahmed Farouk

Computer music creation boasts broad application prospects. It generally relies on artificial intelligence (AI) and machine learning (ML) to generate the music score that matches the original mono-symbol score model or memorize/recognize the rhythms and beats of the music. However, there are very few music melody synthesis models based on artificial neural networks (ANNs). Some ANN-based models cannot adapt to the transposition invariance of original rhythm training set. To overcome the defect, this paper tries to develop an automatic synthesis technology of music teaching melodies based on recurrent neural network (RNN). Firstly, a strategy was proposed to extract the acoustic features from music melody. Next, the sequence-sequence model was adopted to synthetize general music melodies. After that, an RNN was established to synthetize music melody with singing melody, such as to find the suitable singing segments for the music melody in teaching scenario. The RNN can synthetize music melody with a short delay solely based on static acoustic features, eliminating the need for dynamic features. The proposed model was proved valid through experiments.

1. Introduction

With the rapid development of modern computer science, many researchers have shifted their focus to computer-based algorithm composition or automatic music melody generation system. The research results on music melody synthesis and music modeling methods are being applied to various fields. The research of computer music creation aims to quantify and combine the emotional tendencies of music, with the aid of computer and mathematical algorithms. The specific tasks include aided composition, sound simulation and storage, and music analysis and creation [1, 2]. Computer music creation generally relies on artificial intelligence (AI) and machine learning (ML) to generate the music score that matches the original mono-symbol score model or memorize/recognize the rhythms and beats of the music. Despite its broad application prospects, the AI-based composition without needing lots of music knowledge rules is in the theoretical stage [3, 4].

Speech processing has been widely applied in composition and songwriting, record production, and entertainment. Unlike simple speech synthesis, music melody synthesis has two additional processing steps: tone detection and transformation [5, 6]. Wenner et al. [7] preprocessed the musical melody synthesis corpus through automatic note segmentation and voiced/unvoiced sound recognition, constructed a high-quality music melody synthesis system, and proposed a music melody adjustment algorithm, which functions as an adaptive filter capable of detecting musical note cycles.

AI has already been adopted to realize algorithm composition or automatic music generation [8–12]. Bilbao et al. [13] introduced bidirectional long short-term memory (LSTM) neural network to the mixed music generation system and thus realized the training of multi-voice music datasets. Their approach provides effective chord progressions while ensuring melody time and transposition invariance.

Electronic synthetic tones bring rich new sound experience to music of various styles and themes. Electronic musical instruments differ from traditional acoustic instruments in sound rendering principle and acoustic features [14–19]. Miranda et al. [20] expounded the computer-aided means to realize the acoustic features, voice editing, and modulation of electronic sound melodies and provided a valuable reference for applying electronic sound melodies in modern music creation. However, computer-based accompaniment has a rigid chord structure, which cannot easily adapt to diverse music styles. To solve the problem, Taigman et al. [21] put forward an adaptive automatic accompaniment algorithm, including chord series extraction and automatic accompaniment figure acquisition, and created a suitable accompaniment figure database based on chord sequences in the light of the features of music melodies and emotions.

The existing studies at home and abroad mostly concentrate on the methods, melodic forms, and tone synergy of computer music creation [22–26]. However, there are very few music melody synthesis models based on artificial neural networks (ANNs). Some ANN-based models cannot adapt to the transposition invariance of original rhythm training set. To overcome the defect, this paper attempts to develop an automatic synthesis technology of music teaching melodies based on recurrent neural network (RNN).

The remainder of this paper is organized as follows. Section 2 extracts the acoustic features from music melody. Section 3 applies the sequence-sequence model to synthetize general music melodies. Section 4 establishes an RNN to synthetize music melody with singing melody, aiming to find the suitable singing segments for the music melody in teaching scenario. Finally, experiments were carried out to prove the effectiveness of our model.

2. Acoustic Feature Extraction

The automatic synthesis of music melody aims to obtain a melody that is beautiful and pleasant to human ears. To describe the differences in the auditory sensitivity of human ears to music melodies of different frequencies, the linear frequency μ of each music melody was transformed based on mel scale frequency μ_{MR}:

$$\mu_{MR} = 2595 \times \log_{10}\left(1 + \frac{\mu}{700}\right). \tag{1}$$

Under the scale of mel scale frequency μ_{MR}, the multiples of the μ_{MR} difference between two music melodies are roughly equal to those of the tone difference perceived by human ears.

For the above reason, mel scale was adopted to extract acoustic features in our music melody synthesis system. Since the music melody signal in the high-frequency band is relatively weak, such a signal was compensated through preemphasis. Let β be the preemphasis factor. Then, the preemphasis of music melody $a(\tau)$ can be described by

$$b(\tau) = a(\tau) - \beta \cdot a(\tau - 1). \tag{2}$$

To prevent spectrum leakage and enhance the continuity of the left end and right ends of the signal frame, it is necessary to perform framing and windowing of the music melody signal with short-time stationarity features. Let $CH(m)$, $m = 0, 1, \ldots, M-1$, be the framed music melody signal and $CK(m)$ be the function of the Hamming window. Then, the windowed signal $CH^*(m)$ can be described by

$$CH^*(m) = CH(m) \times CK(m), \tag{3}$$

where $CK(m)$ can be described by

$$CK(m) = \begin{cases} 0.54 - 0.46\cos\left(\dfrac{2\pi m}{M-1}\right), & 0 \le m \le M-1, \\ 1, & \text{otherwise}. \end{cases} \tag{4}$$

It is difficult to extract the features from time-domain music melody signal. The general practice is to convert the signal to the frequency domain through short-time Fourier transform (STFT) before further analysis. Let $CH^*(m)$ be the input signal of STFT and M be the number of Fourier points. Then, the fast Fourier transform of the M points of the windowed framed time-domain music melody signal $CH^*(m)$ can be expressed as

$$CH(l) = \sum_{m=0}^{M-1} CH^*(m)\exp\left(-\frac{j2\pi lm}{M}\right), \quad 0 \le l \le M. \tag{5}$$

In the frequency domain, the absolute value of the spectrum of the music melody signal can be described as

$$PT(l) = |CH(l)|. \tag{6}$$

The human ears can only detect the frequency components in a certain range. Therefore, the human auditory system could be treated as a filter bank that only allows some frequency signals to pass through. This paper simulates the human auditory system with a mel filter bank. Let μ_n, μ_{max}, and μ_{min} be the central, upper, and lower frequencies of the filter bank, respectively. Then, the transfer function of the filter bank can be described by

$$QF_n(l) = \begin{cases} 0, & k < \mu_{min}, \\ \dfrac{l - \mu_{min}}{\mu_n - \mu_{min}}, & \mu_{min} \le l \le \mu_n, \\ \dfrac{\mu_{max} - l}{\mu_{max} - \mu_n}, & \mu_n \le l \le \mu_{max}, \\ 0, & l > \mu_{max}. \end{cases} \tag{7}$$

Let N be the number of triangular filters. Then, the signal o_n passing through the mel filter bank $QF_n(l)$ can be expressed as

$$o_n = \sum_{l=\mu_{\min}}^{\mu_{\max}} PT(l)QF_n(l) \quad n = 0, 1, 2, \ldots, N-1. \tag{8}$$

The mel spectrum can be extracted by taking the logarithm of o_n.

3. Sequence-Sequence Model-Based Music Melody Synthesis

Both speech synthesis based on statistical parameters and music melody synthesis based on neural networks face the following defects: the complexity of model construction and the dependence of front-end text processing on texts with strong linguistics knowledge. Unlike these approaches, sequence-sequence model-based speech synthesis can directly transform phonetic notations to waveforms and significantly simplify the front-end module. Since a standard neural network cannot directly process input and variable sequences with variable length, a sequence-sequence model is needed to handle the scenario that input sequence is not equal to the output sequence.

This paper constructs a sequence-sequence model of music melody to realize the automatic synthesis of melody sequences. Figure 1 shows the structure of the music melody synthesis system based on the sequence-sequence model. In the proposed model, the music melody recognition module receives a music melody sequence and outputs a singing melody sequence. The synthesis module receives the target melody sequence and outputs an audio sequence.

The RNN model consists of an encoder and a decoder, using an activation function Γ. The hidden state g_τ at the current moment τ depends on the input g_τ at the current moment and the hidden state $g_{\tau-1}$ at the previous moment $\tau-1$:

$$g_\tau = \Gamma(g_{\tau-1}, a_\tau). \tag{9}$$

Let $g_{\psi a}$ be the hidden layer state of the neural network at moment ψ_a and $s(^*)$ be the nonlinear transform. Then, the middle vector p of the encoder can be obtained through the nonlinear transform of each hidden layer states:

$$p = s\left(g_1, g_2, g_3, g_4 \ldots g_{\psi_a}\right). \tag{10}$$

The middle vector p is equivalent to the final encoded state of the hidden layer:

$$p = s\left(g_1, g_2, g_3, g_4 \ldots g_{\psi_a}\right) = g_{\psi_a}. \tag{11}$$

The next output b_i of the encoder can be generated based on the middle vector p and historical outputs $b_1, b_2, \ldots, b_{i-1}$. The encoder is often adopted to predict the next acoustic feature in music melody composition. It is necessary to determine the middle vector p and the existing acoustic features:

$$b_i = \arg\max O(b_i) = \prod_{i=1}^{n} o(b_i | b_1, b_2, \ldots, b_{i-1}, p). \tag{12}$$

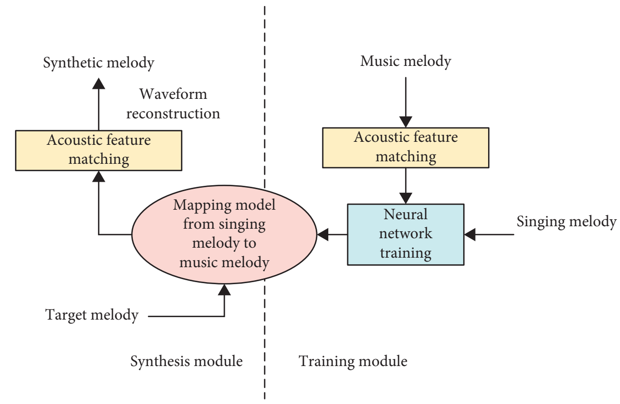


Figure 1: Music melody synthesis system based on the sequence-sequence model.

Let r_{i-1} be the state of a hidden layer node in the RNN of the decoder; b_{i-1} be the output of that node at the moment $i-1$; and $s(^*)$ be the nonlinear transform. Then, formula (12) can be simplified as

$$b_i = s(b_{i-1}, r_{i-1}, p). \tag{13}$$

The sequence-sequence model is prone to a potential problem: the input sequence has the same influence on the weight of each element in the output sequence. This problem can be solved by the attention mechanism. Figure 2 shows the structure of the attention-based model.

The attention mechanism highlights that different nodes belong to different parts of the input sequence. Let g_v be the hidden layer output of the encoder at the moment v; $r_{\tau-1}$ be the hidden layer output of the encoder at the moment $\tau-1$; and e be the alignment model. Then, the matching degree $DO_{\tau j}$ between the location of input layer nodes and output layer nodes can be calculated by

$$DO_{\tau v} = e(r_{\tau-1}, g_v), \tag{14}$$

where e is a nonlinear function to compare and compute the matching degree between g_v and $r_{\tau-1}$. The greater DO_τ is, the more necessary it is to emphasize the input sequence at the current moment during the decoding of music melody signal. Let U, V, and W be weight matrices. Then, the point multiplication, weighting, weight stitching, and sensing of the alignment model e can be, respectively, described by

$$\begin{aligned} e\left(r_{\tau-1}, g_j\right) &= r_{\tau-1}^{\psi} g_j, \\ e\left(r_{\tau-1}, g_j\right) &= r_{t-1}^{\psi} V g_j, \\ e\left(r_{\tau-1}, g_j\right) &= V\left[r_{\tau-1}^{\psi}; g_j\right], \\ e\left(r_{\tau-1}, g_j\right) &= U^{\psi} \quad \tanh V r_{\tau-1} + W g_j. \end{aligned} \tag{15}$$

$DO_{\tau j}$ can be normalized by

$$\beta_{\tau j} = \frac{\exp\left(DO_{\tau j}\right)}{\sum_{l=1}^{\psi_a} \exp\left(DO_{\tau l}\right)}. \tag{16}$$

The middle vector p_τ can be obtained through weighted summation:

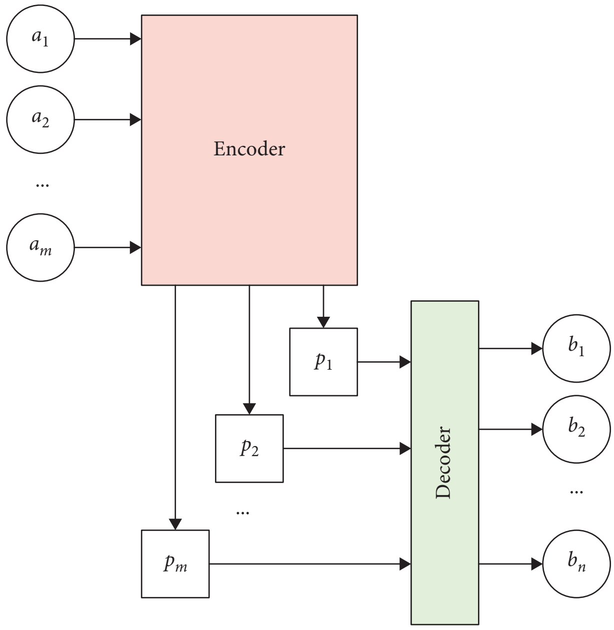


Figure 2: Attention-based model.

$$p_\tau = \sum_{j=1}^{\psi_a} \beta_{\tau j} g_j. \tag{17}$$

Let $s(*)$ be the nonlinear transform. Then, the next hidden layer state can be calculated by

$$r_\tau = s(r_{\tau-1}, b_{\tau-1}, p_\tau). \tag{18}$$

To realize frame-level feature mapping from the input to the output, the proposed model needs to transform the contextual features on the phoneme level and the frame level. This section puts forward a length prediction model for music melody, which supports the time supervision labeling. Suppose a phoneme sequence is given for a rhythm in a music melody sequence of the length M. Let ε be the model parameter of the RNN; w be the rhythm state sequence of the melody; and L_m be the number of rhythm states of the melody. Then, the length prediction of music melody states can be regarded as the forecast of the length of the state allocation sequence. The prediction goal is to maximize the likelihood in the following formula:

$$\log O(w|\varepsilon, \psi) = \sum_{m=1}^{M} \sum_{l=1}^{L_m} \log o_{m,l}(\delta_{m,l}). \tag{19}$$

Let $o_{m,l}(\delta_{m,\,l})$ be the probability density function of the length model of the music melody; $\delta_{m,l}$ be the time of the l-th state of the m-th phoneme; Ψ be the total length constraint; $n_{m,l}$ be the length of rhythm state predicted by network model; and $\varphi_{m,l}$ be the variance obtained from the individual length of each phoneme in the music melody database. Solving the maximum likelihood of formula (19), the rhythm state length of each melody can be obtained by

$$\delta_{m,l} = n_{m,l} + \sigma \cdot \phi_{m,l}^2. \tag{20}$$

Let ψ_S be the phoneme length specified in the music score. Then, σ can be calculated by

$$\sigma = \frac{\left(\psi - \sum_{m=1}^{M} \sum_{l=1}^{L_m} n_{m,l}\right)}{\sum_{m=1}^{M} \sum_{l=1}^{L_m} \phi_{m,l}^2}. \tag{21}$$

4. RNN-Based Melody Synthesis

To find the suitable singing segments for the music melody in the teaching scenario, the RNN-based statistical music melody synthesis algorithm needs to realize the following goal in the synthesis phase: identifying the most possible acoustic feature sequence $\tilde{u}$ from the signing melody sequence k with given linguistic features and a series of trained context-dependent music melodies Φ. Then, we have

$$\begin{aligned}
\tilde{u} &= \arg\max_u o(u|k, \tilde{\Phi}) \\
&= \arg\max_u \sum_{\forall w} \chi(u, w|k, \tilde{\Phi}) \\
&= \arg\max_{u,w} \chi(u, w|k, \tilde{\Phi}) \\
&= \arg\max_{u,w} \chi(u, w|k, \tilde{\Phi}) \Delta(w|k, \tilde{\Phi}) \\
&= \arg\max_u \chi(u|\widehat{w}, \tilde{\Phi}),
\end{aligned} \tag{22}$$

where $\hat{w}$ is the rhythm state of a melody:

$$\widehat{w} = \arg\max_w \Delta(w|k, \tilde{\Phi}). \tag{23}$$

Let $\lambda_{\hat{w}i}$ be the mean vector under state $\hat{w}_i$; $\sum_{\hat{w}i}$ be the corresponding covariance matrix; and $\lambda_{\widehat{w}i} = \lambda_{\widehat{w}1}^T, \ldots, \lambda_{\widehat{w}Q}^T$ and $\Sigma_{\widehat{w}} = \Sigma_{\widehat{w}1}^T, \ldots, \Sigma_{\widehat{w}Q}^T$ be the mean vector and covariance matrix under the given state w of singing melody sentence, respectively. If the output probability of the neural network obeys single Gaussian distribution, then formula (25) can be rewritten as

$$\begin{aligned}
\tilde{u} &= \arg\max_u o(u_\tau|\widetilde{w}_\tau, \Phi) \\
&= \arg\max_u \prod_{\tau=1}^{Q} M\left(u_t; \lambda_{\widehat{w}_\tau}, \sum_{\widehat{w}_\tau}\right) \\
&= \arg\max_u \mathfrak{R}\left(u_\tau; \lambda_{\widehat{w}}, \sum_{\widehat{w}}\right) \\
&= \lambda_{\widehat{w}}.
\end{aligned} \tag{24}$$

From the statistical features of output probability (Figure 3), it can be learned that $\lambda_{\hat{w}i}$ is a jump series because the rhythm states of a melody are discrete and independent. The music melody signal reconstructed from $\lambda_{\hat{w}i}$ has a discontinuous boundary of rhythm states. To solve the problem, this paper introduces an observation vector u, which covers the static acoustic feature and its first- and second-order derivatives with respect to time:

$$u_\tau = \left[\theta_\tau^T, \Delta\theta_\tau^T\right]^T. \tag{25}$$

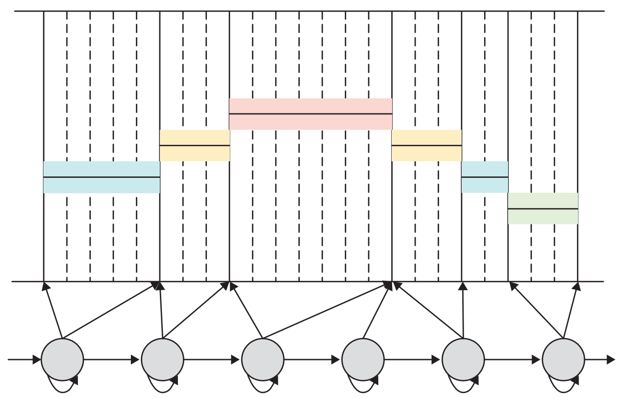


Figure 3: Statistical features of output probability.

Let SC be the sparse coefficient matrix. Then, the relationship between the observation vector sequence $u = [u_1^T, \ldots, u_Q^T]$ and the acoustic eigenvector sequence $\theta = [\theta_1^{\mathrm{T}}, \ldots, \theta_Q^T]$ can be described by

$$\begin{bmatrix} u_{\tau-1} \\ u_\tau \\ u_{\tau+1} \end{bmatrix} \begin{bmatrix} \vdots \\ \theta_{\tau-1} \\ \mathrm{d}\theta_{\tau-1} \\ d_\tau \\ \mathrm{d}\theta_\tau \\ d_{\tau+1} \\ \mathrm{d}\theta_{\tau+1} \\ \vdots \end{bmatrix} = SC = \begin{bmatrix} \cdots & \vdots & \vdots & \vdots & \vdots & \cdots \\ \cdots & 0 & I & 0 & 0 & \cdots \\ \cdots & -1/2I & 0 & 1/2I & 0 & \cdots \\ \cdots & 0 & 0 & I & 0 & \cdots \\ \cdots & 0 & -1/2I & 0 & 1/2I & \cdots \\ \cdots & 0 & 0 & 0 & I & \cdots \\ \cdots & 0 & 0 & -1/2I & 0 & \cdots \\ \cdots & \vdots & \vdots & \vdots & \vdots & \cdots \end{bmatrix} = \begin{bmatrix} \vdots \\ \theta_{\tau-2} \\ \theta_{\tau-1} \\ \theta_\tau \\ \theta_{\tau+1} \\ \vdots \end{bmatrix}. \tag{26}$$

Combining formulas (24) and (26):

$$\begin{aligned} \tilde{u} &= \arg\max_u \mathfrak{R}\left(u_\tau; \lambda_{\widehat{w}}, \sum_{\widehat{w}}\right) \\ &= SC \cdot \theta. \end{aligned} \tag{27}$$

The maximization of the output probability is equivalent to finding the maximum of θ:

$$\begin{aligned} \tilde{\theta} &= \arg\max_\theta \mathfrak{R}\left(SC \cdot \theta; \lambda_{\widehat{w}}, \sum_{\widehat{w}}\right) \\ &= \arg\max_\theta \log\, \mathfrak{R}\left(SC \cdot \theta; \lambda_{\widehat{w}}, \sum_{\widehat{w}}\right). \end{aligned} \tag{28}$$

Find the partial derivative of θ in formula (28):

$$\frac{\partial \log\ \mathfrak{R}\left(SC \cdot \theta; \lambda_{\widehat{w}}, \Sigma_{\widehat{w}}\right)}{\partial\theta} \propto \frac{\partial}{\partial\theta}\left(SC \cdot \theta - \lambda_{\widehat{w}}\right)^T \sum_{\widehat{w}}^{-1}\left(SC \cdot \theta - \lambda_{\widehat{w}}\right) = SC^T \sum_{\widehat{w}}^{-1} SC \cdot \theta - SC^T \sum_{\widehat{w}}^{-1} \lambda_{\widehat{w}}. \tag{29}$$

Make formula (29) equal to 0, and a linear equation about θ can be obtained:

$$SC^T \sum_{\widehat{w}}^{-1} SC \cdot \theta = SC^T \sum_{\widehat{w}}^{-1} \lambda_{\widehat{w}}. \tag{30}$$

Unlike other deep neural networks, the RNN combines the output of the input layer and the output of the hidden layer at the previous moment into the input of the hidden layer. Therefore, the network can capture the dynamic law of sequential music melodies from the periodic connections between hidden layer nodes. Let ω_{ga}, ω_{bg}, and ω_{gg} be the weight matrices of input layer-hidden layer, hidden layer-output layer, and hidden layer-hidden layer, respectively; γ_g and γ_b be the bias vectors of hidden layer and output layer, respectively; $G(.)$ be the activation function between hidden layers; and $\{a_\tau\}\psi_{\tau=1}$, $\{g_\tau\}^{\psi}_{\tau=1}$, and $\{b_\tau\}^{\psi}_{\tau=1}$ be the input music melody features, hidden layer sequence, and output features, respectively. Then, g_τ can be expressed as

$$g_\tau = G\left(\omega_{ga}\tau + \omega_{gg}g_{\tau-1} + \gamma_g\right). \tag{31}$$

Besides, b_τ can be given by

$$b_\tau = \omega_{bg}g_\tau + \gamma_b. \tag{32}$$

For the traditional RNN, vanishing gradient problem might occur during network training, owing to the use of backpropagation algorithm. To prevent this problem, the LSTM, a time RNN model, was adopted to synthetize the teaching audios including both singing melody and music melody. As shown in Figure 4, an LSTM unit contains an input gate IG_τ, a forget gate FG_τ, and an output gate OG_τ, as well as a memory cell MC_τ. Let g_τ and a_τ be the hidden layer output and input signal of the network at the moment τ, respectively; $\omega_I{}^*$ and $\omega_{XH}{}^*$ be the weight matrices of input layer nodes and hidden layer nodes, respectively; $C_{PH}{}^*$ and γ^* be the weight and bias, respectively; and $\bigcirc$ be the Hadamard product of the elements of a matrix. Then, the operations of the input gate IG_τ, the forget gate FG_τ, the memory cell MC_τ, and the output gate OG_τ can be, respectively, expressed as

$$\begin{aligned}
IG_\tau &= \text{sigmoid}\left(\omega_I^{IG}a_\tau + \omega_{XH}^{IG}g_{\tau-1} + C_{PH}^{IG}\circ MC_{\tau-1} + \gamma^{IG}\right),\\
FG_\tau &= \text{sigmoid}\left(\omega_I^{FG}a_\tau + \omega_{XH}^{FG}g_{\tau-1} + C_{PH}^{FG}\circ MC_{\tau-1} + \gamma^{FG}\right),\\
MC_\tau &= FG_\tau\circ MC_{\tau-1} + IG_\tau\circ\ \text{Tanh}\left(\omega_I^{MC}a_\tau + \omega_{XH}^{MC}g_{\tau-1} + \gamma^{MC}\right),\\
OG_\tau &= \text{sigmoid}\left(\omega_I^{OG}a_\tau + \omega_{XH}^{OG}g_{\tau-1} + C_{PH}^{OG}\circ MC_{\tau-1} + \gamma^{OG}\right).
\end{aligned} \tag{33}$$

Then, g_τ can be calculated by

$$g_\tau = OG_\tau\circ\ \text{Tanh}\left(MC_\tau\right). \tag{34}$$

To reduce the delay of singing melody relative to music melody, the LSTM was adopted to build the acoustic model, and recurrent output layers were configured to further smoothen the acoustic features between adjacent frames. Figure 5 shows the framework of the low-delay synthesis model of singing melody relative to music melody. Let ω_{bb} be the weight matrix of the recurrent connections of the output layer extended from the traditional RNN. Then, we have

$$b_\tau = \omega_{bg}g_\tau + \omega_{bb}b_{\tau-1} + \gamma_b. \tag{35}$$

Dynamic features are needed to smoothen the parameter trajectories. It is possible to obtain smooth parameter trajectories by smoothing the acoustic parameters with recurrent output layers. The LSTM-based recurrent output layers receive the activation g_τ of the hidden layer and the output $b_{\tau-1}$ at the moment $\tau-1$, process them with the activation function and the input gate operation, and save some of the information to the state of the memory cell:

$$IG_\tau = \text{sigmoid}\left(\omega_I^{IG}g_\tau + \omega_{XH}^{IG}b_{\tau-1} + C_{PH}^{IG}\circ MC_{\tau-1} + \gamma^{IG}\right). \tag{36}$$

The state MC_τ of the memory cell at time τ can be obtained through forget gate operation and scrapping some useless information:

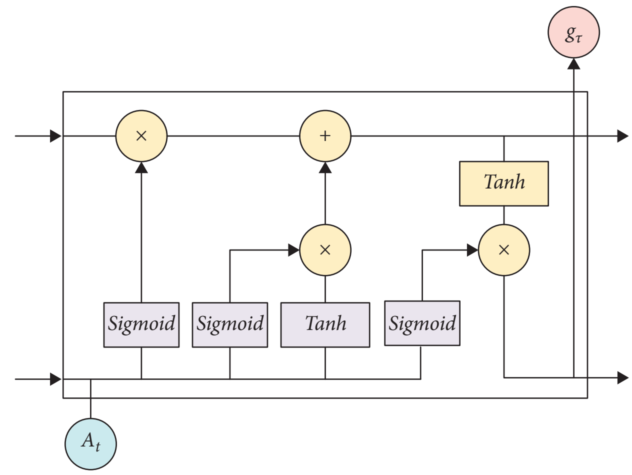


Figure 4: Structure of an LSTM unit.

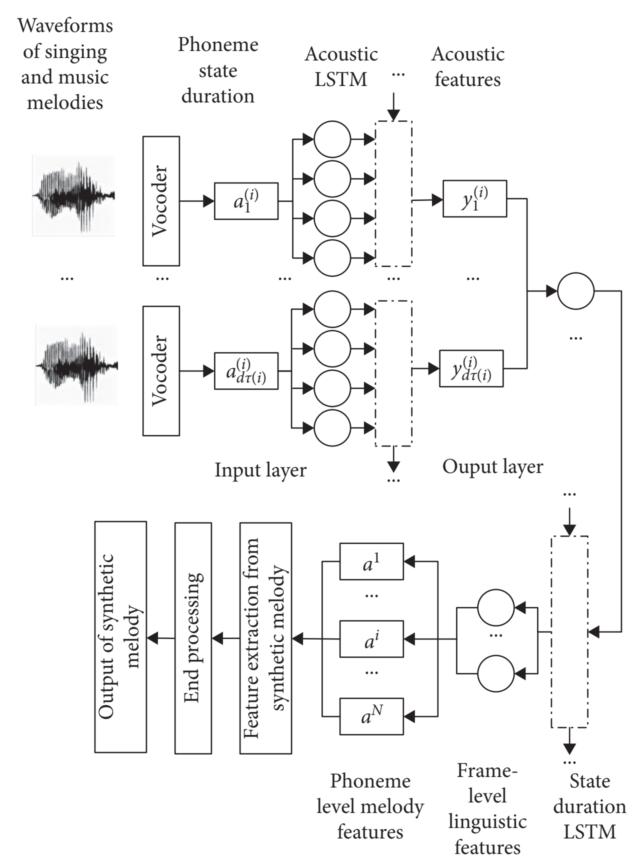


Figure 5: Low-delay synthesis framework of singing melody relative to music melody.

$$\begin{aligned}
FG_\tau &= \text{sigmoid}\left(\omega_I^{FG}g_\tau + \omega_{XH}^{FG}b_{\tau-1} + C_{PH}^{FG}\circ MC_{\tau-1} + \gamma^{FG}\right),\\
MC_\tau &= FG_\tau\circ MC_{\tau-1} + IG_\tau\circ\left(\omega_I^{MC}g_\tau + \omega_{XH}^{MC}b_{\tau-1} + \gamma^{MC}\right).
\end{aligned} \tag{37}$$

Finally, the network output b_τ at time τ can be obtained through output gate operation of MC_τ:

$$OG_\tau = \text{sigmoid}\left(\omega_I^{OG} g_\tau + \omega_{XH}^{OG} b_{\tau-1} + C_{PH}^{OG} \circ MC_{\tau-1} + \gamma^{OG}\right),$$
$$b_\tau = OG_\tau \circ MC_\tau. \tag{38}$$

5. Experiments and Result Analysis

To compare the convergence of different music melody synthesis models, Figure 6 shows the trend of the loss function value on the verification set of four models: DCNN based on static acoustic feature, LSTM, LSTM-RNN, and our model. The value of the loss function is the difference of model output and the actual value. Extended from AlexNet, the DCNN boasts deep layers and numerous parameters and has been widely applied to signal recognition and image processing. As an RNN, the LSTM is suitable for processing and predicting important events with relatively long intervals and delays in the time series. The network has been adopted in many scientific fields, namely, language learning and translation, robotic control, image analysis, document summarization, speech and image recognition, handwriting recognition, chatbot control, disease, click rate and stock prediction, and music synthesis.

The loss of each model continued to decrease with the growing number of iterations and eventually converged. After convergence, the DCNN had the greatest loss, the LSTM and LSTM-RNN had similar losses, and the proposed low-delay LSTM-LSTM realized the smallest loss.

To compare the music melody generated by our model with the original music melody, forty segments of music melodies were randomly selected from a test set containing 577 segments. The music melodies synthetized by different networks were objectively measured by four metrics: BAP distortion, F0 RMSE, LE, and MCD. The results in Table 1 show that MCD had the greatest influence on the synthetic music melodies. Overall, our model, which further smooths the acoustic features between adjacent frames with recurrent outputs, outperformed other networks, as evidenced by the small gaps of the four metrics. Therefore, our model is highly robust in finding the suitable singing segments for teaching.

Table 2 presents the errors of different model configurations in predicting phoneme length. It can be seen that the optimal configuration is our model with four layers, whose RMSE was 5.19 and the sum of RMSE and cross entropy was 4.18. Besides, our model had better phoneme synthesis effect than DCNN and LSTM, a sign of superiority in the modeling of music melody sequence. Based on RMSE + cross entropy, the least mean square (LMS) of the synthetic melody can be predicted, in order to effectively reduce the RMSE of phoneme length prediction. However, the predicted phoneme length might deviate from the actual length of the music melody. It is important to apply a constraint on the phoneme length of the two melodies. Table 3 shows the errors in the phoneme length before and after applying the constraint.

As shown in Table 3, before the constraint was applied, the predicted phoneme length was inconsistent with the given value. After applying the constraint, the mean error between the predicted value and the given value dropped. This proves the reasonability of introducing the constraint on the phoneme level.

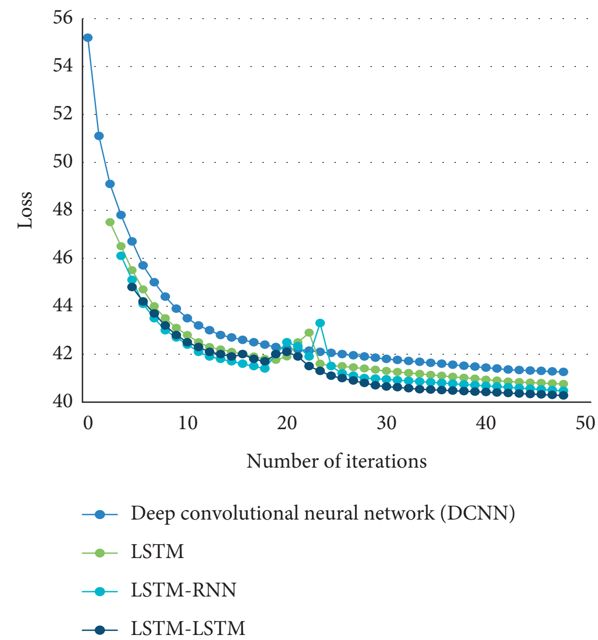


Figure 6: Convergence of different network models.

Table 4 presents the prediction errors of acoustic features of different model configurations on the test set. As shown in Tables 3 and 4, our model achieved a lower prediction error of the acoustic features of the test set than LSTM and DNN, during the synthesis of singing and music melodies. This means that our model can establish a good time series dependence and thus achieve an ideal synthesis effect.

For the proposed low-delay synthesis model of singing melody relative to music melody, it is important to evaluate the influence of the decoding consistency between singing melody and music melody on the modeling accuracy of acoustic parameters in the synthetic melody. For this purpose, a contrastive experiment was designed to compare the melody generated from natural music melody and that generated from score notes, under different lengths of historical access points (HAPs).

Table 5 shows the F0 values under different HAP lengths. As shown in Table 5, the F0 RMSE and F0 Pearson correlation did not change with the utilization rate of historical frames and remained independent of the type of source melody (natural melody or score notes). In addition, the HAP length had a limited influence on F0 Pearson correlation and LE.

Next, the mean length of the sliding window was set to 5, 10, 15, and 20 frames in turn for the end processing module. After verification and optimization, it was found that the window of 15 frames led to the best experimental results. Table 6 presents the prediction errors of different models in fundamental frequency and spectrum. Taking the melody generated from score notes for reference, the melody synthetized by our model had a lower F0 RMSE and a higher F0 Pearson correlation than that obtained by DCNN and LSTM, that is, our model can find the

Table 1: Results before and after the addition of singing melodies.

		BAP distortion	F0 root mean square error (RMSE)	Labeling error of voiced/nonvoiced sound (LE)	Mel cepstral distance (MCD)
DCNN	Preaddition	0.248	12.375	5.459	5.135
	Postaddition	0.239	11.892	5.374	4.913
LSTM	Preaddition	0.241	12.841	5.621	5.092
	Postaddition	0.244	12.163	5.548	4.836
Our model	Preaddition	0.246	12.715	5.539	5.051
	Postaddition	0.248	12.734	5.568	4.993

Table 2: Errors of different model configurations in predicting phoneme length.

	RMSE			RMSE + cross entropy		
Number of layers	DCNN	LSTM	Our model	DCNN	LSTM	Our model
1	6.35	5.81	**5.82**	5.31	4.82	**4.76**
2	5.93	5.46	**5.48**	5.13	4.51	**4.34**
3	5.74	5.23	**5.24**	4.86	4.35	**4.23**
4	5.89	5.65	**5.19**	4.92	4.53	**4.18**
5	5.82	5.67	**5.81**	4.89	4.59	**4.47**

Table 3: Errors in the phoneme length before and after applying the constraint.

	Relative to the phoneme length of music melody	Relative to the given phoneme length
Preconstraint	4.15	7.36
Postconstraint	4.07	0

Table 4: Prediction errors of acoustic features of different model configurations on the test set.

Model	Number of layers	F0 correlation	F0 RMSE	LE	LCD
DCNN	1	0.73	41.39	3.95	6.25
	2	0.85	40.72	2.67	5.12
	3	0.89	38.85	2.53	4.87
	4	0.84	39.03	2.51	4.82
	5	0.82	39.73	2.54	4.83
LSTM	1	0.86	39.46	3.76	5.14
	2	0.85	37.12	2.64	4.69
	3	0.84	36.80	2.68	4.23
	4	0.89	36.71	2.63	4.52
	5	0.88	38.62	3.85	4.34
Our model	1	**0.86**	**38.94**	**2.67**	**5.09**
	2	**0.85**	**35.23**	**2.59**	**4.72**
	3	**0.89**	**35.89**	**2.52**	**4.24**
	4	**0.88**	**35.42**	**2.63**	**4.12**
	5	**0.87**	**35.73**	**2.51**	**4.35**

Table 5: F0 values under different HAP lengths.

HAP length		1	2	3	4
F0 RMSE	Natural melody	22.34	21.76	22.32	21.35
	Score notes	19.38	19.34	19.26	23.48
F0 correlation	Natural melody	0.94	0.95	0.93	0.99
	Score notes	0.97	0.92	0.98	0.92
LE		2.35	2.34	2.31	2.39

Table 6: Prediction errors of different models in fundamental frequency and spectrum.

Model		DCNN	LSTM	Our model
F0 RMSE	Natural melody	35.21	21.79	**20.45**
	Score notes	34.68	19.36	**8.59**
F0 correlation	Natural melody	0.85	0.94	**0.93**
	Score notes	0.86	0.95	**0.98**
LE			2.34	**2.38**
		4.34	3.59	**3.53**

singing melody of better tonal consistency with music melody.

6. Conclusions

Based on the RNN algorithm, this paper probes deep into the automatic synthesis of music teaching melodies. After extracting the acoustic features from music melodies, the authors established a sequence-sequence model for synthetizing general music melodies. To find the suitable signing segments for a given music melody in the teaching scenario, an RNN was set up to synthetize music melody with singing melody. After that, the convergence of different network models was compared through experiments, which verifies the feasibility of our model. In addition, the results of different models were compared before and after adding the singing melody, and the difference of the melody generated by our model and the original music melody was quantified accurately. Furthermore, the prediction error of phoneme time of each model configuration and that after applying the time constraint were obtained through experiments. The relevant results confirm the superiority of our model over DCNN and LSTM in modeling music melody sequence.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] T. Tang, J. Jia, and H. Mao, "Dance with Melody: An Lstm-Autoencoder Approach to Music-Oriented Dance Synthesis," in *Proceedings of the Twenty sixth ACM international conference on Multimedia*, pp. 1598–1606, Seoul, Korea, October 2018.

[2] M. Eppe, T. Alpay, and S. Wermter, "Towards End-To-End Raw Audio Music Synthesis," in *Proceedings of the International Conference on Artificial Neural Networks*, pp. 137–146, Rhodes, Greece, October 2018.

[3] S. Nease, A. Lanterman, and J. Hasler, "Applications of current-starved inverters to music synthesis on field programmable analog arrays," *Journal of the Audio Engineering Society*, vol. 66, no. 1/2, pp. 71–79, 2018.

[4] S. Demircan and H. K. Örnek, "Comparison of the effects of Mel coefficients and spectrogram images via deep learning in emotion classification," *Traitement du Signal*, vol. 37, no. 1, pp. 51–57, 2020.

[5] C. Haworth, "Sound synthesis procedures as texts: an ontological politics in electroacoustic and computer music," *Computer Music Journal*, vol. 39, no. 1, pp. 41–58, 2013.

[6] C.-F. Huang and W.-P. Nien, "A study of the integrated automated emotion music with the motion gesture synthesis via ZigBee wireless communication," *International Journal of Distributed Sensor Networks*, vol. 9, no. 11, Article ID 645961, 2013.

[7] S. Wenner, J. C. Bazin, A. Sorkine-Hornung, C. Kim, and M. Gross, "Scalable music: automatic music retargeting and synthesis," *Computer Graphics Forum*, vol. 32, no. 2, pp. 345–354, 2013.

[8] M. Otsuka, S. Okayasu, T. Fukumori, T. Nishiura, and R. Akama, "Sound Reproduction by Concatenative Synthesis for Japanese Traditional Music Box," in *Proceedings of the 2017 International Conference On Culture And Computing (Culture And Computing)*, pp. 153-154, Kyoto, Japan, September 2017.

[9] M. Moussa, W. Guedri, and A. Douik, "A novel metaheuristic algorithm for edge detection based on artificial bee colony technique," *Traitement du Signal*, vol. 37, no. 3, pp. 405–412, 2020.

[10] U. K. Roy, "Instrumental Bengali Music Synthesis from Transcription with Indian Percussion Instruments," in *Proceedings of the 2016 International Conference On Computer, Electrical & Communication Engineering (ICCECE)*, pp. 1–6, Kolkata, India, December 2016.

[11] S. Ouchtati, A. Chergui, S. Mavromatis, B. Aissa, D. Rafik, and J. Sequeira, "Novel method for brain t classification based on use of image entropy and seven hu's invariant moments," *Traitement du Signal*, vol. 36, no. 6, pp. 483–491, 2019.

[12] F. Ofli, E. Erzin, Y. Yemez, and A. M. Tekalp, "Learn2dance: learning statistical music-to-dance mappings for choreography synthesis," *IEEE Transactions on Multimedia*, vol. 14, no. 3, pp. 747–759, 2012.

[13] S. Bilbao, J. Perry, P. Graham et al., "Large-scale physical modeling synthesis, parallel computing, and musical experimentation: the NESS project in practice," *Computer Music Journal*, vol. 43, no. 2-3, pp. 31–47, 2019.

[14] M. R. Velankar, H. V. Sahasrabuddhe, and P. A. Kulkarni, "Modeling melody similarity using music synthesis and perception," *Procedia Computer Science*, vol. 45, pp. 728–735, 2015.

[15] C. d'Alessandro, L. Feugère, S. Le Beux, O. Perrotin, and A. Rilliard, "Drawing melodies: evaluation of chironomic singing synthesis," *Journal of the Acoustical Society of America*, vol. 135, no. 6, pp. 3601–3612, 2014.

[16] R. Liu, B. Sisman, F. Bao, J. Yang, G. Gao, and H. Li, "Exploiting morphological and phonological features to improve prosodic phrasing for Mongolian speech synthesis," *IEEE/ACM Transactions on Audio, Speech, and Language Processing*, vol. 29, pp. 274–285, 2020.

[17] M. R. Rajan, "Singing Voice Synthesis System for Carnatic Music," in *Proceedings of the 2018 Fifth International Conference On Signal Processing And Integrated Networks (SPIN)*, pp. 831–835, Noida, India, February 2018.

[18] H. Ahn, J. Kim, K. Kim, and S. Oh, "Generative autoregressive networks for 3d dancing move synthesis from music," *IEEE Robotics and Automation Letters*, vol. 5, no. 2, pp. 3501–3508, 2020.

[19] T. Tanprasert, T. Jenrungrot, M. Müller, and T. J. Tsai, "Midi-sheet Music Alignment Using Bootleg Score Synthesis," in *Proceedings of the Twentyth International Society for Music Information Retrieval Conference*, pp. 91–98, Delft, Netherlands, November 2019.

[20] E. R. Miranda, L. Bull, F. Gueguen, and I. S. Uroukov, "Computer music meets unconventional computing: towards sound synthesis with in vitro neuronal networks," *Computer Music Journal*, vol. 33, no. 1, pp. 9–18, 2009.

[21] Y. Taigman, L. Wolf, A. Polyak, and E. Nachmani, "Voice-Loop: Voice Fitting and Synthesis via a Phonological Loop," in *Proceedings of the International Conference on Learning Representations*, Vancouver, Canada, May 2018.

[22] H. Romsdorfer, B. Pfister, and R. Beutler, "A Mixed-Lingual Phonological Component Which Drives the Statistical Prosody Control of a Polyglot TTS Synthesis System," in *Proceedings of the International Workshop On Machine Learning For Multimodal Interaction*, pp. 263–276, Martigny, Switzerland, June 2004.

[23] H. Romsdorfer and B. Pfister, "Multi-context Rules for Phonological Processing in Polyglot TTS Synthesis," in *Proceedings of the Eighth International Conference On Spoken Language Processing*, Jeju Island, Republic of Korea, october 2004.

[24] M. Toman, M. Pucher, S. Moosmüller, and D. Schabus, "Unsupervised and phonologically controlled interpolation of Austrian German language varieties for speech synthesis," *Speech Communication*, vol. 72, pp. 176–193, 2015.

[25] E. V. Mistyukov and D. V. Alexandrov, "Musical Synthesis for Certain Music Styles Based on Machine Learning Algorithms," in *Proceedings of the SAI Intelligent Systems Conference*, pp. 543–562, London, UK, September 2016.

[26] H. Wierstorf, C. Hold, and A. Raake, "Listener preference for wave field synthesis, stereophony, and different mixes in popular music," *Journal of the Audio Engineering Society*, vol. 66, no. 5, pp. 385–396, 2018.

Hindawi
Scientific Programming
Volume 2021, Article ID 7944300, 10 pages
https://doi.org/10.1155/2021/7944300

Research Article

Automatic Manipulator Tracking Control Based on Moving Target Trajectory Prediction

Haifeng Luo

Hubei University of Education, Wuhan 430205, China

Correspondence should be addressed to Haifeng Luo; haifengluo@hue.edu.cn

Received 12 October 2021; Accepted 17 November 2021; Published 30 November 2021

Academic Editor: Ahmed Farouk

The core issue of automatic manipulator tracking control is how to ensure the given moving target follows the expected trajectory and adapts to various uncertain factors. However, the existing moving target trajectory prediction methods rely on highly complex and accurate models, lacking the ability to generalize different automatic manipulator tracking scenarios. Therefore, this study tries to find a way to realize automatic manipulator tracking control based on moving target trajectory prediction. In particular, a moving target trajectory prediction model was established, and its parameters were optimized. Next, a tracking-training-testing algorithm was proposed for manipulator's automatic moving target tracking, and the operating flows were detailed for training module, target detection module, and target tracking module. The proposed model and algorithm were proved effective through experiments.

1. Introduction

With the rapid development of industrial technology, manipulators have been successfully applied to original manual operations, becoming the most widely used manmade tool for industrial production [1–6]. The application of manipulators makes production more efficient and flexible. The core issue of automatic manipulator tracking control is how to ensure the given moving target follows the expected trajectory and adapts to various uncertain factors [7–11]. It is of great practical significance to derive an automatic tracking control strategy for moving targets under uncertainties and external interference.

Target tracking is an important prerequisite for manipulator-assisted services. Zhu et al. [12] improved the near-field computer vision system for intelligent fire robots. The improved system can predict the falling jet path under the complex light environment and interference during firefighting, identify the jet path based on length and area ratio, and parametrize and extract the features of jet path by superposing radial centroids. Wu et al. [13] adopted a human-following method suitable for a manipulator containing visual sensors with a limited perception range, integrated two physical motion models into an adaptive trajectory prediction algorithm, and improved the prediction accuracy by adaptive adjustment of model parameters. For the trajectory control of Par4 parallel robot, Zhang and Ming [14] designed a type 2 fuzzy predictive compensation proportional-integral-derivative (PID) controller based on the improved dynamic gray wolf optimizer (GWO) based on the mutation operator and the eliminating-reconstructing mechanism (DMR-GWO2). The proposed controller speeds up the response of the parallel robot and improves the adaptability of the entire system.

In actual conditions, two manipulators are often needed to pick up and place moving objects through the planning and execution of collision-free trajectories. Tika et al. [15] put forward a layered control strategy for collaborative picking and placement tasks in a narrow, shared workspace and realized the synchronous execution of task scheduling in top-level design, path planning, and robot tasks. Xia et al. [16] proposed a visual prediction framework based on time granularity. The core of the framework is an integrated moving target prediction module based on multiple long short-term memory (LSTM) neural network. Compared with the latest prediction algorithms, the framework excels in prediction accuracy, success rate, and robustness. Focusing on the action understanding of mirror neurons, Zhong et al. [17] simulated the walking mode of humanoid robots and predicted the moving direction according to the previous walking trajectory.

Trajectory prediction is the last step in the visual perception of the manipulator. After a series of segmentation, detection, and tracking, the algorithm could determine the type, bounding box, and other information of the object. However, the future movement trend and trajectory of the target must be predicted to realize automatic tracking control. To sum up, the traditional trajectory prediction methods for moving targets mainly rely on features such as color and contour. The recognition effect is very poor, if the target has multiple features. Moreover, the existing moving target trajectory prediction methods rely on highly complex and accurate models, lacking the ability to generalize different automatic manipulator tracking scenarios [18–22]. Therefore, this study develops an approach for automatic manipulator tracking control based on moving target trajectory prediction, aiming to improve the manipulator's trajectory prediction accuracy and automatic tracking control effect. Section 2 establishes a moving target trajectory prediction model and optimizes its parameters. The established model can predict the position and pose of irregular moving objects at the same time and boast a strong generalization ability. Section 3 details the principles of the tracking-training-testing algorithm for manipulator's automatic moving target tracking and explains the operating flows for the training module, target detection module, and target tracking module in the algorithm. The proposed model and algorithm were proved effective through experiments.

This study solves the problems of the manipulator in recognition, positioning, and trajectory prediction of moving objects, models the error in target tracking, and tests the feasibility of the proposed method through tracking experiments. The internal parameters of the proposed trajectory prediction network for moving objects were all trained on datasets. The training ensures the degree of modularity and generalization ability of the network. However, the prediction precision of our network could be further improved by changing network structure and modifying network parameters, when the network is applied to predict the position and pose of complex and irregular moving targets.

2. Moving Target Trajectory Prediction Model

The precision of moving target trajectory prediction hinges on the accuracy of motion model. This study establishes a moving target trajectory prediction model based on LSTM, which is known for its good accuracy and generalizability, and further enables the manipulator to recognize, and automatically track and control the moving target.

2.1. Model Construction. To accurately predict moving target trajectory, this study imports the three-dimensional (3D) spatial position of a moving target from time h to time $h+K$ into the trajectory prediction model, which outputs the 3D spatial position of the moving target at time $h+K+1$.

Figure 1 shows the overall structure of our moving target trajectory prediction model. The model consists of an input layer, a hidden layer, an output layer, and a training module. In the input layer, a complete sequence of moving target trajectories $G=\{g_1, g_2, \ldots, g_m\}$ is subjected to Z-score normalization:

$$\begin{aligned} G^* &= \{g_1^*, g_2^*, \ldots, g_m^*\}, \\ g_h^{*'} &= \frac{\left(g_h - \sum_{h=1}^{m} g_h/m\right)}{\sqrt{\sum_{h=1}^{n}\left(g_h - \sum_{h=1}^{m} g_h/m\right)^2/m}}. \end{aligned} \tag{1}$$

To satisfy the input requirements of the hidden layer, the input data were segmented. Let K be the prediction step length of the model. Then, the tensor of the input data after the segmentation can be expressed as follows:

$$A = \{A_1, A_2, \ldots, A_K\}. \tag{2}$$

Batch processing is applied on the input data to fully utilize computer resources and improve the training efficiency of the neural network. That is, A is treated as a tensor composed of a batch of 3D spatial coordinates $[r, K, 3]$, where r is the number of batch processing samples. The training accuracy of the model must ensure that each batch of data is a complete trajectory of the moving target; i.e., the batch size should be defined as $(m-K)$. Then, we have the following equation:

$$A_o = \{g_o^*, g_{o+1}^*, \ldots \infty, g_{m-K+o-1}^*\} 1 \le o \le K; o, K \in m. \tag{3}$$

The theoretical output of the input layer can be expressed as follows:

$$\begin{aligned} B &= \{B_1, B_2, \ldots, B_K\}, \\ B_o &= \{g_{o+1}^*, g_{o+2}^*, \ldots, g_{m-K+o}^*\}. \end{aligned} \tag{4}$$

The hidden layer in the trajectory prediction model contains K LSTM nodes, which are connected in chronological order. Each node has F LSTM units. The output of the hidden layer can be expressed as follows:

$$O = \{O_1, O_2, \ldots, O_K\}. \tag{5}$$

The dimensionality $[r, K, F]$ of O should be consistent with that of model output. Let ω_{ti} be the weight of a fully connected layer, and t be the output of the output layer. Before outputting the predicted position of the moving target, the data must be handled by a fully connected layer:

$$t_h = \sum_{i=1}^{F} \omega_{ti} O_h. \tag{6}$$

To test the prediction accuracy, the number r of batch processing samples is set to 1. The first K 3D spatial coordinates of a complete trajectory in the test set are imported:

$$A_g = \{g_1^*, g_2^*, \ldots, g_K^*\}. \tag{7}$$

Based on the input A_g, the model outputs the predicted trajectory:

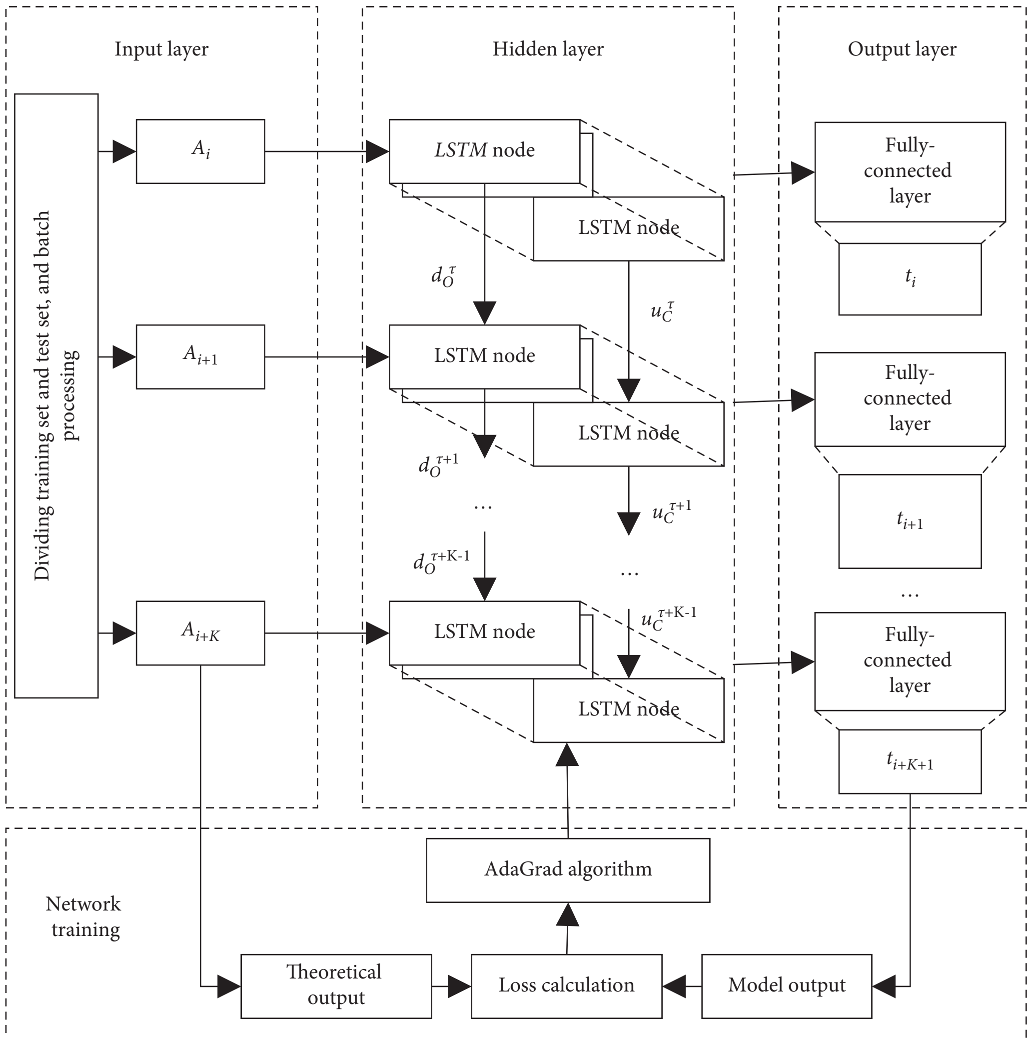


Figure 1: Overall structure of moving target trajectory prediction model.

$$t_g = \{t_2, t_3, \ldots, t_{K+1}\}. \tag{8}$$

Let t_{K+1} be the 3D spatial position predicted for the moving target at time $K+1$. This position is merged with the last $K-1$ 3D spatial positions in A_g to obtain the new input for the trajectory prediction model:

$$A_{g+1} = \{g_2^*, g_3^*, \ldots, g_K^*, t_{K+1}\}. \tag{9}$$

Then, A_{g+1} is imported to the trajectory prediction model. The model will output the predicted 3D spatial position t_{K+2} of the moving object at time $K+2$. The above steps are iteratively executed, and the final prediction of the 3D spatial position of the moving object can be obtained as follows:

$$t = \{t_{K+1}, t_{K+2}, \ldots, t_m\}. \tag{10}$$

The fitting and prediction accuracy of the model can be quantified by the error between input A and output t.

Both the predicted value and theoretical output of the trajectory prediction model are 3D spatial coordinates. The loss of the model is calculated by the Euclidean loss function. Let b be the theoretical output of the model. The error between predicted value and theoretical output can be calculated by the following equation:

$$K(t,b) = \frac{1}{2M} \sum_{m-1}^{M} \|t-b\|_2^2. \tag{11}$$

The model training aims to gradually reduce the value of the loss function. Based on the AdaGrad algorithm, the learning rate δ of our model is updated automatically. Let ξ be the small constant to prevent denominator from being zero; ω be the weight parameter of the model. Then, the model can be updated by the following equation:

$$\delta_m = \frac{\delta}{\xi + \sqrt{\sum_{i=1}^{m-1} p_i \cdot p_i}},$$
$$p = \frac{1}{r} \sum_{i=1}^{r} \frac{\partial K_i(t,b)}{\partial \omega}. \tag{12}$$

2.2. Model Parameter Optimization. There are many parameters in our trajectory prediction model. The most critical ones include prediction step length K, the number of hidden nodes F, and the learning rate δ. To weaken their influence on the prediction of moving target trajectory, this study firstly evaluates the prediction accuracy on all test samples and then chooses the optimal combination of K, F, and δ, which leads to the highest prediction accuracy. The objective function can be expressed as follows:

$$\min \sigma(t, A),$$
$$s.t. \begin{cases} 10 \leq K \leq K_{\max} \leq m, \mathrm{step}_K | K \\ 10 \leq F \leq F_{\max}, \mathrm{step}_F | F \\ 0.005 \leq \delta \leq \delta_{\max}, \mathrm{step}_\delta | \delta \\ K, F, \delta, \mathrm{step}_K, \mathrm{step}_F, \mathrm{step}_\delta \in M \end{cases}. \tag{13}$$

The multilayer grid search algorithm is adopted to process K, F, and δ to determine the best values of these crucial parameters. The grid search is carried out from inside to outside in three steps:

Step 1. Set the number of batch processing samples r and number of training steps T_{steps}, which are two key parameters, and preset the value ranges of K, F, and δ based on formula (13).

Step 2. Traverse K, F, and δ layer by layer, and implement model training and prediction in the innermost layer. After the training, maintain the three parameters to obtain the fitting and prediction accuracies of the model.

Step 3. Sort the parameter search results in descending order by the prediction accuracy, and select the K, F, and δ in the top-ranking combination for the optimal model.

3. Automatic Tracking Control Algorithm

3.1. Algorithm Principles. Based on machine vision, manipulator moving target tracking might involve multiple moving targets at a time and needs to consider multiple motion states of each target. The moving targets face changes in moving direction, speed, color, and brightness, and could be occluded by obstacles. Therefore, the tracking technology should be able to detect the 3D spatial position of each moving target in real time and judge whether the target is missing or occluded. This study proposes a tracking-training-testing algorithm for manipulator's automatic moving target tracking and combines the algorithm with moving target trajectory prediction to enable manipulators to grasp, as well as automatically track and control targets.

The automatic tracking algorithm can select the moving target from each frame image of the video stream. The architecture of the algorithm is shown in Figure 2. The training module processes the detection result of the target detection module and the tracking result of the target tracking module. The processing and feedback results from the training module are used to update the target detection module and the target tracking module. This cyclic optimization process can handle complex situations, such as the appearance changes in the moving target over time and the temporary disappearance of the moving target from the shooting range, thereby ensuring the target identification and tracking effects of the algorithm.

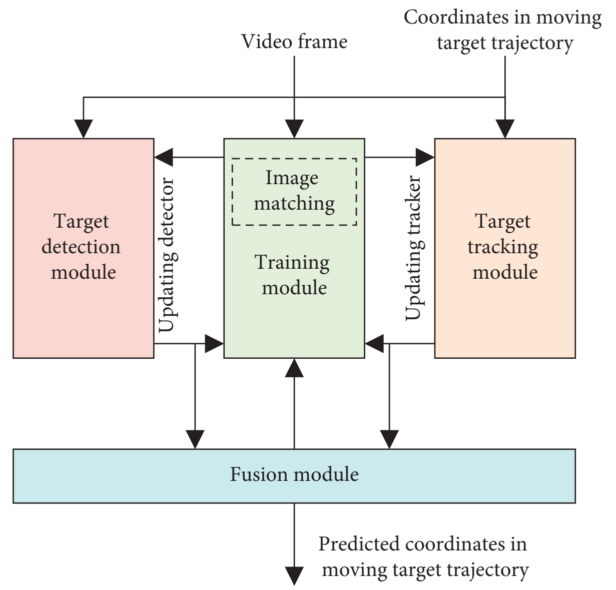


Figure 2: Architecture of manipulator's automatic moving target tracking algorithm.

Let GYH be the normalized cross-correlation coefficient. To select the moving target from the video frame, the similarity between two adjacent frames w_i and w_j must be defined before analyzing the main modules:

$$\mathrm{RE}\left(w_i, w_j\right) = 0.5 * \left(\mathrm{GYH}\left(w_i, w_j\right) + 1\right). \tag{14}$$

The matching image set N containing both positive samples w_i^+ and negative samples w_i^- of moving targets can be expressed as follows:

$$N = \{w_1^+, w_2^+, \ldots, w_n^+, w_1^-, w_2^- \ldots w_n^-\}. \tag{15}$$

Then, n positive sample w_i^+ and n negative samples w_i^- are sorted in the order of $i = 1, 2, 3, \ldots, n$ and then added to the matching image set.

The similarity between a matching image N_G and each frame w can be divided into the similarity with the nearest neighbor of w_i^+ and the similarity with the nearest neighbor of w_i^-:

$$\begin{aligned} \mathrm{RE}^+ (w, N_G) &= \max_{w_i^+ \in N_G} \mathrm{RE}(w, w_i^+), \\ \mathrm{RE}^- (w, N_G) &= \max_{w_i^- \in N_G} \mathrm{RE}(w, w_i^-). \end{aligned} \tag{16}$$

The similarity between the frame w and the labeled first half of the positive samples can be calculated by the following equation:

$$\mathrm{RE}_{1/2}^+ = (w, N_G) = \max_{w_i^{+FL < N_G/2}} \mathrm{RE}(w, w_i^+). \tag{17}$$

The cross-correlation of w can be calculated by the following equation:

$$\mathrm{RE}^s = \frac{\mathrm{RE}^+}{\mathrm{RE}^+ + \mathrm{RE}^-}. \tag{18}$$

Formula (18) shows that the value of RE^s falls in [0, 1]. The greater the RE^s, the more credible that the frame contains a moving target. The conservative similarity of w can be calculated by the following equation:

$$\mathrm{RE}^d = \frac{\mathrm{RE}^+_{1/2}}{\mathrm{RE}^+_{1/2} + \mathrm{RE}^-}. \tag{19}$$

The cross-correlation obtained by formula (18) is the threshold for the nearest neighbor classifier that determines the similarity (RE^s, RE^d) between frame w and matching image N_G. If $\mathrm{RE}^s\,(w, N) > \rho_{\mathrm{MM}}$, w is a positive sample; if $\mathrm{RE}^s\,(w, N) < \rho_{\mathrm{MM}}$, w is a negative sample. Here, $\mathrm{RE}^s\,(w, N)$-ρ_{MM} is the classification threshold ensuring the convergence of the classifier.

3.2. Target Detection Module. The variance classifier is the first link of the cascade classifier in the target detection module. Let $Q\,(w)$ be the expectation of w solved by the integral image method. Then, the variance of any frame w can be calculated by the following equation:

$$Q\left(w^2\right) - Q^2\,(w). \tag{20}$$

If the total variance of gray values for all pixels in the frame within the window is smaller than half of the total variance of gray values for all pixels in the moving target box, then the window is invalid and needs to be removed. In this way, half of the image contents, including ground and shadows, can be eliminated.

The ensemble classifier is the second link of the cascade classifier in the target detection module. The frame outputted by the variance classifier is imported to the ensemble classifier composed of m basic classifiers. Here, each basic classifier is a decision tree (DT). The output of classifier i is a posterior probability vector composed of code a:

$$\mathrm{GV}_1\,(b|a), b \in (0, 1). \tag{21}$$

The m classifiers output m posterior probability vectors. The mean of all vectors can be calculated by the following equation:

$$\mathrm{GV}^* = \frac{\left(\sum_{i=0}^{m} \mathrm{GV}_i\,(b|a)\right)}{m}, b \in (0, 1). \tag{22}$$

If $\mathrm{GV}^* > 1/2$, the window is retained; if $\mathrm{GV}^* > 1/2$, the window is eliminated.

As the eigenvalue of the frame, the combined code vector is distributed to all the basic classifiers of the ensemble classifier. Each basic classifier corresponds to a posterior probability. The ith posterior probability is denoted as $\mathrm{GV}_i\,(b|a)$. If the posterior probability of each basic classifier is described by binary code a, then

$$\mathrm{GV}_i\,(b|a) = \frac{\Delta w}{\Delta w + \Delta m}, \tag{23}$$

where

$$\begin{cases} \Delta w = M\left(w^+\right) \\ \Delta m = M\left(w^-\right) \end{cases}. \tag{24}$$

During initialization, $w_i\,(b|a) = 0$, and the posterior probability corresponding to each basic classifier characterizes a negative sample. During later training, the ensemble classifier classifies the labeled frames and updates $w_i\,(b|a)\,(b|a)$ (as shown in Figure 3).

Most unqualified contents are eliminated from the input frame through the filtering by both variance filter and ensemble filter. The filtered results are further processed by the nearest neighbor classifier. If $\mathrm{RE}^s\,(w, N) > \omega_{\mathrm{MM}}$, the frame content in the scanning window is a positive sample.

3.3. Target Tracking Module. The target tracking module combines the Lucas–Kanade (LK) optical flow method with the forward and backward error tracking theory. The forward and backward directions refer to the positive and negative directions of the sequence of video frames, respectively. If there is a large error between the target tracking results in the two directions, then the predicted trajectory of the moving target must be incorrect and unreliable. The forward-backward error helps to judge whether the moving target is tracked successfully, but cannot identify unobvious errors in trajectory prediction. Therefore, this study designs an image frame difference comparison method for slow-moving target tracking points. The frame sequence of slow-moving target can be expressed as follows:

$$\mathrm{FD} = \left(J_\tau, J_{\tau+1}, \ldots, J_{\tau+v}\right). \tag{25}$$

Let A_τ be the coordinates of the moving target at time τ; v be the times of forward tracking of point A_τ. Then, the forward trajectory tracking sequence of the moving target can be given by the following equation:

$$\psi_x^v = \left(A_\tau, A_{\tau+1}, \ldots, A_{\tau+v}\right). \tag{26}$$

The forward tracking and backward tracking are denoted by subscripts x and y, respectively. Then, the pixel coordinates $A_{\tau+v}$ are backward tracked to the previous frame. Then, the backward trajectory tracking sequence can be given by the following equation:

$$\psi_y^v = \left(\dot{A}_\tau, \dot{A}_{\tau+1}, \ldots, \dot{A}_{\tau+v}\right). \tag{27}$$

Combining formulae (26) and (27), the tracking error of the moving object can be obtained by the following equation:

$$\mathrm{FB}\left(\psi_x^v|\mathrm{FD}\right) = \mathrm{distance}\left(\psi_x^v, \psi_y^v\right). \tag{28}$$

To sum up, the forward and backward tracking errors can be obtained by formula (28), as long as a suitable threshold is determined for different image sequences. Then, it is possible to judge the success or failure of target tracking. Figure 4 illustrates the flow of tracking error calculation.

3.4. Training Module. The training module contains the classifier to be trained, labeled training set, positive/negative training sample generator, etc. The classifier is trained on the

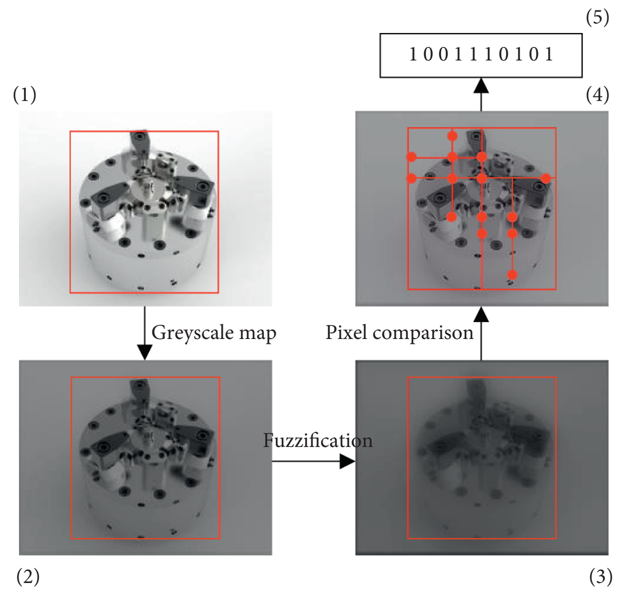


Figure 3: Generation of binary code. Note: subgraph (1) is the input image + window; subgraph (2) is the grayscale map of the input image + window; subgraph (3) is the fuzzified image + window; subgraph (4) is the pixel comparison image + window; and subgraph (5) is the final binary code.

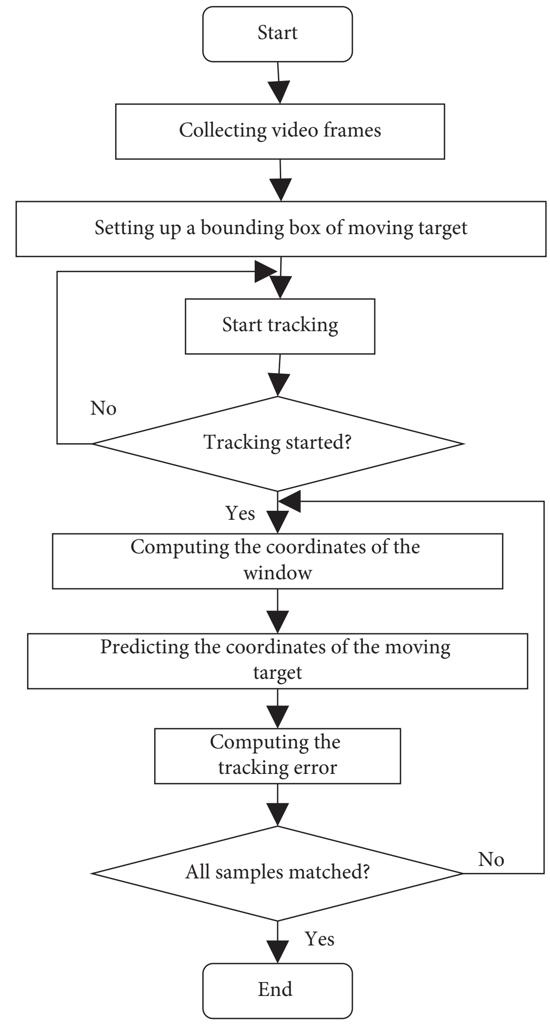


Figure 4: Flow of tracking error calculation.

training set to achieve comprehensive integrated learning. Figure 5 explains the flow of the training module. During classifier training, the training quality is closely associated with the absolute number of labeled positive and negative samples. Hence, the training module should be able to quantify the relationship between the classifier performance and the absolute number of samples. The classifier performance can be characterized by the reliability of positive sample labels, the incorrect detection probability of negative samples, the accuracy of negative sample labels, and the incorrect detection probability of positive samples.

The reliability of positive sample labels can be characterized by the ratio of the number of correctly detected positive samples m_C^+ to the sum of the number of correctly detected positive samples and the number of incorrectly detected positive samples $m_C^+ + m_E^+$:

$$\mathrm{GV}^+ = \frac{m_C^+}{\left(m_C^+ + m_E^+\right)}. \tag{29}$$

The incorrect detection probability of negative samples can be characterized by the ratio of the number of correctly detected positive samples m_C^+ to the number of incorrectly detected negative samples Φ:

$$S^+ = \frac{m_C^+}{\Phi}. \tag{30}$$

The reliability of negative sample labels can be characterized by the ratio of the number of correctly detected negative samples m_C^- to the sum of the number of correctly detected negative samples and the number of incorrectly detected negative samples $m_C^- + m_E^-$:

$$\mathrm{GV}^- = \frac{m_C^-}{\left(m_C^- + m_E^-\right)}. \tag{31}$$

The incorrect detection probability of positive samples can be characterized by the ratio of the number of correctly detected negative samples m_C^- to the number of incorrectly detected positive samples Ω:

$$S^- = \frac{m_C^-}{\Omega}. \tag{32}$$

The classifier performance evaluation equations (29)–(32) must satisfy the following equation:

$$\begin{aligned} m_C^-(v) &= S^+\Phi(v), m_E^+(v) = \frac{\left(1 - \mathrm{GV}^+\right)}{\mathrm{GV}^+} S^+\Phi(v), \\ m_C^-(v) &= S^-\Omega(v), m_E^-(v) = \frac{\left(1 - \mathrm{GV}^-\right)}{\mathrm{GV}^-} S^-\Omega(v). \end{aligned} \tag{33}$$

The number of incorrectly detected negative samples Φ and the number of incorrectly detected positive samples Ω can be, respectively, updated by the following equation:

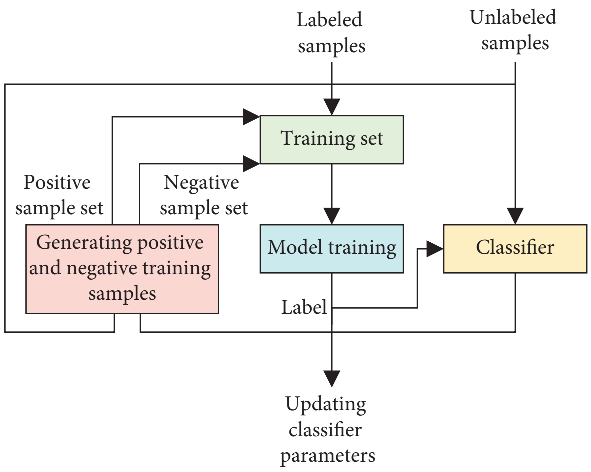


Figure 5: Flow of training module.

$$\Omega(v+1) = (1-S^{-})\Omega(v) + \frac{(1-GV^{+})}{GV^{+}} S^{+}\Phi(v),$$
$$\Phi(v+1) = \frac{(1-GV^{-})}{GV^{-}} S^{-}\Omega(v) + (1-S^{+})\Phi(v). \tag{34}$$

Assume $\dot{O}(v) = [\Phi(v)\cdot\Omega(v)]^T$. Then, a 2×2 matrix Q can be defined as follows:

$$Q = \begin{bmatrix} 1-S^{-} & \frac{(1-GV^{+})}{GV^{+}} S^{+} \\ \frac{(1-GV^{-})}{GV^{-}} S^{-} & (1-S^{+}) \end{bmatrix}. \tag{35}$$

After rewriting formulae (25) and (26) as matrices, the recursive formula of $\dot{O}(v)$ can be established as follows:

$$\dot{O}(v+1) = Q\cdot\dot{O}(v). \tag{36}$$

The above formula shows that the recursive system of the manipulator's moving target tracking is both discrete and dynamic. Thus, the ultimate control goal of our algorithm is to gradually reduce the system error increment to zero, with the growing number of iterations.

4. Experiments and Result Analysis

The multilayer search algorithm was introduced to optimize the three parameters K, F, and δ of the proposed moving target trajectory model. Firstly, the number of the training steps was set to 120, and the value ranges of the three parameters were preset as follows: $K\in\{15, 20, 25, 30\}$, $F\in\{60, 120, 180, 240\}$, and $\delta\in\{0.01, 0.02, \ldots, 0.1\}$. The objective function is to maximize the prediction accuracy of moving target trajectory, i.e., minimize the prediction error. The possible parameter combinations were sorted in descending order of error. Table 1 lists the top five parameter combinations and their errors. It can be seen that the optimization of the three parameters greatly enhanced the accuracy of our moving target trajectory model.

Table 1: Top five parameter combinations and their errors.

Ranking	Model parameters K	H	δ	Training error	Test error
1	30	60	0.08	$5.0441e-06$	0.001753
2	30	180	0.08	$4.2582e-06$	0.002096
3	30	60	0.01	$4.7857e-06$	0.002162
4	30	60	0.02	$5.6412e-06$	0.001781
5	30	120	0.06	$4.4325e-06$	0.002318

Table 2: Prediction results of different models.

Models	Model parameters K	H	δ	Training error	Test error
RNN	30	60	0.08	$9.4781e-06$	0.089156
GRNN	30	60	0.08	$6.5428e-06$	0.036843
Our model	30	60	0.08	$5.2657e-06$	0.011891

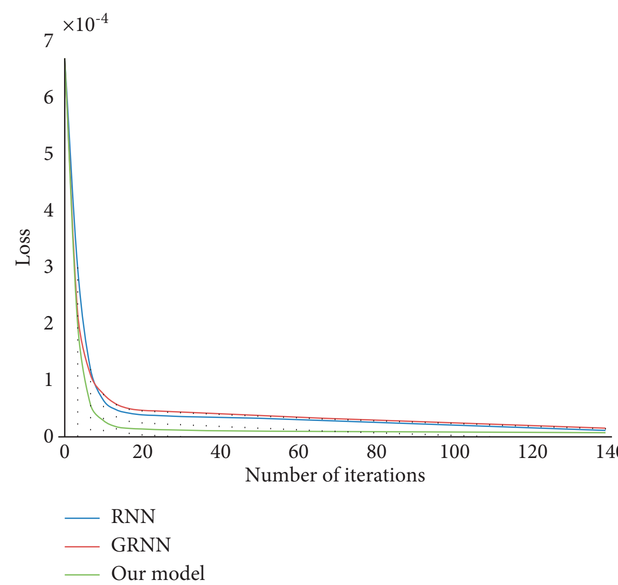


Figure 6: Loss variations of different prediction models.

The three key parameters of the moving target trajectory prediction model were optimized as $K=30$, $H=60$, and $\delta=0.08$. Next, the hidden units in the hidden layer nodes were configured as recurrent neural network (RNN) and gated RNN (GRNN). The prediction results of these two models were compared with those of our model (Table 2). Our model achieved better training accuracy and test accuracy than RNN and GRNN.

Figure 6 records the loss variations of different prediction models during the training. Overfitting occurs to the RNN when the training lasts too long; i.e., the number of iterations is too large. As shown in Figure 6, the loss of the RNN dropped the fastest, but the loss of our model gradually moved below that of RNN and GRNN, with the growing number of iterations.

Table 3: Prediction errors of different models.

Models	Model parameters K	H	δ	Trajectory coordinate error
RNN	30	60	0.08	0.9874
GRNN	30	60	0.08	0.5592
Our model	30	60	0.08	0.4275

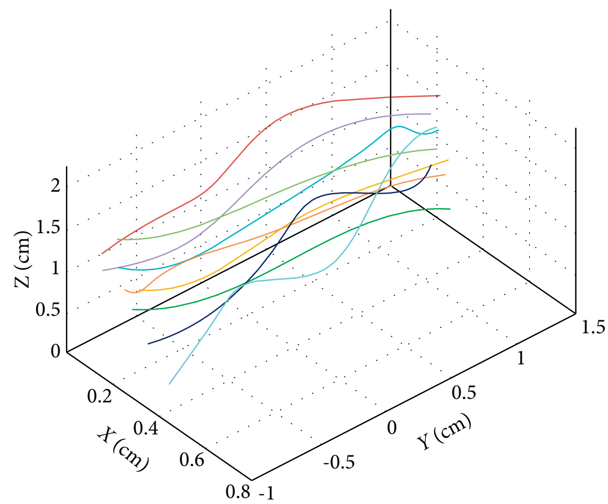


Figure 7: Trajectory of moving targets.

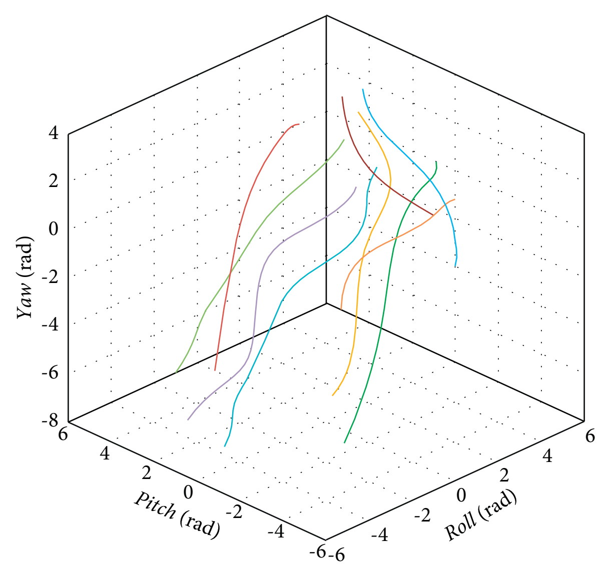


Figure 8: Grasping position trajectory of the manipulator.

The prediction error was defined as the distance from the spatial coordinates on the predicted trajectory of the moving target to those on the actual trajectory. Table 3 compares the prediction errors of our model with RNN and GRNN. When too many trajectory points needed to be predicted, RNN had a lower prediction accuracy than GRNN and our model, because it cannot effectively process the historical positions on distant trajectories. Our model surpassed the GRNN by 56.7% in the prediction accuracy of the spatial coordinates on the trajectory of moving targets.

Figures 7 and 8 show the predicted trajectory of moving targets and the predicted grasping position trajectory of the manipulator. Figure 9 presents the prediction error of moving target trajectory. Table 4 lists the prediction error of moving target trajectory. Most errors were within 0.2 cm, which verify the generalizability of the proposed tracking control algorithm.

To verify the learning effect of our training module, the probability density of classification error was calculated. The classification error of the classifier fell in (−0.9142, 0.8747), which basically obeys normal distribution (as shown in Figure 10).

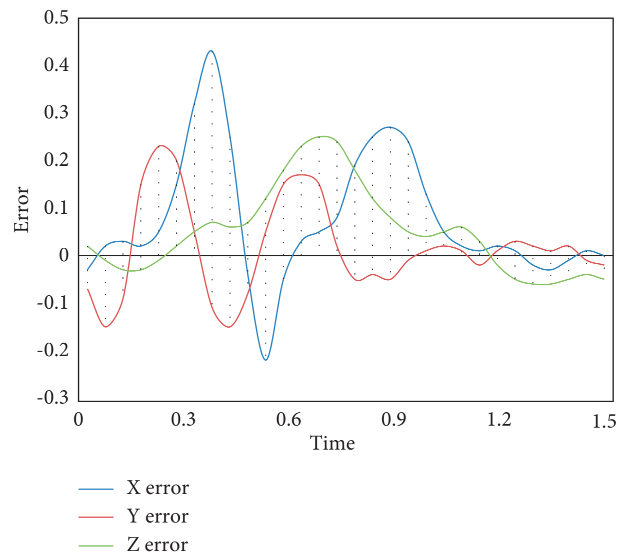


Figure 9: Prediction error of moving target trajectory.

Table 4: Prediction error of moving target trajectory.

Serial number	ΔPitch	ΔRoll	ΔYaw	ΔX	ΔY	ΔZ
1	0.068915	0.031406	−0.07264	0.196543	−0.056134	0.179623
2	0.035234	0.107545	0.0135	0.034126	−0.026247	0.106412
3	0.108972	0.135621	−0.019232	0.049862	−0.00572	0.281565
4	0.16152	−0.008942	−0.003757	0.005741	0.017964	0.297534
Mean	0.09366025	0.0664075	−0.02053225	0.071568	−0.01753425	0.2162835

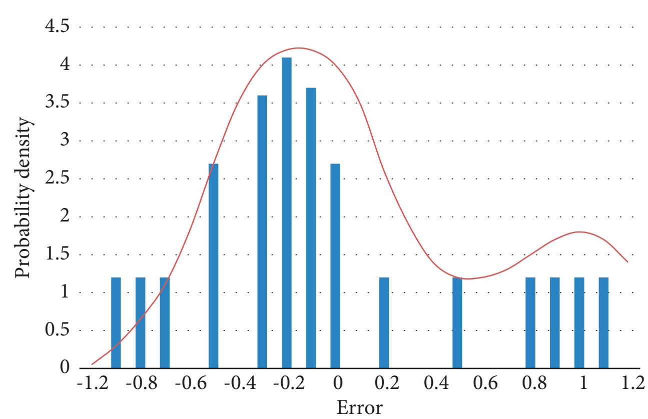


Figure 10: Probability density distribution of classification error.

5. Conclusions

This study explores how to realize automatic manipulator tracking control based on moving target trajectory prediction. Firstly, a moving target trajectory prediction model was established, and its parameters were optimized. Next, a tracking-training-testing algorithm was proposed for manipulator's automatic moving target tracking, and the operating flows were detailed for training module, target detection module, and target tracking module. The experimental results show the effectiveness of the proposed model and algorithm. During the experiments, the parameter combination was optimized, the corresponding errors were obtained, and the values of three key parameters K, F, and δ were optimized. The prediction results and losses of different models were compared, revealing that our model is more accurate in prediction than other models. Finally, the moving object trajectory and the manipulator's grasping position trajectory were predicted, and the prediction error of moving target trajectory was used to confirm the generalizability of the proposed tracking control algorithm.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This research was supported by the National Natural Science Foundation of China (Grant No. 51902094).

References

[1] F. Ore, J. L. Jiménez Sánchez, M. Wiktorsson, and L. Hanson, "Design method of human-industrial robot collaborative workstation with industrial application," *International Journal of Computer Integrated Manufacturing*, vol. 33, no. 9, pp. 911–924, 2020.

[2] V. Nguyen, T. Cvitanic, and S. Melkote, "Data-driven modeling of the modal properties of a six-degrees-of-freedom industrial robot and its application to robotic milling," *Journal of Manufacturing Science and Engineering*, vol. 141, no. 12, Article ID 121006, 2019.

[3] F. Gao and P. Wu, "A trajectory planning algorithm for medical manipulators based on adaptive particle swarm optimization and fuzzy neural network," *Journal Européen des Systèmes Automatisés*, vol. 53, no. 3, pp. 429–435, 2020.

[4] G. Cao and G. Cao, "Application of industrial robot in automatic transformation of compressor pump production line," *Journal of Computational Methods in Science and Engineering*, vol. 19, no. S1, pp. 293–298, 2019.

[5] C. Garriz and R. Domingo, "Development of trajectories through the Kalman algorithm and application to an industrial robot in the automotive industry," *IEEE Access*, vol. 7, pp. 23570–23578, 2019.

[6] V. Verma, P. Chauhan, and M. Gupta, "Distributed association rule mining with minimum communication overhead," *Journal Européen des Systèmes Automatisés*, vol. 52, no. 4, pp. 355–362, 2019.

[7] D. Schwung, F. Csaplar, A. Schwung, and S. X. Ding, "An application of reinforcement learning algorithms to industrial multi-robot stations for cooperative handling operation," in *Proceedings of the 2017 IEEE 15th International Conference on Industrial Informatics (INDIN)*, pp. 194–199, Emden, Germany, July 2017.

[8] A. Rout, D. Bbvl, B. B. Biswal, and G. B. Mahanta, "Optimal trajectory planning of industrial robot for improving positional accuracy," *Industrial Robot: The International Journal of Robotics Research and Application*, vol. 48, no. 1, pp. 71–83, 2019.

[9] Y.-H. Lee, S.-C. Hsu, T.-Y. Chi, Y.-Y. Du, J.-S. Hu, and T.-C. Tsao, "Industrial robot accurate trajectory generation by nested loop iterative learning control," *Mechatronics*, vol. 74, Article ID 102487, 2021.

[10] L. Li, Y. Huang, and X. Guo, "Kinematics modelling and experimental analysis of a six-joint manipulator," *Journal Européen des Systèmes Automatisés*, vol. 52, no. 5, pp. 527–533, 2019.

[11] X. Yin and L. Pan, "Enhancing trajectory tracking accuracy for industrial robot with robust adaptive control," *Robotics and Computer-Integrated Manufacturing*, vol. 51, pp. 97–102, 2018.

[12] J. Zhu, L. Pan, and G. Zhao, "An improved near-field computer vision for jet trajectory falling position prediction of intelligent fire robot," *Sensors*, vol. 20, no. 24, p. 7029, 2020.

[13] H. Wu, W. Xu, B. Yao, Y. Hu, and H. Feng, "Interacting multiple model-based adaptive trajectory prediction for anticipative human following of mobile industrial robot," *Procedia Computer Science*, vol. 176, pp. 3692–3701, 2020.

[14] X. Zhang and Z. Ming, "Par4 parallel robot trajectory tracking control based on DMR-GWO2 and fuzzy predictive," *International Journal of Computational Intelligence Systems*, vol. 14, no. 1, pp. 1597–1606, 2021.

[15] A. Tika, N. Gafur, V. Yfantis, and N. Bajcinca, "Optimal scheduling and model predictive control for trajectory planning of cooperative robot manipulators," *IFAC-PapersOnLine*, vol. 53, no. 2, pp. 9080–9086, 2020.

[16] C. Xia, C.-Y. Weng, Y. Zhang, and I.-M. Chen, "Vision-based measurement and prediction of object trajectory for robotic manipulation in dynamic and uncertain scenarios," *IEEE Transactions on Instrumentation and Measurement*, vol. 69, no. 11, pp. 8939–8952, 2020.

[17] J. Zhong, C. Weber, and S. Wermter, "Robot trajectory prediction and recognition based on a computational mirror neurons model," in *Proceedings of the International Conference on Artificial Neural Networks*, pp. 333–340, Espoo, Finland, June 2011.

[18] C. Deng, Y. Mao, X. Gan, and J. Tian, "Application of independent component analysis in target trajectory prediction based on moving platform," in *Proceedings of the AOPC 2015: Optical Design and Manufacturing Technologies*, vol. 9676, Article ID 96760T, Beijing, China, 2015.

[19] Y. Du, Y. Wang, X. Zhang, and Z. Nie, "Automatic separation management between multiple unmanned aircraft vehicles in uncertain dynamic airspace based on trajectory prediction," *Revue d'Intelligence Artificielle*, vol. 33, no. 3, pp. 171–180, 2019.

[20] J. Hu and Q. B. Zhu, "A multi-robot hunting algorithm based on dynamic prediction for trajectory of the moving target and hunting points," *Dianzi Xuebao (Acta Electronica Sinica)*, vol. 39, no. 11, pp. 2480–2485, 2011.

[21] G. F. Sun, B. Zhang, and H. Z. Lu, "The detection algorithm based on predicting-matching-window for moving point target trajectory in image sequences," *Journal of National University of Defense Technology*, vol. 26, no. 2, pp. 25–29, 2004.

[22] S. Liu, Y. Guo, H. Jia, S. Lin, and D. Zhao, "Mechanism principle and obstacle-crossing analysis of robot with automatic-strained track and variable main arm configuration," *Journal of Central South University*, vol. 44, no. 6, pp. 2289–2297, 2013.

Hindawi
Scientific Programming
Volume 2021, Article ID 8934632, 12 pages
https://doi.org/10.1155/2021/8934632

Research Article

Information Visualization from the Perspective of Big Data Analysis and Fusion

Xiang Lin

Research Center for Advertising and Media Economics, Wuhan Technology and Business University, Wuhan 430065, China

Correspondence should be addressed to Xiang Lin; linxiang@wtbu.edu.cn

Received 18 September 2021; Revised 18 October 2021; Accepted 25 October 2021; Published 8 November 2021

Academic Editor: Ahmed Farouk

In the big data environment, the visualization technique has been increasingly adopted to mine the data on library and information (L&I), with the diversification of data sources and the growth of data volume. The previous research into the information association of L&I visualization network rarely tries to construct such a network or explore the information association of the network. To overcome these defects, this paper explores the visualization of L&I from the perspective of big data analysis and fusion. Firstly, the authors analyzed the topology of the L&I visualization network and calculated the metrics for the construction of L&I visualization topology map. Next, the importance of meta-paths of the L&I visualization network was calculated. Finally, a complex big data L&I visualization network was established, and the associations between information nodes were analyzed in detail. Experimental results verify the effectiveness of the proposed algorithm.

1. Introduction

In the big data environment, digital L&I information resources increase and age at a growing pace, with the diversification of data sources and the growth of data volume. Meanwhile, the user demand for discovery services is changing rapidly [1–6]. The visualization technique has been increasingly adopted to mine the data on L&I [7–11]. Therefore, it is of certain practical significance to study the L&I visualization from the perspective of big data analysis and fusion.

Currently, the research on L&I visualization mainly focuses on the visualization methods and visualization analysis tools of information resources and information retrieval [11–15]. Mo et al. [16] analyzed the status quo of L&I visualization in terms of annual number of published papers, authors, journals, and keywords and explained the utilization of visualization software CiteSpace with an actual case. To deeply mine potential knowledge and disclose the deep correlations between L&I, Rowley et al. [17] introduced cooccurrence analysis to visualize L&I and quantified the cooccurrence information in L&I information carriers. Borrego [18] sorted out and summarized the current research of L&I data-driven knowledge discovery, clarified the core ideas of library knowledge discovery and L&I visualization service, and detailed the innovative data environment, driving mechanism, and pattern application, which are necessary for digital library knowledge discovery and L&I visualization service. Johnson [19] reviewed the results of cross disciplinary research on L&I in China, visualized the relevant research results with automated valuation models (AVMs), and discussed the differences between various methods, namely, cluster analysis, survey method, and strength, weakness, opportunity, and threat (SWOT) analysis.

The information isolated island and overloading of book data hinder users from acquiring and sharing of L&I [20, 21]. L&I information is commonly organized in two modes: information fusion and information aggregation [22, 23]. Paramonova [24] enhanced the semantics of L&I information through information classification, ontology analysis, and data association method and relied on the semantics for knowledge organization and visual metering. In this way, knowledge organization was integrated with econometric analysis to mine the resource associations, through the analysis of cooccurrence relationships, coupling relationships, and social network analysis.

Through the above analysis on domestic and foreign research, there are several defects with the research on information association of L&I visualization network: the lack of optimization of network layout algorithms, and the absence of L&I information fusion and comparison in multiple disciplines, in the big data environment [25–27]. To overcome these defects, this paper explores the visualization of L&I from the perspective of big data analysis and fusion. Section 2 analyzes the topology of the L&I visualization network and calculates the metrics for the construction of L&I visualization topology map, node degree distribution, clustering coefficient, and mean path length. Section 3 calculates the importance of meta-paths of the L&I visualization network. Section 4 establishes a complex big data L&I visualization network and analyzes the associations between information nodes. The visualization results of the proposed algorithm were obtained through experiments, which confirm the effectiveness of our algorithm.

2. Topology Analysis

L&I information is a dataset composed of books, literature information, and archival information on the library management platform. Let $V_1, V_2, \ldots, V_m$ be the information of a book or document in the L&I group information and let AS_m be the association between multiple books or documents. Then, the set QX of L&I group information can be expressed as

$$QX = \{V_1, V_2, \ldots, V_m\}. \tag{1}$$

Figure 1 visualizes the L&I network. On the left side is the visualized information of different disciplines and books, as well as L&I nodes. On the right side are the visualized codes of the visualized information on the left. In Figure 1, the L&I nodes are coded in multiple dimensions by their respective size and color, according to the type of book resources. From the structural features of the visualized network, the following will calculate the metrics of the topology of L&I visualization network, including node degree distribution, clustering coefficient, and mean path length.

Let l be a node with the degree of l in the L&I visualization network; let M be the total number of nodes. Then, the node degree distribution $ND\ (l)$ can be described by

$$N\ D(l) = \frac{l}{M}. \tag{2}$$

If the constructed network is a scale-free network, the degree distribution of nodes can be obtained by the power law distribution features:

$$N\ D(l) \sim l^{(-e)}. \tag{3}$$

The mean clustering coefficient AC^* that measures the closeness between multiple book or document nodes can be expressed as

$$AC^* = \sum_l N\ D(l) AC. \tag{4}$$

Let $N_{mn}\ (l)$ be the mean number of connections between a node with the degree of l and its adjacent nodes. Then, the local clustering coefficient in formula (4) can be calculated by

$$AV(l) = N_{mn}\frac{(l)}{(l-1)}. \tag{5}$$

Network closeness NC, which represents the associations between book or document nodes in the L&I visualization network, can be calculated by

$$NC = \frac{\sum_{r,o} b_{r-o}}{M(M-1)}. \tag{6}$$

Let QX_{r-o} be the number of the shortest paths between nodes r and o; let $QX_{r-o(q)}$ be the number of the shortest paths between nodes r and o, which pass through node q. Then, the betweenness centrality BE, which reflects the influence of a node in the L&I visualization network, can be calculated by

$$BE = \frac{\sum_{q<0} QX_{r-o(q)}}{QX_{r-o}}. \tag{7}$$

Formula (7) shows that the greater the BE is, the more likely the corresponding node will be visualized in the information network.

In essence, the information query in the L&I visualization network is to find the L&I nodes with similar semantic relationships as the input node in the query. This paper abstracts the multiple paths between two nodes into a meta-path and describes the semantic association between nodes in an advanced level. Figure 2 provides the examples of the paths and meta-path between nodes.

For the L&I visualization network, the minimum mean path length can be denoted as K_{AV}, and the maximum clustering coefficient can be denoted as $CO_{\max}$. Suppose all the nodes in the network are connected by meta-paths; then the network is fully coupled; i.e., the network state satisfies $K_{AV} = 1$ and $CO_{\max} = 1$. The length of meta-paths changes regularly with the distances between nodes. In the fully coupled state, the L&I visualization network has a fixed number of nodes and a fixed number of meta-paths. M nodes need to be connected by $M(M-1)/2$ meta-paths.

In the network, a node r is connected to its adjacent nodes and the nodes within the distance of l/2 on the left and right. Let l be the number of nearest neighbors of the node. Then, the clustering coefficient of node r can be calculated by

$$CO_r = \frac{3(l-2)}{4(l-1)} \approx \frac{3}{4}. \tag{8}$$

When the number of nodes is infinitely large, the mean path length of the L&I visualization network can be calculated by

$$K_{AV} \approx \frac{M}{2l} \longrightarrow \infty (M \longrightarrow \infty). \tag{9}$$

Suppose the L&I visualization network is a star network, in which any node is only connected to one node. Then, the

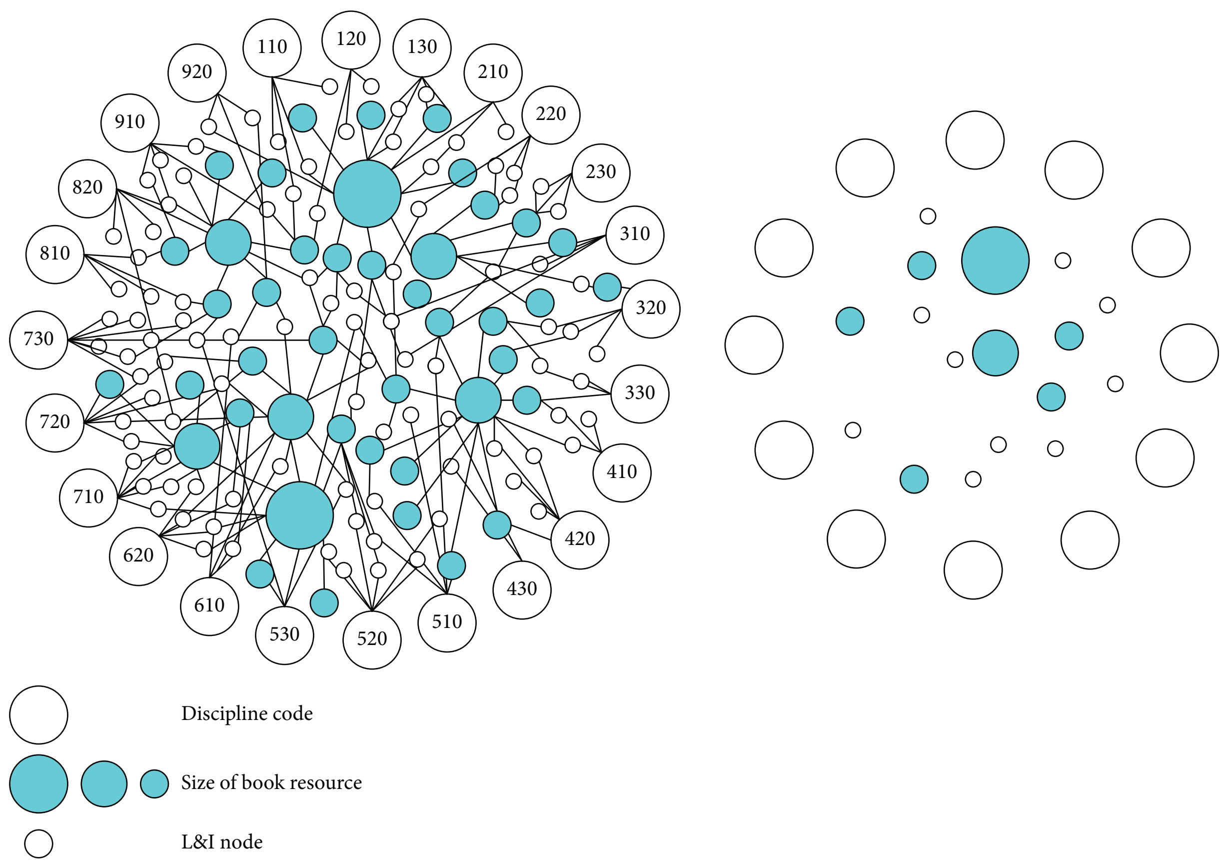


Figure 1: Visualization of L&I network.

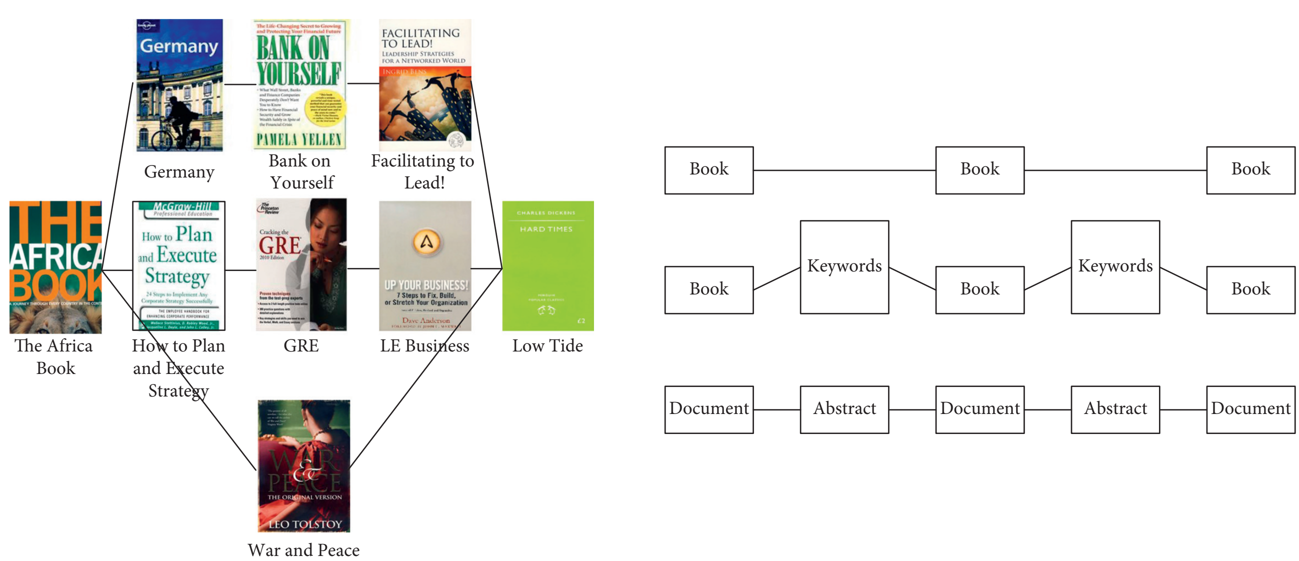


Figure 2: Examples of the paths and meta-path between nodes.

clustering coefficient of the M-node network can be calculated by

$$CO_{ST} \approx \frac{M}{M-1} = 1\,(M \longrightarrow \infty). \tag{10}$$

The mean path length of the network can be calculated by

$$K_{ST} = 2 - \frac{2\,(M-2)}{M\,(M-1)} = 2\,(M \longrightarrow \infty). \tag{11}$$

If the number and distribution meta-paths are random, then the L&I visualization network is a stochastic network. As long as the mean node degree l remains unchanged, the presence/absence of each meta-path in the random network is uncertain. Then, the node degree distribution of the meta-paths in the network can be described by Poisson's distribution as follows:

$$PO(l) = CO^{l}_{M-1} PO^{l} (1-s)^{M-1-l}. \quad (12)$$

3. Calculation of Meta-Path Importance

Without considering the limitations on L&I contents, the first step to find the optimal meta-path that depicts node relationships is to determine the meta-path length, path number, and path rarity. The optimal meta-path refers to the meta-path with the greatest importance. Let $LU_{r\longrightarrow o}$ be the set of meta-paths between nodes r and o, $R_{r-o}(LU)$ the importance support function of meta-path LU, $E_{r-o}(LU)$ the rarity of LU, and $PE(|LU|)$ the length attenuation function of LU. Then, the importance $ZY_{r,o}(LU)$ of meta-path LU connecting the given node pair <r, o> can be calculated by

$$ZY_{r-o}(LU) = R_{r-0}(LU) \cdot E_{r-o}(LU) \cdot PE(|LU|)(LU \in LU_{r\longrightarrow 0}). \quad (13)$$

Traditionally, the word frequency of L&I contents is calculated by counting the term frequency-inverse document frequency (TF-IDF) value. However, the TF-IDF-based method performs poorly on relatively short L&I texts, which has a few words and lacks context information after word segmentation. In this paper, short L&T texts are firstly segmented into words, and high-quality Chinese word vectors are generated by the directional skip-gram (DSG) model. Let ST be the input short L&I text, $[w_0, w_1 \ldots w_i \ldots w_L]$ the word sequence corresponding to the short text, L the length of the word sequence, w_i the i-th word, and U_{wi} the corresponding word vector. From the word vector, the sentence vector U_{ST} can be derived as

$$U_{ST} = \frac{1}{L} U_{w_i}. \quad (14)$$

Compared with short L&I texts, the abstracts of books and documents offer clear contextual relationships and many word vectors. To acquire the weighted mean sentence vector, the weight coefficients of words can be determined through statistical method. Let Φ be the abstract of a book or a document, $[w_0, \ldots w_i \ldots, w_L]$ the word sequence segmented from the abstract, and $[\omega_0, \ldots, \omega_i, \ldots, \omega_n]$ be the weight sequence of the segmented words. Then, a word vector $U_{\Delta wi}$ can be constructed for each word Δw_i segmented from the abstract. Then, the weighted mean sentence vector U_Φ can be calculated by

$$U_\Phi = \frac{1}{n} \omega_j \cdot u_{\tau_j}. \quad (15)$$

The similarity between the sentence vectors of two texts, namely, the input short text and the abstract of a book or document, can be measured by cosine similarity:

$$S(ST, \Phi) = 1 - \frac{U_{ST} \cdot U_\Phi}{\| U_{ST} \| \cdot \| U_\Phi \|}. \quad (16)$$

Based on the similarity of the short text of abstract, the importance of meta-paths $R_{r-o}(LU)$, $E_{r-o}(LU)$, and $PE(|LU|)$ can be measured. Let $\alpha \in (0,1)$ be the attenuation coefficient. Then, a length penalty function $PE(|LU|) = \alpha^{|LU|}$ can be configured to effectively lower the importance of meta-path LU, when it is relatively long. The length attenuation of the length penalty function could be adjusted by changing the value of α.

The rarity function $E_{r-o}(LU)$ aims to evaluate how rare is the meta-path LU in the set of node pairs WC_{r-o} similar to node pair <r, o>. WC_{r-o} can be defined as

$$WC_{r-o} = WC_o \bigcup WC_r, \quad (17)$$

where set WC_o can be expressed as

$$WC_o = \{(r,u) | u \in U, \rho(u) \cap \rho(o) \neq \phi\}. \quad (18)$$

Set WC_r can be described as

$$WC_r = \{(u,o) | u \in U, \rho(u) \cap \rho(r) \neq \phi\}. \quad (19)$$

Since o does not belong to set WC_o, then r does not belong to set WC_r. Drawing the idea of IDF calculation, the rarity function $E_{r-o}(LU)$ can be described as

$$E_{r-o}(LU) = \log \frac{|WC_{r-o}|}{|\{(v,u) \in WC_{r-o}, LU \in LU_{v\longrightarrow u}\}|}. \quad (20)$$

To rank the meta-paths by importance, the meta-path importance function $ZY_{r-o}(LU)$ must be monotonically decreasing and have a maximum. Since the length penalty function $PE(|LU|)$ is a strict monotonically decreasing function, formula (20) must satisfy

$$\frac{|WC_{s-t}|}{|\{(v,u) \in WC_{r-o}, LU \in LU_{v\longrightarrow u}\}|} \geq 1. \quad (21)$$

Formula (21) shows that $E_{r-o}(LU)$ is monotonically increasing, with a minimum of 0. According to formula (13), for $ZY_{r-o}(LU)$ to be monotonically decreasing and have a maximum, $R_{r-o}(LU)$ must have the same properties. To ensure that $R_{r-o}(LU)$ have these properties, this paper adopts the minsize of path that can represent the minsize of each type of nodes in LU. The meta-path of a given node pair <r, o> can be described by

$$LU = D_1 \xrightarrow{E_1} D_2 \xrightarrow{E_2} \ldots \xrightarrow{E_k} D_{k+1}. \quad (22)$$

Let IC_i be the number of instances for the i-th node on the meta-path. Then, the minsize of LU can be calculated by

$$MU_r(LU) = \min_{1<i<j+} \left| \left\{ |IC_i| IC \in LU \right\} \right|. \quad (23)$$

This is due to the existence of the following inequality:

$$\min_{1<i<j+1} \left| \left\{ |IC_i| IC \in LU \right\} \right| \leq \min_{1<i<j+2} \left| \left\{ |IC_i| IC * E_i \right\} \right|. \quad (24)$$

The minsize MU of LU is monotonically decreasing. In the L&I visualization network, the relationships do not take the same form. Instead, imbalanced relationships might exist, such as one-to-many or one-to-one relationships. To solve the problem, this paper resorts to the calculation of enhanced minsize, which is obtained by applying an intensity factor to the minsize. The intensity factor can be calculated by

$$\mathrm{STR}(LU) = \frac{1}{\min(UZ(D), RZ(D))}. \tag{25}$$

Let D be the nodes with minsize obtained by formula (23); let UZ (D) and RZ (D) be the out-degree and in-degree of D, respectively. If node D is a book or document, UZ (D) can be calculated by

$$\text{If } D = MO, UZ(D) = \sum_{n \in IC^D} S(U_n, U_{ST}). \tag{26}$$

Formula (26) shows that UZ (D) is the sum of similarities between the short L&I text and each node vector in instance set D. Through the above analysis, MU_{r-o} and STR (LU) can be combined to get the support function $R_{r-o}(LU)$ of meta-path importance:

$$R_{r-o}(LU) = \mathrm{STR}(LU) \cdot MU_{r-o}(LU). \tag{27}$$

Meta-paths are extensible. The importance of an extended meta-path equals the product between the current $R_{r-o}(LU)$ and the intensity coefficient STR (E_i) of the extended edge E_i.

In most of the existing studies, it is assumed that the meta-paths are provided by experts in the relevant fields. If the network is sufficiently large, it is impossible to know the type of all nodes or edges. The only solution to meta-path generation is to fix the length of the meta-path for each dataset.

According to the example node pair provided by the users, this paper automatically generates the meta-path that best explains the node pair. That is, all the possible meta-paths and the possible subsets of meta-paths were enumerated for the given node pair, and the meta-path that gives the example node pair the highest similarity was selected. Then, the forward hierarchical path generation algorithm was improved to adapt to the query task of this paper, thereby generating reliable meta-paths. The meta-paths were then sorted by importance.

4. Network Construction and Association Analysis

The existing studies have raised different opinions and drawn various conclusions about whether the visualization network nodes are associated with each other, but they did not measure the intensity of the associations. To fill up the gap, this paper introduced edge weight into the visualization network model and extracted the intensity of the interaction between associated nodes in the network.

4.1. Network Construction. Let CP_{r-o} be the probability for an edge to link up two nodes at the same time. The probability indicates how many of the edges to node o also link up node r. The conditional probability for the connection from node r to node o can be defined as

$$CP_{r-o} = \frac{LI_{r-o}}{LI_r}, \tag{28}$$

where LI_{r-o} is the number of other nodes connected to nodes r and o; LI_o is the number of other nodes connected to node o. Then, the following inequality holds:

$$LI_o \le \sum_r LI_{r-o}. \tag{29}$$

Some edges could link up more than 2 nodes. Hence, the correlations vary from node to node:

$$CP_{r-o} = \frac{r \longrightarrow o}{LI_r}. \tag{30}$$

Let $r \longrightarrow {}^{LI} o$ be the number of edges from node r to node o; let LI_o be the change in the number of edges to node o. If many values with the association of 1 are obtained, and if the sample size is small, it is improper to judge that the two nodes have a close linear relationship, solely based on the correlation coefficient. Thus, it is necessary to remove the repetitive values during network construction and parameter screening. The similarity between two nodes in the L&I visualization network can be calculated by

$$COR_{r-o} = \frac{LI_{r-0}LI - LI_r LI_o}{\sqrt{(LI - LI_r)(LI - LI_o)LI_r LI_0}}. \tag{31}$$

The calculation of network instances shows that the correlation between most information nodes equals 1. When there are only a few nodes, the linear relationship between variables LI_r and LI_o cannot be judged by correlation coefficient alone. Table 1 shows the calculation results of scale-free network.

Figure 3 presents the calculated node degree distribution of the established scale-free L&I visualization network. Only 3.6% of all network nodes had a correlation greater than 0.8, which satisfies the construction principle of complex network and the theoretical power law distribution of node degree.

4.2. Association Analysis. To further measure the association between L&I nodes, this paper analyzes the similarity of individual books and documents and that of a group of books and documents in L&I visualization network. The most important aspect of the analysis is the modeling of network nodes. The L&I nodes were analyzed and modeled from three aspects: the basic information BA, the text information TE, and the relationship information RE.

Let IM (r, o) be the similarity between two nodes r and o. For node r, a model can be established as $US(r) = \{BA(r), TE(r), RE(r)\}$. For node o, another model can be

Table 1: Some calculation results of scale-free network.

Serial number	Node r	Node o	Number of nodes	Correlation
1	4.023	4.172	31	1
2	4.176	4.36	31	1
3	5.38	5.37	11	1
4	10.82	10.58	32	1
5	10.49	10.53	42	1
6	11.374	11.372	12	1
7	16.275	15.981	14	1
8	10.73	10.76	26	1
9	15.072	15.492	10	1
10	4.127	4.39	31	1

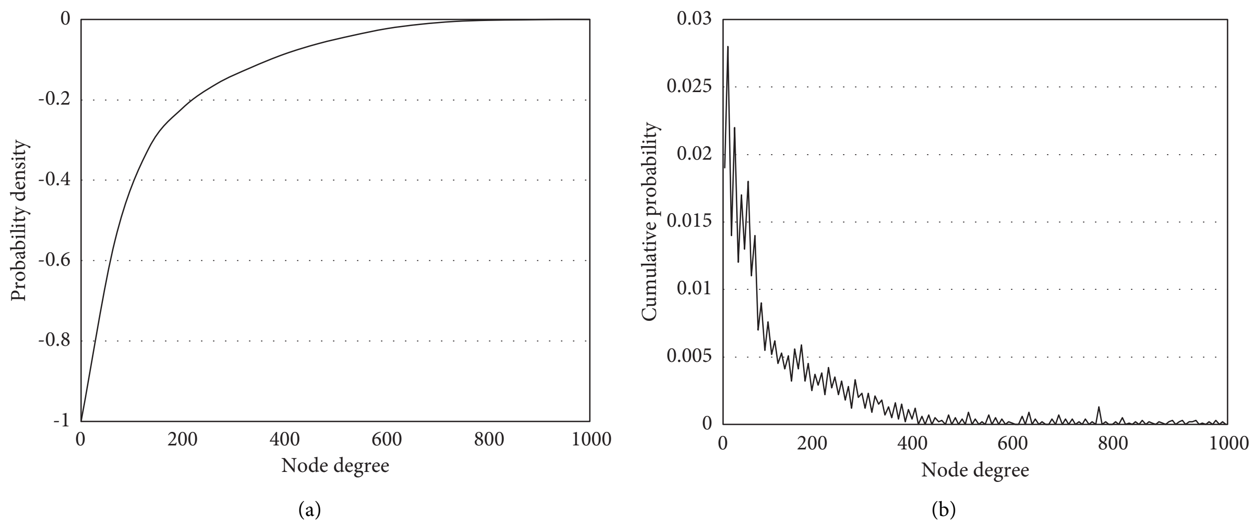


Figure 3: Power law distribution features of node degree.

established as $US(o) = \{BA(o), TE(o), RE(o)\}$. Based on the data of BA, TE, and RE, the similarity between nodes could be calculated. Firstly, the similarity of nodes was calculated in terms of the three attributes. The similarity $S(r_\mu, o_\mu)$ between the basic information $BA(r)$ and $BA(o)$ of nodes r and o can be described by

$$S(r_\mu, o_\mu) = S(BA(r), BA(o)). \tag{32}$$

The similarity between the text information $TE(r)$ and $TE(o)$ of nodes r and o can be described by

$$S(r_\sigma, o_\sigma) = S(TE(r), TE(o)). \tag{33}$$

The similarity between the relationship information $RE(r)$ and $RE(o)$ of nodes r and o can be described by

$$S(r_\gamma, o_\gamma) = S(RE(r), RE(o)). \tag{34}$$

The basic information of network nodes mainly includes the publisher, publication date, and number of pages. The basic information of nodes r and o can be expressed as $BA(r) = \{LO(r), AG(r), TA(r)\}$, and $BA(o) = \{LO(o), AG(o), TA(o)\}$, respectively. Let δ_i be the weight of the similarity for each attribute of the basic information. Then, the similarity between the basic information can be calculated by

$$\begin{aligned} S(r_\lambda, o_\mu) = {} & \delta_1 (LO(r), LO(o)) + \delta_2 (AG(r) + AG(o)) \\ & + \delta_1 (TA(r) + TA(o)), \end{aligned} \tag{35}$$

where $\delta_1 + \delta_2 + \delta_3 = 1$. This paper uses the text eigenvector to characterize the text information of books and documents. The similarity between the text information can be calculated by

$$S(r_\sigma, o_\sigma) = \frac{\sum_{i=1}^{m} (\delta_{ri} + \delta_{oi})}{\sqrt{\sum_{i=1}^{m} \delta_{ri}^2}\sqrt{\sum_{i=1}^{m} \delta_{oi}^2}}. \tag{36}$$

The relationship information between nodes can be divided into primary and secondary levels. The relationship information of nodes r and o can be expressed as $RE(r) = \{FO(r), FA(r)\}$ and $RE(o) = \{FO(o), FA(o)\}$, respectively. The similarity analysis of relationship information is equivalent to the similarity analysis of the primary and secondary relationship information. Let η_1 and η_2 be the weights of the similarity between primary relationship information and secondary relationship information, respectively. The similarity between the relationship information can be calculated by

$$S\left(r_\gamma, o_\gamma\right) = \delta_1 S(FO(r), FO(o)) + \delta_2 S(FA(r) + FA(o)), \tag{37}$$

where $\eta_1 + \eta_2 = 1$. The similarity between the primary relationship information can be calculated by cosine similarity:

$$S(FO(r), FO(o)) = \frac{FO(r) \cdot FO(o)}{\|FO(r)\| \cdot \|FO(o)\|}. \tag{38}$$

The similarity between the secondary relationship information can be calculated by cosine similarity:

$$S(FA(r), FA(o)) = \frac{FA(r) \cdot FA(o)}{\|FA(r)\| \cdot \|FA(o)\|}. \tag{39}$$

Then, the weights θ were assigned to the three kinds of information *BA*, *TE*, and *RE*. The relationship between the three weights can be expressed as $\theta_\mu + \theta_\sigma + \theta_\gamma = 1$. The similarity between two nodes r and o can be calculated by

$$S(r, o) = \delta_\mu S\left(v_\mu, u_\mu\right) + \delta_\sigma S\left(v_\sigma, u_\sigma\right) + \delta_\gamma S\left(v_\gamma, u_\gamma\right). \tag{40}$$

Based on the topology of the L&I visualization network, the similarity between network nodes was analyzed according to the primary and secondary relationships between groups of books and documents. The L&I visualization network can be described as a directed graph *QX* (*H*, *K*), where H and K are the set of nodes and set of edges in the network, respectively. Let B be the path connection matrix of the directed graph; and let $\Omega = \{SS\{r, o\}^M r, o = 1$ be the similarity matrix of nodes r and o, with *SS* (r, o) being the structural similarity between r and o:

$$\begin{aligned} SS(r, o) = &\sum_{l=1}^{M} RZ\left(D_{vl} = 1\right) \cdot RZ\left(D_{ul} = 1\right) \cdot \frac{1}{\log RZ_l} \\ &+ \sum_{l=1}^{M} RZ\left(D_{lv} = 1\right) \cdot RZ\left(D_{lu} = 1\right) \cdot \frac{1}{\log UZ_l}, \end{aligned} \tag{41}$$

where $1/\log RZ_l$ and $1/\log UZ_l$ are the weights of primary relationship node l and secondary relationship node l, respectively; RZ_l and UZ_l are the in-degree and out-degree of node l, respectively.

5. Experiments and Results Analysis

The experiments were carried out in the following steps: (1) capture all the associations between the L&I nodes of each discipline; (2) statistically describe different disciplines at different node degrees; (3) compare the structural evolution of the L&I visualization network through discipline crossover; (4) compare the query accuracies of L&I with different encoding schemes.

All the associations between L&I nodes in each type of disciplines were captured under the JavaScript programming environment. However, it is impossible to visualize so many types of disciplines one by one. Figures 4 and 5 present the L&I visualization networks for science and engineering disciplines, respectively. The light blue and light pink clusters are located in the center of the networks, respectively.

Table 2 presents the descriptive statistics (number of nodes, number of edges, node degree, and mean clustering coefficient) on the primary disciplines of the top 8 disciplines, whose L&I visualization network density is greater than 0.5. It can be seen that the L&I networks of disciplines with node degree greater than 0.5 have similar features: the networks of science, engineering, medicine, agronomy, and management have a few nodes, but the nodes boast a high node degree, possess a high mean clustering coefficient, and belong to the fully connected state. To better describe the distance between nodes from the planar perspective, Figure 6 visualizes the L&I networks of different disciplines with node degree smaller than 1. The figure provides a visual display of the cross influence of node distribution density and mean clustering coefficients on the L&I of these disciplines, as well as the status of every secondary discipline network under each primary discipline L&I network. The information in the figure fully demonstrates the superiority of the visualization technology that cannot be reflected by columns of numbers.

Table 3 presents the descriptive statistics on 24 disciplines with network node degree smaller than 0.5. From the statistics on the number of nodes, it can be inferred that this number is negatively correlated with network node degree. There is also a negative correlation between the number of nodes and the sum of the initial cross influence between disciplines. This law can be verified by the number of edges. If a few nodes are connected by many edges, the clustering coefficient and node degree of the visualization network will increase. If many nodes are connected by a few edges, the clustering coefficient and node degree of the visualization network will decrease. This further confirms the cross influence of L&I in terms of discipline.

To measure the influence of discipline integration on the structure of the L&I visualization network, this paper compares the structural evolution of the network before and after discipline integration and analyzes the dynamic evolution law of the interactive operation on the form of L&I visualization. Figure 7 presents the structure of the visualization network for each primary discipline of liberal arts.

Table 4 displays the nodes of visualized paths on different levels of importance, aiming to verify the effectiveness of path importance on L&I visualization tasks. Considering the calculation results on importance levels and the meta-paths for the typical paths in the table, it is possible to generate the node pairs corresponding to the paths and then measure the similarity between nodes by the methods specified in Section 4.2.

Further, our algorithm is expected to correctly guide the similarity measurement of nodes in information flow query tasks. To verify if our algorithm meets the expectation, this paper compares the experimental data under different weight distributions, similarity metrics, and edge properties. Figure 8 compares the L&I query accuracies under different visualization encoding schemes. There is a total of eight curves in the figure, including the curved edges with no weight and no similarity metric CUR1, the curved edges with

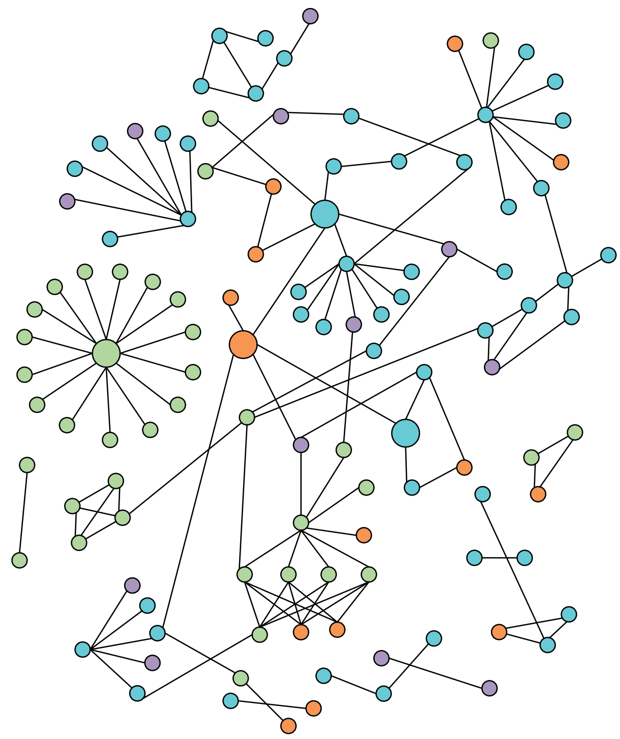


Figure 4: L&I visualization network for science disciplines.

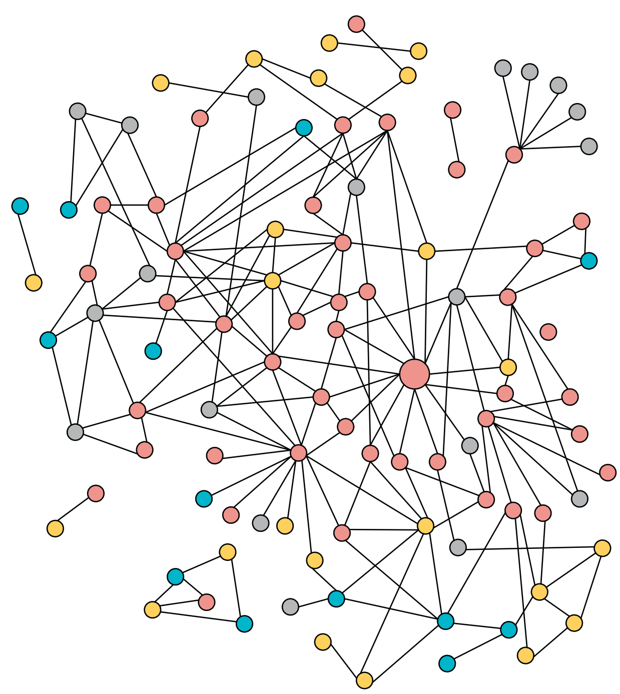


Figure 5: L&I visualization network for engineering disciplines.

no weight yet similarity metric CUR2, the curved edges with weight and no similarity metric CUR3, the curved edges with weight and similarity metric CUR4, the straight edges with no weight and no similarity metric SL1, the straight edges with no weight yet similarity metric SL2, the straight edges with weight and no similarity metric SL3, and the straight edges with weight and similarity metric SL4. It can be observed that, under any encoding scheme, the nodes with similarity metric had higher accuracies than those without similarity metric. Regardless of the presence or absence of weight, the similarity metric and modeling difficulty both greatly affected the L&I query accuracy.

Table 2: Descriptive statistics on the primary disciplines with node degree greater than 0.5.

Serial number	Primary discipline	Number of nodes	Number of edges	Node degree	Mean clustering coefficient
1	Science	7	16	1	1
2	Engineering	5	7	1	1
3	Engineering	6	11	1	1
4	Medicine	7	16	1	1
5	Science	15	79	0.98624531	0.986243138
6	Science	6	8	0.82356213	0.828856904
7	Agronomy	12	37	0.63577895	0.812524782
8	Management	7	9	0.52225542	0.567790876

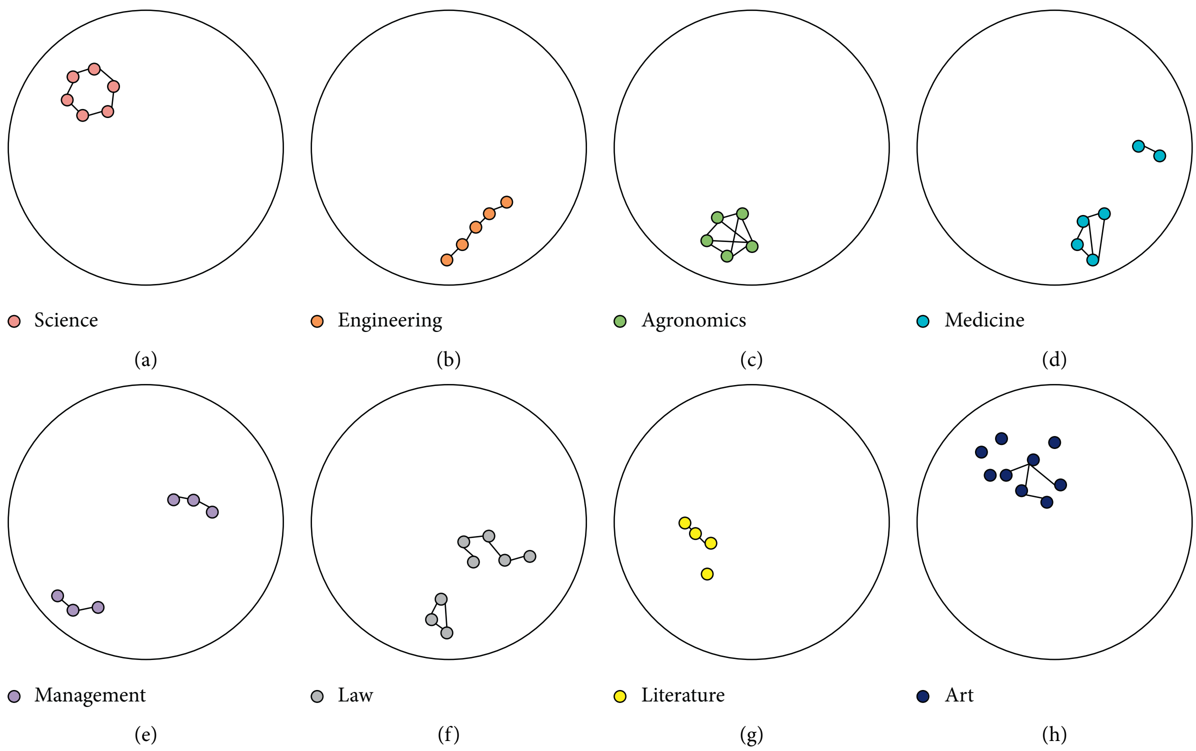


Figure 6: L&I visualization networks of different disciplines with node degree smaller than 1. (a) Science, (b) engineering, (c) agronomics, (d) medicine, (e) management, (f) law, (g) literature, and (h) art.

Table 3: Descriptive statistics on 24 disciplines with node degree smaller than 0.5.

Serial number	Name of discipline	Number of nodes	Number of edges	Network density	Mean clustering coefficient
1	Philosophy	25	28	0.46321458	0.69849156
2	Economics	13	131	0.40961562	0.68595231
3	Law	66	129	0.38915615	0.66241782
4	Sociology	65	23	0.30897034	0.72420423
5	Education	12	792	0.30741159	0.60225465
6	Journalism and communication	19	613	0.29459192	0.41460262
7	History	10	15	0.26489414	0.42163075
8	Art	27	41	0.24563437	0.21784579
9	Math	45	10	0.24419193	0.59712653
10	Physics	58	82	0.24556232	0.72345632
11	Chemical	65	231	0.21849248	0.60245620
12	Astronomy	53	339	0.20113861	0.62162664
13	Geography	15	400	0.19841563	0.49423346
14	Biology	36	238	0.18771669	0.47312304
15	Mechanical engineering	59	16	0.16895613	0.17692613
16	Material science	59	106	0.15489156	0.40465792
17	Electrical engineering	100	305	0.14518965	0.72332643

Table 3: Continued.

Serial number	Name of discipline	Number of nodes	Number of edges	Network density	Mean clustering coefficient
18	Architecture	45	276	0.13192632	0.61976221
19	Civil engineering	55	683	0.12231568	0.55343579
20	Hydraulic engineering	61	133	0.12052491	0.53143923
21	Mining engineering	132	184	0.11891562	0.58432634
22	Veterinary science	95	220	0.10247959	0.48323316
23	Clinical medicine	97	931	0.10137563	0.66312978
24	Business management	98	462	0.10112315	0.59463123

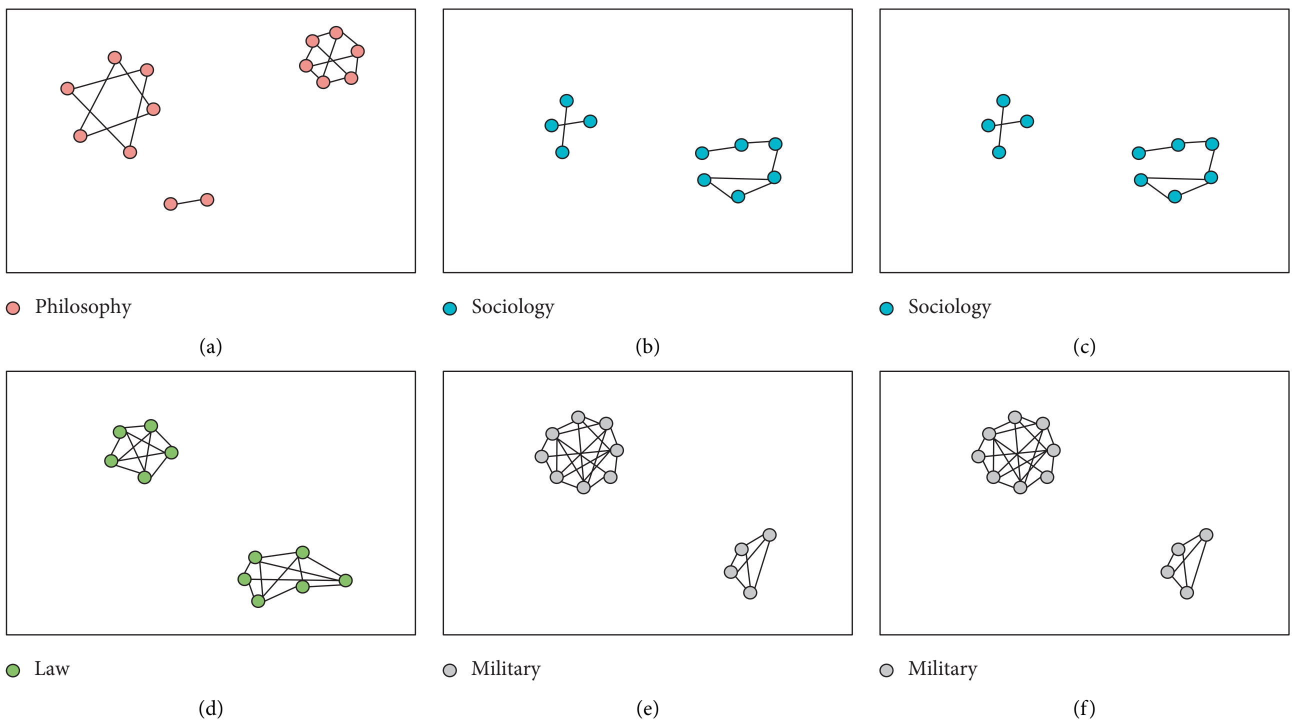


Figure 7: Structural evolution of L&I visualization network before and after discipline integration. (a) Philosophy, (b) economics, (c) sociology, (d) law, (e) history, and (f) military.

Table 4: Nodes of visualized paths on different levels of importance.

Number of shortest paths	Start points	End points	Nodes on the shortest paths
3	16.723	16.21	16.723, 16.21
3	16.12	16.849	16.12, 16.23, 16.849
4	18.372	16.314	18.372, 17.25, 16.953, 16.314
4	2.135	16.756	2.135, 4.623, 7.968, 15.562, 16.756
5	16.74	16.23	16.74, 17.25, 18.31, 15.26, 17.48, 16.23
5	16.37	16.95	16.37, 18.25, 17.42, 18.93, 17.25, 18.84, 16.95
6	3.82	16.12	3.82, 5.67, 7.24, 9.85, 7.52, 12.79, 14.56, 15.19, 16.12
6	5.94	16.71	5.94, 6.08, 7.67, 9.52, 10.24, 11.75, 12.43, 14.69, 15.72, 16.71
7	12.35	16.45	12.35, 12.75, 13.18, 13.84, 14.23, 15.37, 16.75, 18.92, 18.05, 16.45
7	9.51	16.53	9.51, 10.72, 14.35, 16.21, 18.79, 17.63, 16.54, 18.31, 17.25, 18.35, 16.53

6. Conclusions

This paper probes into the visualization of L&I from the perspective of big data analysis and fusion. The first step is to analyze the topology of the L&I visualization network and calculate the metrics for the construction of L&I visualization topology map, as well as the importance of meta-paths of the L&I visualization network. After that, a complex big data L&I visualization network was established to analyze the associations between information nodes. Through experiments, the

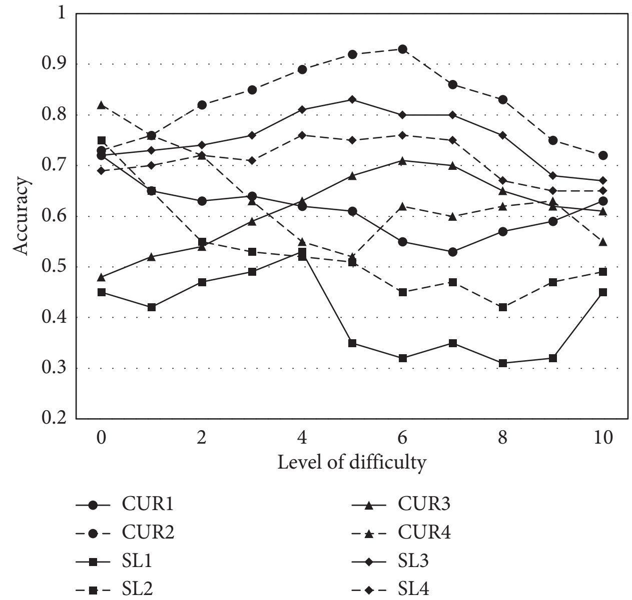


Figure 8: L&I query accuracies under different visualization encoding schemes.

disciplines with network node degree greater or smaller than 0.5 were described statistically, and the structural evolution of the L&I visualization network before and after discipline integration was demonstrated to confirm the effectiveness of our visualization strategy. Further, the nodes of the visualized paths were obtained under different levels of difficulty, which verify that the path importance is effective in L&I visualization tasks. It is also proved that, during the information flow query, the node similarity metric derived by our algorithm can correctly guide the query process.

This paper needs to be further improved in many aspects. For one thing, the meta-path features can be learned by attention-based neural network models, in order to generate more explanatory meta-path importance. For another, big data can be visualized in various forms. It is meaningful to explore the data visualization of multiple variables. The future work will analogize and analyze big data visualization more systematically.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] M. A. Islam and N. K. Agarwal, "What is the impact of library and information science on knowledge management research?" *VINE Journal of Information and Knowledge Management Systems*, vol. 51, no. 1, pp. 1–26, 2020.

[2] H. Alrubaye, M. W. Mkaouer, and A. Ouni, "On the use of information retrieval to automate the detection of third-party java library migration at the method level," in *Proceedings of the 2019 IEEE/ACM 27th International Conference on Program Comprehension (ICPC)*, pp. 347–357, Montreal Quebec, Canada, May 2019.

[3] D. Hienert, D. Kern, K. Boland, B. Zapilko, and P. Mutschke, "A digital library for research data and related information in the social sciences," in *Proceedings of the 2019 ACM/IEEE Joint Conference on Digital Libraries (JCDL)*, pp. 148–157, Champaign, IL, USA, 2019.

[4] N. Kalenov, I. Sobolevskaya, and A. Sotnikov, "Hierarchical representation of information objects in a digital library environment," in *Proceedings of the Russian Conference on Artificial Intelligence*, pp. 93–104, Ulyanovsk, Russia, 2019.

[5] B. D. Lund, T. Wang, and D. E. White, "University program rankings in the United States: failures in assessing important factors for library and information science students," *Education for Information*, vol. 35, no. 4, pp. 419–438, 2019.

[6] L. Salisbury, A. O. Omolewu, and J. J. Smith, "Technology use for non-educational purposes during library instruction: effects on students learning and retention of information," *Science & Technology Libraries*, vol. 37, no. 3, pp. 274–289, 2018.

[7] N. Xiao and X. Zhang, "A target positioning method for industrial robot based on multiple visual sensors," *Traitement du Signal*, vol. 37, no. 3, pp. 469–475, 2020.

[8] C. Zhang, D. Zha, S. Zhou, H. Zhou, and H. Jiang, "3D visualization of landslide based on close-range photogrammetry," *Instrumentation, Mesure, Métrologie*, vol. 18, no. 5, pp. 479–484, 2019.

[9] Y. M. Zhao, "Design and application of an adaptive slow feature extraction algorithm for natural images based on visual invariance," *Traitement du Signal*, vol. 36, no. 3, pp. 209–216, 2020.

[10] R. Han, D. Shao, L. Wang, and M. Wang, "A novel communication and monitoring system for integrated utility tunnel," *Instrumentation, Mesure, Métrologie*, vol. 18, no. 2, pp. 195–200, 2019.

[11] X. Li, "Young people's information practices in library makerspaces," *Journal of the Association for Information Science and Technology*, vol. 72, no. 6, pp. 744–758, 2021.

[12] H. D. Zou and R. Q. Jia, "Visual positioning and recognition of gangues based on scratch feature detection," *Traitement du Signal*, vol. 36, no. 2, pp. 147–153, 2020.
[13] A. Habib, M. Islam, M. Kabir, M. Mredul, and M. Hasan, "Staircase detection to guide visually impaired people: a hybrid approach," *Revue d'Intelligence Artificielle*, vol. 33, no. 5, pp. 327–334, 2019.
[14] J. Ren, "An empirical study of evaluation of library wechat micro service by mobile information network technology," *Journal Of Physics: Conference Series*, vol. 1952, no. 3, Article ID 032018, 2021.
[15] Q. Xiao, "Resource classification and knowledge aggregation of library and information based on data mining," *Ingénierie des Systèmes d'Information*, vol. 25, no. 5, pp. 645–653, 2020.
[16] Y. Mo, E. Seon, G. Park, and H. Kim, "Course analysis of library and information science in Korea," *Information*, vol. 11, pp. 1–19, 2020.
[17] E. Rowley, L. Kuryloski, and K. Moore, "Extending the role of the library and librarian: integrating alternative information literacy into the engineering curriculum," in *Proceedings of the 2020 ASEE Virtual Annual Conference Content Access*, Article ID 30249, June 2020.
[18] Á. Borrego, "The impact of MOOCs on library and information science education," *Education for Information*, vol. 35, no. 2, pp. 87–98, 2019.
[19] Q. Johnson, "Privacy considerations for library and information professionals," *Information Services & Use*, vol. 40, no. 3, pp. 255–258, 2020.
[20] C. C. Okeji and O. Mayowa-Adebara, "An evaluation of digital library education in library and information science curriculum in Nigerian universities," *Digital Library Perspectives*, vol. 37, no. 1, pp. 91–107, 2020.
[21] F. Peset, F. Garzón-Farinós, L. González et al., "Survival analysis of author keywords: an application to the library and information sciences area," *Journal of the Association for Information Science and Technology*, vol. 71, no. 4, pp. 462–473, 2020.
[22] J. T. Mickel, "Digital culture and information: a library-based minor focusing on how modern information access impacts society," in *Proceedings of the 20th Annual SIG Conference on Information Technology Education*, p. 151, Tacoma, WA, USA, October 2019.
[23] J. Griffin, "Leadership to advance data and information science at Virginia Tech library," *Information Services & Use*, vol. 39, no. 3, pp. 177–181, 2019.
[24] I. E. Paramonova, "Information interactions: the criteria of the choice of communication channels in a scientific and technical library," *Scientific and Technical Information Processing*, vol. 46, no. 3, pp. 181–186, 2019.
[25] H. A. Pradana, P. P. G. P. Pertama, M. S. Mayasari, Y. Andrika, F. P. Juniawan, and D. Y. Sylfania, "Audit of provincial library information system based on COBIT 4.1," *2019 1st International Conference on Cybernetics and Intelligent System (ICORIS)*, vol. 1, pp. 18–22, 2019.
[26] R. Haunschild, L. Leydesdorff, and L. Bornmann, "Library and information science papers discussed on twitter: a new network-based approach for measuring public attention," *Journal of Data and Information Science*, vol. 5, no. 3, pp. 5–17, 2020.
[27] G. Retscher and A. Leb, "Development of a smartphone-based university library navigation and information service employing wi-fi location fingerprinting," *Sensors*, vol. 21, no. 2, p. 432, 2021.