Mobile Information Systems

State-of-the-Art Wireless Emerging Technologies for Beyond 5G/B5G Communication

Lead Guest Editor: Imran Khan
Guest Editors: Peerapong Uthsansakul and Heejung Yu

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

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

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

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

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

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[1] C. Xu, "Adaptive Classification Algorithm Design for Online Teaching Resources of Opera Singing," *Mobile Information Systems*, vol. 2022, Article ID 8609097, 9 pages, 2022.

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In addition, our investigation has also shown that one or more of the following human-subject reporting requirements has not been met in this article: ethical approval by an Institutional Review Board (IRB) committee or equivalent, patient/participant consent to participate, and/or agreement to publish patient/participant details (where relevant).

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Research Article

Application Analysis of Intelligent Particle Swarm Algorithm in the Development of Modern Tourism Intelligence

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Information technology has been increasingly vital in the rapid expansion of the tourism industry economy. The new information technology has become a significant driving force and factor in the tourism industry's economic development. The application of new information technology to the advancement of modern tourist intelligence has emerged as an essential study area. Smart tourism, aided by informatization, can frequently provide more attractive economic benefits to tourism businesses. Tourism is being positioned as a new economic growth point and core business in an increasing number of cities. Various measures have been taken among the main body of the city to improve the tourism competitiveness of the city, so as to be in an advantageous position in the fierce market competition. Under this background, the research on urban tourism competitiveness has become a research hotspot in the development of modern tourism intelligence. This study used a combined PSO and neural network to assess the competitiveness of urban tourism. First, this paper offers a method that makes use of an improved IPSO. It changes the inertia weight dynamically and nonlinearly based on the particle fitness value. Simultaneously, the particle swarm technique is enhanced by combining the particle iterative cycle to boost position disturbance. Second, in order to build an IPSO-BP network, this work optimizes the initial weights and thresholds of the BP network based on IPSO. This work uses this network to evaluate the competitiveness of urban tourism, which can overcome the defects of traditional BP network. Third, this work conducts systematic experiments on the IPSO-BP method, and the experimental results confirm the superiority of this method in the evaluation of urban tourism competitiveness.

1. Introduction

With the rapid development of modern information technology and its wide application in the world, information technology has played a subversive and revolutionary role in the development, management, and marketing of the tourism industry. The new information technology provides strong support and new impetus for the innovation, construction, and development of the vast number of facilities. The smooth implementation and promotion of new information technology and intelligent systems will definitely have a subversive and revolutionary impact on people's travel patterns and habits. In addition, the launch of intelligent tourism projects will inevitably promote the upgrading and transformation of the traditional tourism industry to the modern tourism industry and the transformation from the traditional service industry to the modern service industry. Smart tourism driven by modern information technology will be a new product developed through the deep integration of information technology and traditional industry development. This is a new direction for the development of my country's tourism industry. Compared with traditional tourism methods, smart tourism places more emphasis on the needs of tourists. This strengthens the provision of more intimate and convenient travel services, which is supported by new generation information technologies such as wireless Internet technology, cloud computing technology, big data technology, Internet of Things, and modern multimedia technology. It focuses on realizing the mutual connection and perception between tourists and various tourism products and service elements in the scenic spot and finally completes the comprehensive

promotion and application of smart tourism services after experiencing perception [1–5].

The Ministries of Culture and Tourism places a high value on enhancing the service quality and reception capacity of tourist destinations. Because its construction and development are critical to the transformation and upgrading of the domestic tourist sector, optimizing the structure of tourism products, and leading the national leisure and holiday tourism industry's development. National-level tourism resorts in large cities have recently emerged as new industry indicators, following the national 5A-level scenic sites. The Ministry of Culture and Tourism has also built a dynamic management framework for assessing tourist resorts in order to ensure that tourist resorts are progressing toward high-quality growth. The government has attached great importance to the informatization development of smart tourism, and local governments at all levels have successively issued guidelines to accelerate the green development of the tourism industry. This clearly requires that local governments at all levels should cultivate the tourism industry into a strategic emerging industry and leading industry that supports the transformation of economic structure and sustainable development. The local government should also develop the tourism industry into a modern and new service industry that satisfies the people. The government also emphasized that to develop the tourism industry, it is necessary to break the traditional old development model and thinking and focus on developing smart tourism projects. Smart tourism especially vigorously develops informatization as the main means. Whether it is tourism products or tourism services, the improvement of their quality and the building of brands are inseparable from informatization and intelligence. The main leaders of the national tourism authorities have repeatedly emphasized on many occasions that all localities should accelerate the construction of demonstration projects of tourism informatization and promote the vigorous development of smart tourism [6–10].

A city is a hub for multiple consumptions as well as a distribution point for diverse flows of people, logistics, and capital. Cities are the foundation of modern smart tourism, and their flawless functions can suit the needs of visitors. Urban tourism is the core and primary body of modern tourism, and cities with great urban competitiveness can assist the growth of urban tourism in this region. As a result, when analyzing the competitiveness of urban tourism, a significant topic in smart tourism should strengthen research on the competitiveness of urban tourism. The survival and development of tourism within a country or region are influenced to some extent by the region's urban tourism competitiveness. It can scientifically and objectively evaluate the development status and potential of urban tourism. This avoids unnecessary duplication of construction, resulting in a significant waste of resources. In today's vigorous development of smart tourism, we should pay attention to the role of urban tourism competitiveness in the process of developing urban tourism. The cultivation and promotion of urban tourism competitiveness requires the guidance of theory. Therefore, the study of urban tourism competitiveness has become a research hotspot in tourism academic circles at home and abroad [11–15].

The paper's organization paragraph is as follows: the related work is presented in Section 2. Section 3 analyzes the methods of the proposed work. Section 4 discusses the experiments and results. Finally, in Section 5, the research work is concluded.

2. Related Work

Literature [16] puts forward the essential problem of the modern development of the tourism industry; that is, the development of the tourism industry must focus on bringing more convenient, low cost, and efficient services to tourists. Information technology can help tourism enterprises achieve this goal, which pointed out a clear direction for the organic combination of digital technology and tourism industry at that time. Literature [17] proposed that the development of tourism e-commerce is inseparable from the support of digital technology. Especially for mobile marketing platforms, stable and reliable wireless Internet technology is needed for protection. Literature [18] proposes that the key to the smooth development and implementation of tourism informatization is the direction selection, policy support, professional talent introduction and training, network security protection, and technological innovation. Literature [19] did an extensive and comprehensive study on the promotion and use of intelligent tourism systems, as well as the integration of information technology and the tourism industry from an information technology standpoint. The literature [20] examined in depth the constraints of the traditional tourism industry chain management paradigm against the backdrop of tourism information industrialization promotion. Using the promotion of large travel agencies' smart tourist management model as an example, it exhibits the tremendous impact of tourism informatization and management intelligence on conventional cooperation and labour division in the tourism industry chain. The authors of [21] take the construction of a smart city tourism system as an example and focus on research on urban tourism consultation, service system, online ticketing, and travel reservation services. The authors of [22] study the impact of new information technology on tourism. It proposed that relevant departments should attach importance to the development of smart tourism and take measures to build network infrastructure. The authors of [23] discuss how tourism enterprises can participate in smart tourism projects. It proposed that enterprises should increase investment, increase departments and personnel, and build a free smart tourism service platform. Enterprises should also seamlessly connect with relevant platforms of government departments. With the help and guidance of the government, use smart tourism tools to enhance and improve service quality. The authors of [24] proposed the concept of digital tourism service based on new communication technology. It proposes to use virtual reality technology to satisfy tourists' desire to play. At the same time, it actively promotes the picturesque spot's brand publicity and market marketing. The literature [25]

investigated the effect of smart tourism and discovered that smart tourism can boost tourist satisfaction to a certain level. However, there will be certain misunderstandings in the process of building smart tourism in various regions due to differing understandings of the notion of smart tourism. The authors of [26] analyze it from the standpoint of smart cities built by a number of cities. It defines smart tourism by elaborating on the relationship between smart cities and smart tourism. This has become a standard study on the subject of smart tourism.

Literature [27] believes that the strength of urban tourism competitiveness is mainly affected by the need of tourists and the behavior of tourism enterprises. Therefore, a city with strong urban tourism competitiveness must be a destination with tourism attractiveness, and tourism enterprises can develop products that meet the needs of tourists. Literature [28] believes that information network has become an important way to connect tourism suppliers and tourism demanders. In the future, tourists will look for the recreational places they want to visit on the Internet. Tourism competition sites can reflect competitiveness through information structure, information accessibility, information quality, and dissemination speed. According to the literature [29], the competitiveness of tourism destinations should be based on their ability for long-term development rather than their current development. According to the literature [30], the determinants of tourism destination competitiveness include four factors. It also develops a conceptual paradigm for assessing tourist locations' competitiveness. Literature [31] uses urban tourism places with relatively high competitiveness as the research object. It thinks that every link in the destination's chain will have an impact on competitiveness and that competitiveness can only be attained via the application of comprehensive quality management. Literature [32] investigated the disparities in tourism competitiveness due to differences in tourism destination marketing. It believes that the improvement of the competitiveness of tourist destinations requires attention to marketing factors. It should strive to achieve a balance between strategic marketing objectives and sustainable tourism development. The authors of [33], with the help of the tourism environment competitiveness theory, discuss that the environment of the tourism destination is also an important part of the competitiveness of the tourism destination. Therefore, in the process of developing tourism, appropriate environmental management measures and methods should be carried out. This is also an important means to improve the competitiveness of tourist destinations.

3. Method

First, this work proposes an algorithm that utilizes an improved IPSO. It uses the particle fitness value to dynamically and nonlinearly change the inertia weight. At the same time, the particle swarm algorithm is improved by combining the particle iterative cycle to increase the position disturbance. Second, this work optimizes the initial weights and thresholds of the BP network based on IPSO to construct an IPSO-BP network. This work uses this network to evaluate the competitiveness of urban tourism, which can overcome the defects of traditional BP network.

3.1. BP Network. Backpropagation neural network is also known as BP network. Its construction includes hidden layers and input and output layers. The input layer mainly receives the incoming feature data. It is then transmitted to the hidden layer to complete the processing of the hidden layer and passed to the output layer, which completes the final processing. If an error occurs, the weight is altered, and the network is updated by input from the back to the front. The BP network operates on the principle of forward signal propagation and reverse error propagation. The initial feature input is routed through the input layer into the BP network. The outcomes of neuron processing in the hidden layer are finally delivered through the output layer. This is known as forward propagation. At this stage, the connection weight of the network has not changed, and its connection weight is related to the adjacent neurons. Then, if there is only forward propagation, its network accuracy and convergence cannot meet the requirements of target setting. Therefore, the error still needs to be propagated back. If there is an error between the output layer output and the known target, it is passed through the output layer to the next time of the network. The transmission process of the error is the adjustment process of the network to the neuron connection weights and thresholds, and its goal is to make the results more accurate. The structure of BP is demonstrated in Figure 1.

In the input stage, the signal is conducted through neurons. The initial information enters the entire network structure through the input layer and enters the hidden layer through the transfer matrix. After its comprehensive processing, it is passed to the output layer. The output layer completes the final processing of the signal through the activation function and outputs the result.

$$\begin{aligned} \widehat{y}_i &= f\left(\sum_{i=1}^{M} w_i x_i + b_i\right), \\ \text{Loss} &= \sum_{i=1}^{M} \left(y_i - \widehat{y}_i\right)^2. \end{aligned} \tag{1}$$

The network error is obtained by comparing the output with the measured value during the training phase. If the error is acceptable, the training is complete. When the output does not reach the preset threshold, backpropagation is performed to correct various parameters of the neural network.

$$\begin{aligned} w' &= \frac{w - \partial \text{Loss}}{\partial w}, \\ b' &= \frac{b - \partial \text{Loss}}{\partial b}. \end{aligned} \tag{2}$$

The BP algorithm can approximate any objective function under the premise of nonlinearity. Theoretically, it can achieve any small error precision value and is easy to

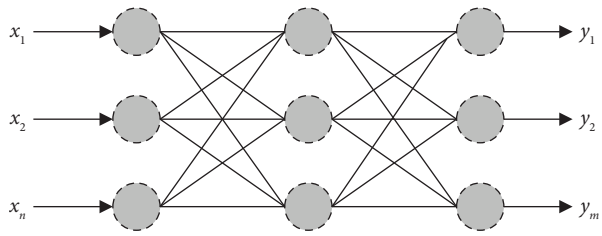

Figure 1: BP structure.

operate, with good generalization ability and strong fault tolerance. Although BP neural network has many advantages, it has some problems. First is random weight threshold for initially training the network. The initial values are all set by the algorithm using random functions. Even if the predefined network training error number is used to validate the output results, it is still possible to slip into a local optimum while the algorithm is running. This causes noticeable discrepancies between the hidden layer's transmission results and the output results, resulting in a considerable disparity between the algorithm's final output results and the predicted outcomes. Second, the algorithm is slow to converge. When the BP network's objective function is somewhat complex, increasing the learning rate of the training network cannot change the fact that the gradient of the error changes very little. As a result, the number of BP network training iterations is too many, and the overall training time becomes longer, and it may take hundreds or thousands of training to achieve the convergence effect. If the learning rate is small, more iterations are required for training, which will cause the training process and convergence time to become longer. If the learning rate is too large, it will cause the training network to diverge, so that the BP network algorithm cannot achieve convergence. Third, the network structure is difficult to build. The number of training network layers and nodes of the BP algorithm directly affects the convergence performance and running time of the algorithm. When the algorithm faces different data, how to build the network structure is particularly important. More and less neurons will produce two different effects. The effect of overfitting can occur if there are too many algorithms. If it is too small, it will directly affect the approximation effect of the algorithm in the training process. In addition, the setting of the network structure is also limited by the hardware device, and the overly complex network structure has very high requirements for the hardware device.

3.2. PSO Algorithm. PSO is an optimization algorithm, which uses Heppner's biological model to analyze, model, and simulate the flock behavior of birds. Its model is similar to most models at the level of group behavior research. It is assumed that all of the birds are in a chaotic flight state from the start, with no objectives and no planned courses. When a bird returns to its habitat, if the set perching threshold is higher than when it continues to accompany the flock, all of the birds will fly to the habitat independently to form another group. Birds use simple laws to decide where they fly and how quickly they fly. When one flies away from the population and returns to its habitat, the others also fly to the habitat. And once the habitat is found, it will not leave, and the entire population will stay here. Birds that first find habitat, and stay, will cause the surrounding population to fly towards their location. This greatly increases the probability that the entire population will find habitat. Such problems are analogous to finding the optimal solution to a particular problem, so Heppner's model was modified so that it could fly into space and find the optimal solution. The basic flow of the PSO algorithm is demonstrated in Figure 2.

The standard PSO algorithm is a global optimization algorithm, which integrates the swarm and optimization principles and optimizes through the fitness value of the particles. The PSO algorithm retains the population-based global search strategy, treating each individual as a particle without weight and volume in an n-dimensional search space. It also flies at a certain speed in the search space. The flight speed is dynamically adjusted by the individual flight experience and the group's flight experience. In each iteration, each particle adjusts its flight speed and position according to the following:

$$\begin{aligned} v_{id}^{t+1} &= wv_{id}^{t} + c_1 r_1 \left(p_{\text{ibest}}^{t} - x_{id}\right) + c_2 r_2 \left(p_{g\text{best}}^{t} - x_{id}\right), \\ x_{id}^{t+1} &= x_{id}^{t} + v_{id}^{t+1}. \end{aligned} \tag{3}$$

The conventional PSO method has delayed convergence, particularly as the number of iterations grows. Second, it is quite easy to become trapped in a local optimum. Finally, a larger learning step will skip the target solution and lose the convergence target.

3.3. IPSO-BP Algorithm. Since the initial weight of the original BP network adopts the method of random assignment, it will cause the algorithm to converge slowly and easily fall into the local extreme value. In order to overcome this defect, this paper firstly improves the inertia weight and position update mechanism of PSO. The optimal solution obtained by the improved PSO algorithm is used as the initial weight of the BP network to construct IPSO-BP. Then, IPSO-BP is used as a prediction model for the evaluation of urban tourism competitiveness.

First, this paper suggests an adaptive inertia weight (AIW). The PSO algorithm's performance is directly tied to the parameter parameters. The inertia weight and two acceleration constants are the primary parameters. The inertia weight is critical in balancing the algorithm's global search capability and local development capability. Many researchers have dynamically changed w using the methods of each A to conform to the principles of nonlinear particle motion. Because the majority of these enhancements are proportional to the number of rounds, there will be flaws. First, the particle's inertia weight is only nonlinearly decreased as the number of repetitions increases. At the beginning of the iteration, the particle inertia weight is the largest, and at the end of the iteration, the particle inertia weight is the smallest. Such a simple change only allows the

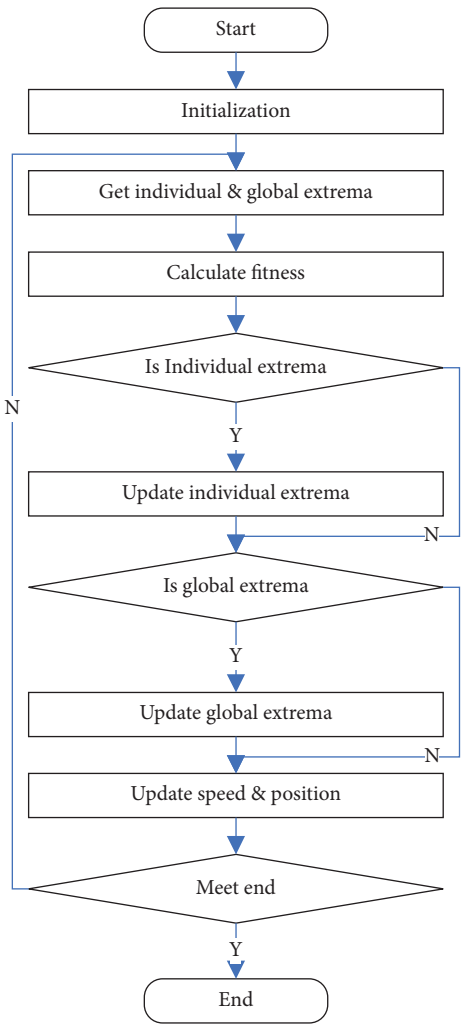

Figure 2: PSO pipeline.

particles to gradually decrease in each iteration and cannot reflect the repeated changes of particles in the iterative process. Second, the inertia weight changes of all particles in an iteration cycle refer to the number of iterations. Then, all particles in the same iteration cycle will only have the same inertia weight. This will reduce the diversity of particles, which is not conducive to particles seeking optimal solutions. In view of the above deficiencies, and combined with the minimization problem, the smaller the particle fitness value, the better the position of the particle. According to the fitness value of particles, this paper proposes an adaptive inertia weight strategy.

$$w = w_{\min} + \frac{(w_{\max} - w_{\min})(\ln f_i - \ln f_{g\text{best}})}{\left[6(\ln \overline{f} - \ln f_{g\text{best}})\right]}. \quad (4)$$

In this improved method, the inertia weight is a nonlinear dynamic change depending on the gap between the particle's fitness value and the optimal fitness value. This firstly overcomes the shortcoming that the inertia weight can only perform decreasing motion only by relying on the number of iterations. The inertia weight can be changed dynamically based on the difference between its own fitness value and the optimal fitness value. Because particles change based on their own fitness values, each particle has its own fitness value. Because of their own fitness values, particles in the same iteration cycle will have different inertia weights. This has a number of implications, including increasing the diversity of particle populations and seeking the best answer as quickly as possible. Simultaneously, the better method avoids the flaw in which the inertia weight of particles is greatest in the early iteration and lowest in the later iteration. This enables some particles with larger fitness values but not in the optimal range in the later iteration to enhance their global search ability through larger inertia weights, to break through their own limitations, and to find the optimal position again.

Second, this work uses the location perturbation factor (LPF). The standard PSO algorithm is often prone to fall into local optimum, and it is difficult to solve this problem effectively by simply relying on the adaptive dynamic inertia weight. This paper proposes to add a disturbance factor to the position update formula, so that the particle can effectively break through the local optimal defect in the update iteration and quickly find the global optimal range.

$$x_{id}^{t+1} = x_{id}^{t} + \left(\ln\left(\frac{t}{t_{\max}} + 1\right) + 1\right) v_{id}^{t+1}. \quad (5)$$

In the typical position update formula, the velocity is multiplied by a disturbance term. This permits the particles created to have a wider spread and to search the global space more thoroughly. Population updates that are only based on adaptive inertia weights appear monotonous. The fitness value and the number of iterations are combined in this paper to update the particles. This can combine the advantages of the interaction between the two, and the particles can update themselves with each iteration and each change of the fitness value. This enables the particles to comprehensively search for the optimal solution in the space and enhances the population diversity of the particles. This more effectively prevents particles from falling into local optima and improves the performance of particle swarms.

The main idea of the IPSO optimization BP network based on position disturbance of logarithmic function and adaptive inertia weight is to use the optimal solution obtained by IPSO as the initial weight and threshold of the BP network. The IPSO-BP is demonstrated in Figure 3.

4. Experiment

4.1. Data Information. This work collects the corresponding data on the tourism competitiveness of smart tourism cities, and the training set and the test set account for half each. The data information of each data sample is demonstrated in Table 1, and its corresponding label is urban tourism competitiveness.

4.2. IPSO-BP Training. First, this work trains the IPSO-BP network, which is an indispensable step. This work analyzes the network training process of IPSO-BP. The main analysis

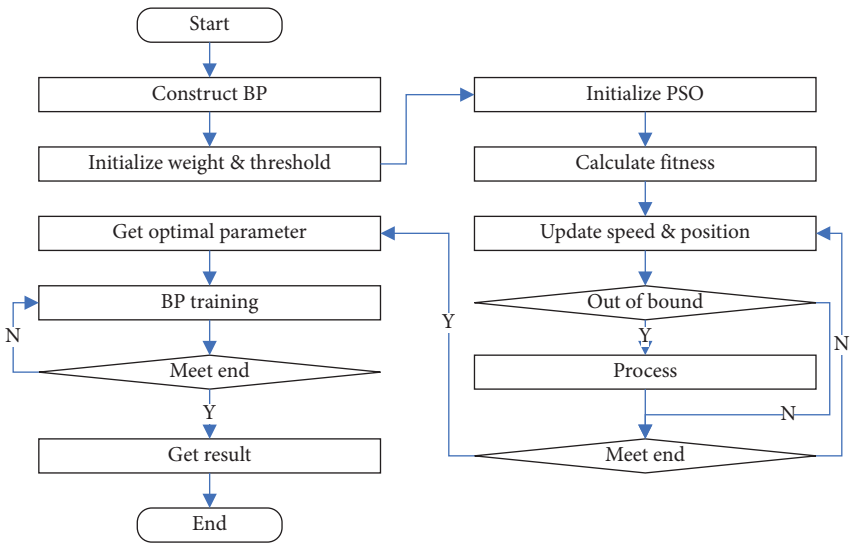

Figure 3: IPSO-BP pipeline.

Table 1: The data information.

Index	Information
x_1	Traffic capacity
x_2	Communication ability
x_3	Degree of openness
x_4	Medical ability
x_5	Economic environment
x_6	Ecosystem
x_7	Social environment
x_8	Demand scale
x_9	Cultural resource

data are the training accuracy and $F1$ score, as demonstrated in Figure 4.

With the increase in training times, the training accuracy and $F1$ score of the IPSO-BP network increased significantly. At this point, IPSO-BP has reached the convergence condition.

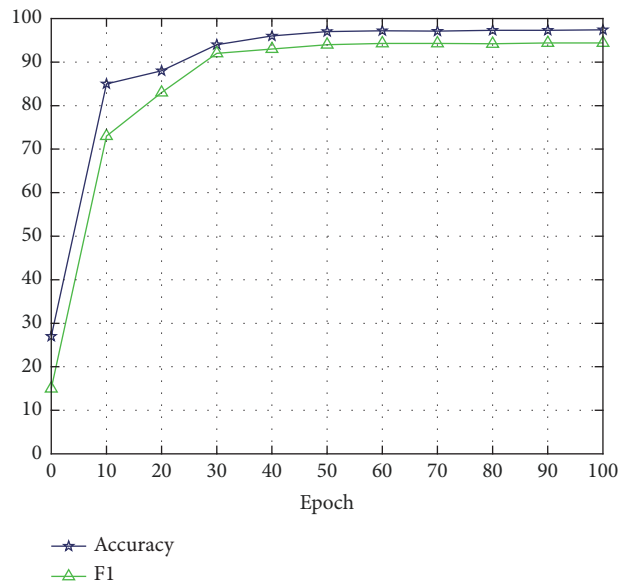

Figure 4: Training performance of IPSO-BP.

4.3. Method Comparison. To verify the superiority of IPSO-BP, this work compares it with other machine-learning algorithms. The experimental results are demonstrated in Figure 5.

In this paper, IPSO-BP outperforms other machine-learning algorithms in terms of evaluation performance. Compared with any other method, IPSO-BP can obtain corresponding performance improvement.

4.4. AIW Evaluation. IPSO-BP uses the AIW strategy. To verify the superiority of this strategy, this work compares the accuracy and $F1$ score without AIW and when AIW is used, as demonstrated in Figure 6.

Compared with the performance without AIW, after using the AIW strategy, IPSO-BP can achieve 1.6% improvement in accuracy rate and 1.70% improvement in $F1$ score.

4.5. LPF Evaluation. IPSO-BP uses the LPF strategy. To verify the superiority of this strategy, this work compares the accuracy and $F1$ score without LPF and when LPF is used, as demonstrated in Figure 7.

Compared with the performance without LPF, after using the LPF strategy, IPSO-BP can achieve 1.4% improvement in accuracy rate and 1.3% improvement in $F1$ score.

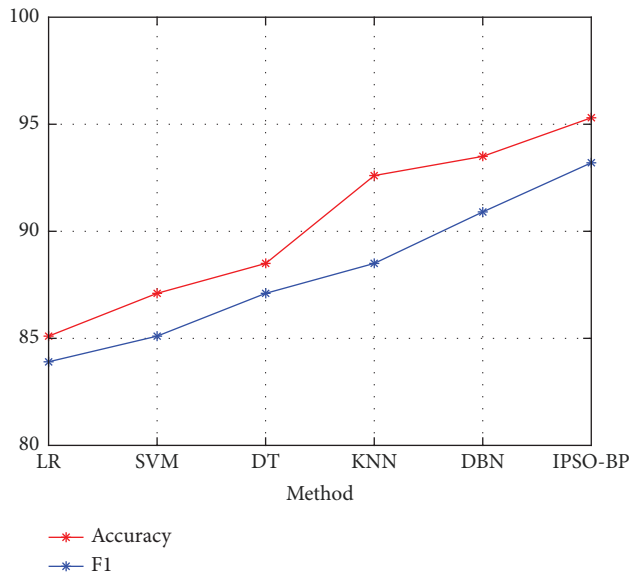

Figure 5: Method comparison.

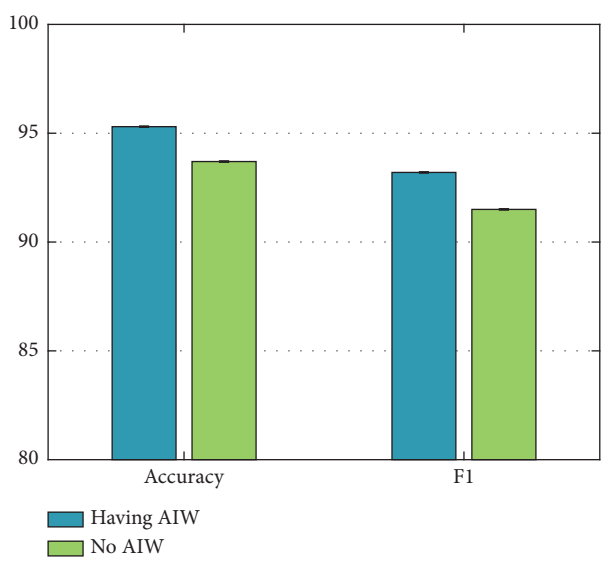

Figure 6: AIW evaluation.

4.6. IPSO Evaluation. This work firstly improves the PSO and then uses the improved IPSO to optimize the BP network. To verify the superiority of this measure, this work compares the performance of BP, PSO-BP, and IPSO-BP networks, respectively, as demonstrated in Table 2.

Clearly, the performance associated with the classic BP network is the weakest. The accuracy and $F1$ score can be enhanced to some level when applying PSO to optimize it. If the PSO is improved and the IPSO is used for the optimization of the BP network, the highest performance can be obtained.

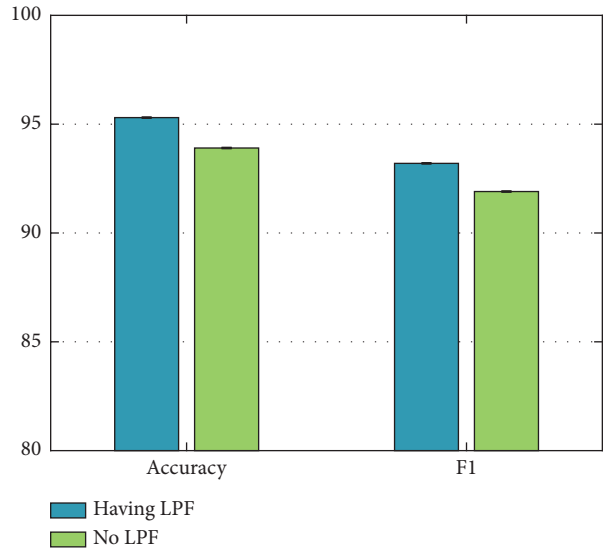

Figure 7: LPF evaluation.

Table 2: IPSO evaluation.

Network	Accuracy	$F1$ score
BP	90.80	89.70
PSO-BP	92.40	91.30
IPSO-BP	95.30	93.20

5. Conclusion

The continuous and in-depth development of information technology in the tourism industry has prompted the birth of the concept of smart tourism. In a smart tourism city, tourists are connected with the network. This enables a deeper understanding of the current tourism economy and related activities, so that tourism plans can be arranged and adjusted in real time and accurately. By perceiving as much travel information as possible, this increases the convenience and experience of travel. Against the backdrop of a thriving economy, the development of urban tourism faces numerous competitions and hurdles. Building a rigorous evaluation system of urban tourist competitiveness to improve urban tourism competitiveness is both theoretical and practical. This work uses a joint PSO and neural network to evaluate urban tourism competitiveness. First, this work proposes an algorithm that utilizes an improved IPSO. It uses the particle fitness value to dynamically and nonlinearly change the inertia weight. Simultaneously, the particle swarm technique is enhanced by combining the particle iterative cycle to boost position disturbance. Second, in order to build an IPSO-BP network, this work optimizes the initial weights and thresholds of the BP network based on IPSO. This paper uses this network to assess the competitiveness of urban tourism, which can compensate for the shortcomings of the standard BP network. Third, this work conducts systematic experiments on the IPSO-BP

method, and the experimental results confirm the superiority of this method in the evaluation of urban tourism competitiveness.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Research on the Prediction of Nonbreakeven Financial Products' Yield of Commercial Banks Based on Machine Learning

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Bank wealth management solutions have now become one of the most important components of the financial industry after nearly two decades of continuous development. However, there are still problems such as an imperfect pricing model and an ambiguous pricing mechanism. In this paper, we use machine learning to predict the yield of nonguaranteed financial products, and after model training and prediction, both the random forest model and the LightGBM model have high applicability; that is, machine learning can be effectively used in the yield forecasting process.

1. Introduction

2018 was a significant turning point for bank wealth management business. With the release of the "New Asset Management Regulations," bank wealth management products have shown a trend of nonguaranteed and net worth in line with policy requirements. Yueqiu and Bo believe that capital-guaranteed wealth management will gradually withdraw from the market and the main task of commercial banks in the future is to actively transform products according to policies and to transparently disclose daily net worth. In fact, nonguaranteed wealth management products are off-balance sheet businesses of banks and can be classified as shadow banking. Due to its high risk and rapid development trend in recent years, shadow banking has attracted great attention from supervisory authorities and scholars [1].

The availability of huge data and the development of a large number of scientific computing tools have fostered the use of machine learning in recent years, as computer science and technology have advanced. Although machine learning has problems, it is still a relatively new topic in asset pricing. However, it is undeniable that in a rapidly changing financial market with a huge amount of data, it is difficult to find the relationship between variables quickly and accurately with traditional forecasting models. Therefore, based on the method of machine learning, we will analyze the rate of return of wealth management products of Chinese commercial banks and predict the rate of return according to its influencing factors.

The rest of the study is organized as follows: Section 2 overviews the background. Section 3 discusses the theoretical analysis of the proposed concepts. Section 4 discusses the model, and in section 5, we explore the training and prediction of the suggested work. Section 6 concludes the article.

2. Background

With the development of bank wealth management products, scholars have begun to pay attention to the influencing variables of product yield. Pelster and Schertler [2] proposed that the most critical impact indicator is the way of capital operation. Acharya et al. [3] made an empirical analysis of wealth management products issued by 25 banks in the past seven years and proposed that the number of wealth management products due this year and the number of new issuance will have an impact on the yield. After empirical model testing, Warne and Sharma [4] determined that investors' investing patterns and investment goals will have a

role, with income being the most important element. Furthermore, freshly produced wealth management products are increasingly popular among investors. Based on the perspective of regulatory policy changes, Na [5] concluded that the introduction of regulatory policies will have a short-term inhibitory effect on the return of wealth management products, and the product term and market interest rate are the decisive factors for the return of wealth management products. Shiyang et al. [6] believe that, on the one hand, commercial banks are subject to strict loan-to-deposit ratio control, and on the other hand, due to their poor ability to absorb deposits, they cannot obtain sufficient funds to expand their business scale and usually need to issue wealth management products as a substitute for deposits. . Therefore, commercial banks with poor deposit-taking ability will tend to formulate higher expected product returns.

Some scholars have also conducted research on the prediction of the yield. Some scholars have also conducted research on the prediction of the rate of return. Ronghua et al. [7] classified financial products according to their risk levels according to the nature of bank financial products and then used a semiparametric model with random effects to construct and analyze the yield curve of financial products. Chunling et al. [8] summarized the research progress on the predictability of capital market returns and found that a machine learning method is a research hotspot in recent years.

Gan et al. [9] suggested a deep learning-based strategy for option pricing that can produce more accurate results at a faster rate. Li et al. [10] generated the stock technical index value using the stock's daily frequency price and trading volume data and then utilized the derived technical index value as an input variable to anticipate the stock price rise or decline in a few days. Pan et al. [11] used neural networks to predict the stock return rate to capture the nonlinear relationship between the three factors of the market portfolio return rate, book-to-market value ratio, and market value. Chen [12] conducted a series of studies on the pricing of catastrophe bond risk spreads and compared the effects of machine learning models and traditional regression models.

Furthermore, machine learning can be applied in fields such as risk prediction. Fang and Luo [13] built a risk indicator alarm mechanism using the random forest algorithm to separate the risk alarm indicator variables into two categories: enterprise characteristics and business conduct.

Some scholars have also compared the application of various algorithms. Breiman [14] believes that the random forest algorithm has obvious superiority. Due to the theorem of large numbers, using this algorithm will not overfit the model. Kampichler et al. [15] compared the practical results of five machine learning algorithms: decision tree, random forest, artificial neural network, support vector machine, and rule-based fuzzy model and finally proposed that the prediction effect of the random forest is the best.

3. Theoretical Analysis

The yield of wealth management products should be impacted heavily by the nature of the product itself. The longer the money is invested, the greater the uncertainty investors bear and the higher the liquidity risk they face. In addition, the risk effect and the threshold effect will also have an impact on the time value of capital, capital liquidity, and investment risk of investment, which are reflected in the product's yield.

There are also some variations between banks. State-owned commercial banks are controlled directly by state-owned capital and are subject to greater regulation. Although wealth management-issued products are not legally guaranteed, they are actually implicitly guaranteed by state credit to investors, and banks will be more cautious when pricing assets.

In addition, smaller banks often need to broaden their funding sources to expand their business scale. The release of wealth management products in asset management business is a form. Therefore, in order to improve operational efficiency and also to absorb funds, formulating higher yields may become a way for commercial banks to increase the scale of wealth management business.

Macroeconomic changes can have a large and far-reaching impact on the financial industry. The position in other marketplaces should also be considered. The interbank market position represents the liquidity of funds in the interbank market and, thus, indirectly reflects the bank's funding channels. In addition, a considerable part of funds raised after the issuance of wealth management products will actually be invested in the fund pool for operation and management, and part of the fund pool involves the stock market.

Therefore, we discuss the independent variables that affect the yield of wealth management products from four aspects: issuing banks, product design, macroeconomics, and other markets. The variables are shown in Table 1.

4. Model

4.1. Multiple Linear Regression Model. The multiple linear regression model is usually used to study the relationship between a dependent variable and multiple independent variables, which is represented by a matrix.

We first use the multiple linear regression model to make regression predictions on the two sample sets and set up model 1 based on the analysis of influencing factors:

$$\begin{aligned}\text{rate\_max}_i = {} & \alpha + \beta_1\text{period}_i + \beta_2\text{risk}_i + \beta_3\text{threshold}_i \\ & + \beta_4\text{bank}_i + \beta_5\text{size}_i + \beta_6\text{quantity}_i + \beta_7 cr_i \\ & + \beta_8 lr_i + \beta_9 l\,d_i + \beta_{10} pc_i + \beta_{11} g\,dp_i + \beta_{12} m2_i \\ & + \beta_{13} cpi_i + \beta_{14}\text{fintech}_i + \beta_{15}\text{shi}_i + \beta_{16}\text{price}_i.\end{aligned} \tag{1}$$

Model 2 is as follows:

$$\begin{aligned}\text{rate\_min}_i = {} & \alpha + \beta_1\text{period}_i + \beta_2\text{risk}_i + \beta_3\text{threshold}_i \\ & + \beta_4\text{bank}_i + \beta_5\text{size}_i + \beta_6\text{quantity}_i + \beta_7 cr_i \\ & + \beta_8 lr_i + \beta_9 l\,d_i + \beta_{10} pc_i + \beta_{11} g\,dp_i + \beta_{12} m2_i \\ & + \beta_{13} cpi_i + \beta_{14}\text{fintech}_i + \beta_{15} shi_i + \beta_{16}\text{price}_i.\end{aligned} \tag{2}$$

Table 1: Independent variables.

Variable	Feature
Length of the commission period	Period
Risk	Risk
Threshold	Threshold
Bank nature	Bank
Asset size	Size
Number of wealth management products issued in the previous year	Quantity
Capital adequacy ratio	Cr
Deposit ratio	Ld
Liquidity ratio	Lr
Provision coverage	Pc
Gross national product	GDP
Broad money supply	m2
National consumption	CPI
Fintech index	Fintech
Interbank market	Shi
Stock market	Price

Table 2: The parameters of the random forest model.

Parameters	Descriptions and settings
n_estimators	The number of classifiers, also called the number of iterations, is the number of decision trees in the forest
Criterion	The standard used for splitting nodes, the default is gini
Max_depth	Maximum depth of trees
Min_samples_split	Minimum number of samples required to split a node inside the tree, defaults to 2
Min_samples_leaf	Minimum number of samples required at leaf nodes, defaults to 1
Min_weight_fraction_leaf	Minimum weighted score in the sum of weights at all leaf nodes, defaults to 0
Max_features	The number of features to consider when finding the best segmentation, the default is none; that is, all features are considered
Max_leaf_nodes	The maximum number of leaf nodes, which must be an integer, the default is none
Min_impurity_decrease	If the decrement of the split index is greater than this value, then split, default is 0
Bootstrap	Whether there is a randomly selected sample to put back, the default is true
Oob_score	Whether to use out-of-bag samples to evaluate the quality of the model, set to true
N_jobs	The number of parallel calculations, the default is none
Random_state	Controls the randomness of bootstrap and randomness of the selected samples. In order to facilitate the adjustment of other parameters, this parameter adopts the default value
Verbose	Controls verbosity when fitting and predicting, default is 0
Warm_start	Whether to use the trained model and add more base learners to it, set to false

4.2. Random Forest Model. The random forest model is constructed based on the bagging ensemble learning method, so the process of training and constructing the random forest model basically follows the basic process of bagging ensemble learning. Specifically, for a data set D containing k samples, we first perform k random self-sampling on D, collect k training sample subsets D1, D2,. . ., Dk, and then select D1, D2,. . ., Dk to trainand construct$k$ decision trees, then we can combine these decision trees to obtain a random forest model.

Table 2 shows the names, descriptions, and settings of important parameters in the random forest model.

4.3. LightGBM Model. The LightGBM model is partially optimized on the traditional boosting algorithm. Since the traditional boosting algorithm needs to scan all the sample points for each feature to select the best segmentation point, it is very time consuming, while the LightGBM algorithm is based on the histogram. The decision tree algorithm greatly reduces the time complexity. The histogram algorithm first performs binning processing on the eigenvalues. For continuous features, binning processing is to discretize continuous data, and then, there is no need to scan each feature as in the traditional algorithm but only need to press the bins that are scanned, which speeds up training.

Table 3 shows the names, descriptions, and settings of important parameters in the LightGBM model.

5. Training and Prediction

5.1. Data. We collected 201,572 nonguaranteed wealth management products issued by 20 commercial banks (five each of state-owned commercial banks, joint-stock commercial banks, city commercial banks, and agricultural commercial banks) from January 2017 to December 2020. The dependent variable is the upper and lower bounds of the yield set at the time of issuance.

Table 3: The parameter of the random forest model.

Parameters	Descriptions and settings
Task	Train
Objective	Model training target, which can be selected as a regression model or binary classification model
Boosing_type	Base learner, for gbdt
Metric	Metrics as a function of evaluating the optimal model
Leaning_rate	Learning rate, the default is 0.1, the smaller the value, the more accurate the learning
n_estimators	The number of iterations in the classifier
Num_leaves	The number of leaves in the tree, the indicator should be less than 2 to the power of max_depth
Max_depth	Tree depth
Feature_fraction	The feature sampling ratio for building the tree, which ranges from 0 to 1
Bagging_fraction	The sample sampling ratio for building the tree, the data range is 0 to 1
Max_bin	The maximum bin value, generally equal to the number of features
Min_data_in_leaf	The minimum number of samples for each leaf node, when the leaf node is smaller than this value, the tree will no longer be split
Min_gain_to_split	The tree stops splitting when the leaf node is smaller than this value

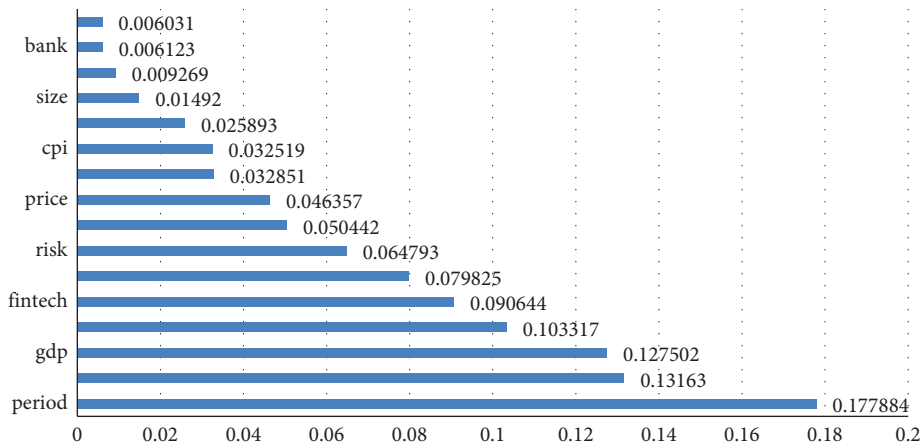

Figure 1: Eigenvalue importance of yield cap samples.

At the same time, we collected data such as the minimum purchase threshold amount and the period set in the product description, as well as the asset size of the issuing bank, the number of wealth management products issued, and the nature of the bank. The sample banks were chosen based on their issuance size in recent years, and the data are all obtained from the wind database. In addition, we have gathered the Shibor Index, Fintech Index, and Consumer Price Index in terms of macroeconomic operation. Because of the short publishing cycle, GDP and m2 only have annual data. At the same time, since the 20 banks in the sample are all listed banks, the closing price is taken as one of the factors to be considered in other markets.

We take the capped expected yield and the floored expected yield of the financial products in the sample as dependent variables, named rate_max and rate_min.

After data preprocessing, we divide samples after removing missing values and extreme values into the training set and the test set. The divided test set ratio is set to 0.2, and the division standard is randomly divided by using software.

5.2. Importance of Features. The random forest algorithm can measure the relative importance of each feature value for prediction, that is, the average contribution of each feature to each tree in the random forest model. An evaluation index is used to calculate the mistake rate. The difference value of out-of-bag data is calculated by randomly adding noise interference to a feature value. We utilize the random forest approach to examine and rank the importance of the sixteen eigenvalues in the sample after processing characteristics one by one, as shown in Figures 1 and 2.

According to the eigenvalue importance ranking results output by the machine learning algorithm, in both samples, the period of entrust is the most important eigenvalue, and the importance of risks and thresholds are also in the upstream position. It can be seen that the design of the wealth management product has a crucial impact on the progress of predicting.

However, whether or not it is a state-owned bank has little bearing. In the two samples, bank assets and the number of issuances in the preceding year have diametrically opposed importance and influence.

Among the macroeconomic operating variables, the gross national product and m2 in the two sample sets are both factors that will have a greater impact on the expected yield.

For other markets, the stock market affects yields more than the interbank market. On the one hand, the stock

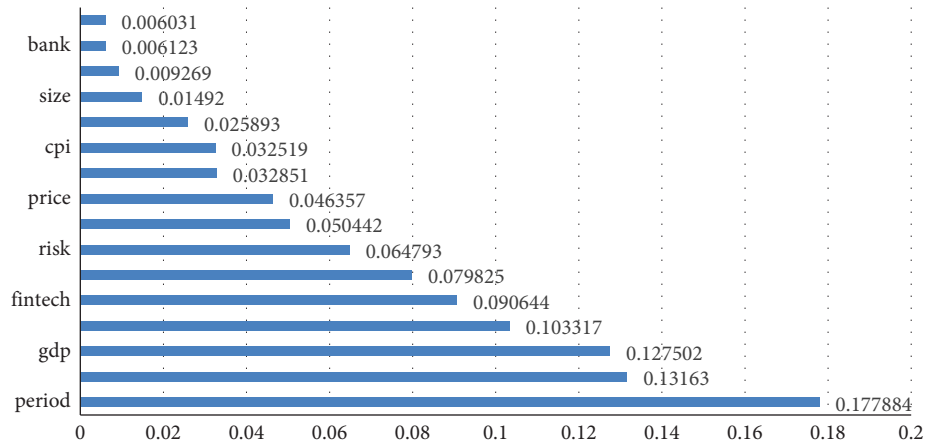

Figure 2: Eigenvalue importance of yield floor samples.

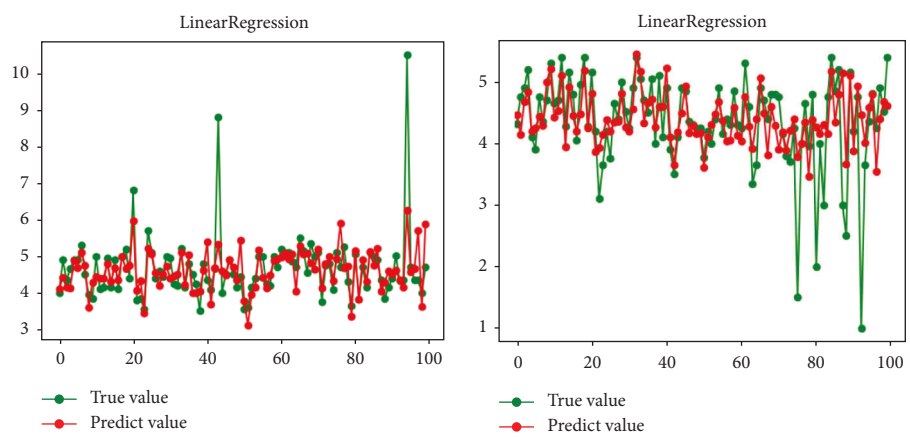

Figure 3: The result of the multiple linear regression model.

market situation of listed commercial banks represents the bank's reputation and the investor's confidence, and on the other hand, the funds obtained by banks through the issuance of wealth management products will also enter the stock market.

5.3. Prediction. The prediction results of the multiple linear regression model are shown in Figure 3. Due to the large sample size, only the results of 100 pieces of data are shown in the graph. The horizontal axis is the serial number of the test set, the vertical axis is the expected return value, and the two lines are the true value and the predicted value obtained by the multiple linear regression model. It can be seen from Figure 3 that the two lines do not fit, and the prediction made by the multiple linear regression model does not coincide with the real value.

We use the mean absolute error (MAE) index, root mean square error (RMSE) index, and R-square to score and analyze the model regression results.

The mean absolute error is used to measure the mean absolute error between the predicted value and the true value. The smaller the MAE, the better the model. It is defined as follows:

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|y_i - y_i^*\right|. \tag{3}$$

The root mean square error is also used to indicate the error that the model will produce in prediction. The smaller the indicator is, the better the model is. It is defined as follows:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(y_i - y_i^*\right)^2}. \tag{4}$$

R-square represents the fit of the model. The closer the value to 1, the better the model. It is defined as follows:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(y_i - y_i^*\right)^2}{\sum_{i=1}^{n}\left(y_i - \overline{y_i}\right)^2}. \tag{5}$$

In the random forest, n_estimators is the maximum number of iterations of the weak learners of the random forest model, also known as the maximum number of weak learners in the random forest. We set the range of this parameter from 1 to 200, and other parameters are temporarily set to default values; then, we use the grid search command to adjust the parameters for the upper and lower limits of the expected rate of return of sample financial products.

Table 4: Random forest model-adjusted parameter results.

Parameters	Yield cap samples	Yield floor samples
n_estimators	120	110
Max_depth	51	50

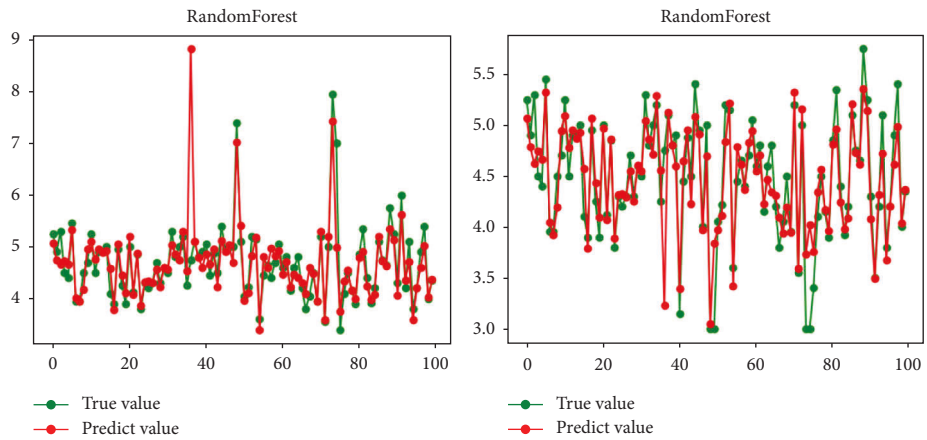

Figure 4: The result of the random Forest model.

Table 5: LightGBM model-adjusted parameter results.

Parameter	Yield cap samples	Yield floor samples
n_estimators	57	90
Max_depth	32	79

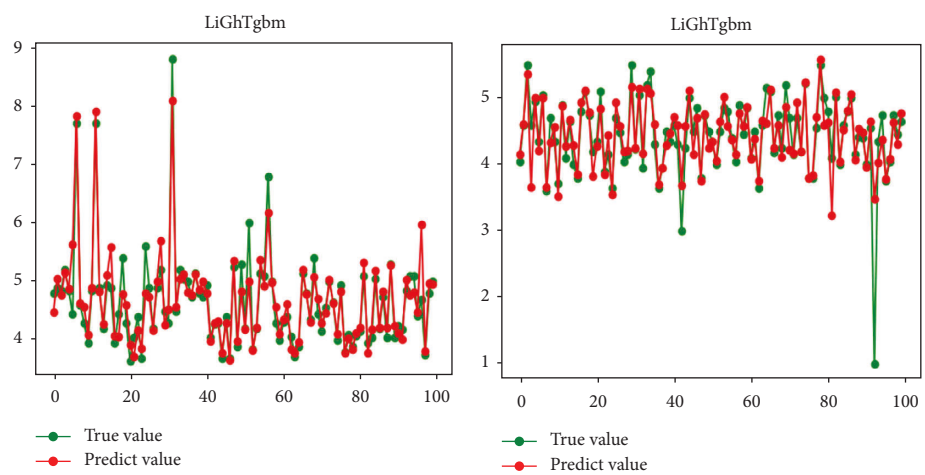

Figure 5: The result of the random forest model.

In the random forest model, max depth is the maximum depth of the tree. If it is not altered, the default value is none, which means that the decision tree will not limit the depth of the subtree when it is built. When the sample size is small, this parameter will not have an excessive impact on the regression process. Our sample size is relatively large, so we adjust the maximum depth parameter for the two sample sets, respectively, and set the max_depth parameter range from 1 to 100. After adjustment, the results of the parameters are shown in Table 4.

After applying the adjusted parameters to the regression prediction model, the specific prediction results are shown in Figure 4, and only 100 results are displayed. It can be seen from Figure 4 that although some points of the two discounts do not overlap, the trends are basically the same.

We used the grid search approach to optimise the parameters of the LightGBM model as we did for the random forest model and continuously changed the interval and step size until we achieved the ideal parameter values, which are displayed in Table 5. Among them, Num_leaves is the

Table 6: The comparison between three models.

	Yield cap samples		
	Multiple linear regression	Random forest	LightGBM
MAE	0.24	0.23	0.21
RMSE	0.28	0.23	0.26
R2	0.39	0.46	0.67
	Yield floor samples		
	Multiple linear regression	Random forest	LightGBM
MAE	0.27	0.18	0.17
RMSE	0.30	0.18	0.20
R2	0.51	0.72	0.81

number of leaves in each tree, and this parameter has an important influence on the complexity of the model tree.

We apply the optimized parameters to the regression model to obtain the prediction result graph. Due to the large sample size, only 100 results are shown in the graph. As shown in Figure 5, the two polylines have a high degree of fit and have the same trend.

5.4. Comparison. To forecast the upper and lower bounds of the predicted return rate of the financial products in this sample, we utilize the multiple linear regression approach, random forest, and LightGBM model, respectively. The comparison results of MAE, RMSE, and R-square values of each model are shown in Table 6.

The MAE and RMSE indicators in the cap sample of the multiple linear regression model are 0.24 and 0.28, respectively and in the floor sample, they are 0.27 and 0.30, respectively, all of which show high errors. However, the error values of the random forest model and the LightGBM model are not much different, and they neither exceed 0.26 in the upper sample set nor 0.20 in the lower sample set.

R-square is a fitness index. In the cap sample set, the R-square of the three models are 0.67, 0.46, and 0.39, respectively. In the floor sample set, they are 0.51, 0.72, and 0.81, respectively. It can be seen that the fitting degree of the LightGBM regression model is the best, followed by the random forest model, and finally the multiple regression model. The prediction efficiency of the multiple linear regression model and the other two models is quite different.

6. Conclusion

We use the multiple linear regression model, random forest, and LightGBM in ensemble learning to predict the yield of the nonguaranteed wealth management products issued by twenty commercial banks in the past four years.

The empirical research on forecasting is typically separated into two components, and the first of which is an examination of eigenvalue importance ranking. Then, based on the importance of the eigenvalues of the two sample sets, we built a machine learning model and made value predictions for returns. Regardless of the sample set, the fitting degree of the LightGBM regression model is the best, followed by the random forest model, and finally the multiple regression model.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Design of Precise Estimation Algorithm for Sports Pose Based on Multifeature Fusion

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The estimation time and estimation precision of motion pose samples are problematic for the pose estimation algorithm of sports movements. This paper proposes a multifeature fusion-based algorithm for accurate posture estimation. The human rod model is constructed after analyzing the human pose estimation technology. Using the Kalman filter method, the degree of freedom and range of motion of the major joints of the human body were determined. The eight-star model was used to extract the sports posture features, and the weighted average method was used to process the grayscale images of sports. Using the multifeature fusion method, the extracted multisource feature vector information is thoroughly analyzed and processed, and a new group of fusion feature vectors is created. Using a mixture Gaussian distribution model, the posture estimation of an athlete's body is accomplished. Experimental results indicate that when the amount of sports pose sample data is 900 GB, the accurate estimation time of the proposed method is 5.3 s, and its accuracy is 100 percent. Improve the estimation accuracy of samples of sports posture.

1. Introduction

With the advancement of society and the improvement of living standards, people are beginning to pay more attention to physical health and other aspects and are constantly improving their physical quality through sports. In the process of movement, standard movement posture can not only determine the effect of movement to a certain extent but also provide the greatest possible protection against injury [1]. In badminton, for instance, the use of standard badminton movements for daily exercise can not only effectively exercise the body but also improve a player's level of competition [2]. However, the definition of standard motor posture during movement is primarily based on images or verbal instruction, resulting in the absence of quantitative evaluation criteria for standard motor posture. Nevertheless, the estimation of human pose and recognition of human motion from the collected image or video sequence provide a theoretical foundation for measuring standard motion pose. Early human action recognition requires external equipment to perceive the change in human posture in order to recognize human action. With the development of machine learning and deep learning, there are numerous research directions in the academic field, including image processing, SVM classifier, and deep neural network [3]. These advancements have made it possible for computers to detect human motion using only devices like cameras, thereby drastically reducing the number of external perceptrons.

Human pose estimation is the most critical technology in the process of sports pose recognition. In order to guide people's posture during the movement process, a series of features derived from human pose estimation are compared with some standard actions. Consequently, the human motion assessment system has evolved significantly. Simultaneously, people's focus is gradually shifting from the professional type to the portable type: a portable human motion assessment system that is unaffected by location and environment can enhance the quality of people's daily exercise. Human pose recognition has garnered the interest of numerous domestic and international research institutes and university-level laboratories [4] due to its high theoretical value and vast application potential. A number of

algorithms for human pose recognition and related specific problems have been proposed domestically and internationally. In addition, advances have been made in the areas of human object recognition, keyframe extraction, human pose estimation, and other specialized issues. The traditional human gesture recognition technology has low recognition rate, high difficulty, high cost, slow speed, and large storage space for human behavior recognition, which is not the requirement for the application of human-computer interaction technology in the future. Combining the keyframe selection technique with the human pose estimation technique drastically reduces computation and saves storage space. In recent years, the research status of human pose estimation at home and abroad is summarized as follows [5].

The authors of [6] proposed a 3D human pose estimation method based on semisupervised learning convolutional neural network, collected video data containing motion pose, built a semisupervised learning convolutional neural network model, and estimated the corresponding 3D pose skeleton changing pose. This method can accurately estimate the 3D pose of the corresponding frame in a video, but sports pose estimation efficiency is low. The method proposed by the authors of [7] for acquiring specific motion frames in motion videos is based on human pose estimation and clustering. Select the HRNet pose estimation model as the basis, establish the model lightweight process and combine with the DARK data encoding, construct the Small-HRNet network model, extract from the video human body joint points, and use the human skeleton features of each frame of video as sample points. The standard skeleton feature of the motion frame is the cluster center, which clusters the entire video. The video's specific motion frame is obtained through clustering, and the experiment is conducted on the motion dataset. This method can reduce the number of body pose estimation model parameters while maintaining accuracy, but the classification effect of the proposed method is inadequate. A human pose estimation optimization algorithm for deformable models is proposed with reference to [8]. The model parameters are extracted from each frame of a color image by a neural network, and the parameters are optimized and solved using human key points and contour as constraints. According to the interframe coherence of the video sequence, the error of the pose estimation results of all video frames is then corrected, making the motion sequence more fluid and smooth. The point cloud obtained from the depth map and the corresponding color map model were used as the joint input, followed by the use of the distance constraint between the point cloud and the corresponding point of the model to optimize and solve the problem. Eventually, a result resembling the actual human pose was achieved. Using point cloud data optimization, the algorithm can effectively correct the single-frame pose estimation results and greatly improve its accuracy. Nonetheless, the accuracy of posture estimation in sports is poor.

This paper proposes an accurate estimation algorithm for sports pose based on the fusion of multiple features.

2. Acquisition of Sports Posture Features

2.1. Human Pose Estimation Techniques. According to the Oxford Dictionary, a posture is a particular posture of the body, and the way a person maintains his or her body. The human pose estimation method is to extract, classify, distinguish, and describe the pose features of the human body, which has been widely paid attention to in recent years. The application of human physiology, digital image processing, pattern recognition, and other disciplines is an interdisciplinary research field [9]. From the perspective of the collection method of human pose information, human pose estimation technology can be divided into two categories: contact recognition and noncontact recognition [10]. According to different classification criteria, it can be divided into a variety of human pose recognition algorithms. From the perspective of implementation methods, it is usually divided into three types: 3D model reconstruction method, which extracts 3D features from effective samples to construct 3D models, human appearance model method, by obtaining the shape features of the human body to establish a two-dimensional model and use the model matching method to complete the recognition, motion model method, according to the motion characteristics of the classification. From the perspective of pattern recognition, attitude recognition is a problem of classifying time-varying features, that is, matching the test sequence with the preset sequence according to the obtained feature information.

2.2. Construction of Human Rod Model. According to the knowledge of human anatomy, there are more than 200 bones in the human body, and the bones are connected by joints, which makes the whole system extremely complex, and the actual data acquisition is very complicated. Due to the particularity of the acquisition unit used in this system, we could not collect all the data for each bone [11].

At present, most of the studies on the human body are simplified modeling and analysis with the rod model; that is, the main joint of the human body is abstracted into a point, and the limbs between the joints are abstracted into a link, mainly considering elbow, shoulder, hip, hip, knee, ankle, and other joints. In this way, the whole human body is simplified into a rod-like model, which is also the premise for the analysis of human posture, as shown in Figure 1.

After the simplified rod human body model has been established, the range of motion of each joint must be constrained in order to bring the model closer to the normal human posture. In rehabilitation medicine, the initial posture of human movement is defined as follows: the body is upright and facing forward, the eyes are flat, the feet are standing together, the toes are pointing forward, the upper limbs are hanging at the side of the body, and the palm is attached to the outer thigh of the side of the body. The joint has three components: the articular surface, the articular capsule, and the articular cavity [12]. The shape and structure of the articular surface determine the axis of joint activity, and the freedom of joint movement is closely associated with the movement around the axis. There are

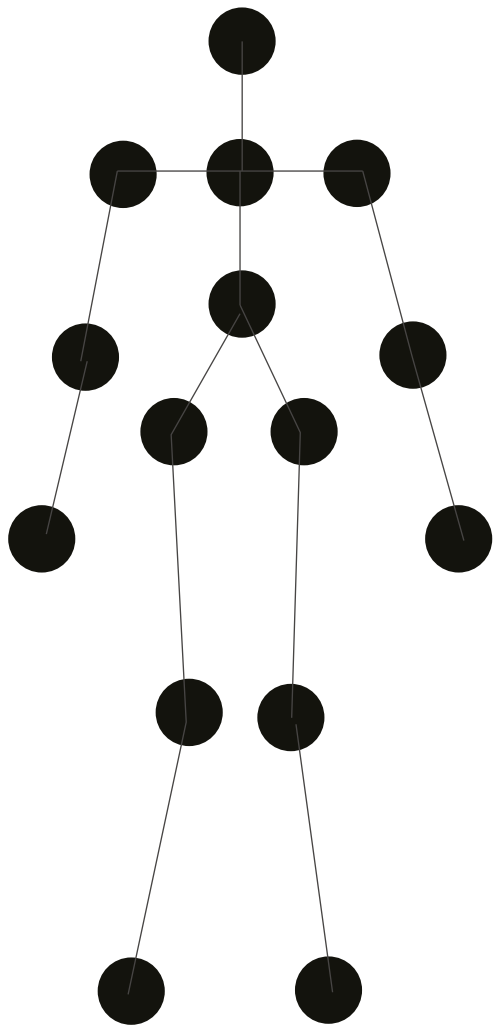

Figure 1: Schematic diagram of rod mannequin.

several degrees of freedom if there are multiple directions of joint activity. All joints with more than two degrees of freedom are capable of producing circumferential motion, and the limb typically rotates about the joint axis. The degrees of freedom and motion range of each major human joint are as follows:

(1) Shoulder joint: there are three degrees of freedom, and the upper arm sags in a neutral position. Its range of motion is forward flexion: 70~90°, posterior extension: 40~45°, forward flexion: 150~170°, upward lift: 160~180°, abduction: 80~90°, adduction: 20~40°, internal rotation: 70~90°, external rotation: 40~50°.

(2) Elbow joint: there is one degree of freedom. The neutral position of the elbow joint is forearm extension. Flexion: 135~150°, overextension: 10°, pronation: 80~90°, supination: 80~90°.

(3) Wrist joint: there are two degrees of freedom. The neutral position is the hand in line with the forearm, and the palm is downward. Dorsal extension: 80~90°, palmar flexion: 50~60°, radial tilt: 25~30°, ulnar tilt: 30~40°.

(4) Hip joint: there are three degrees of freedom. The neutral position is hip joint extension and patella forward. Flexion can reach 130~140°, posterior extension can reach 10~15°, abduction can reach 30~45°, adduction can reach 20~30°, knee flexion 90°, normal external rotation 30~40°, internal rotation 40~50°.

(5) Knee joint: there are two degrees of freedom. The neutral position is knee joint extension, flexion: 120~150°, hyperextension: 5~10°, internal rotation about 10°, and external rotation: 20° when bending the knee.

(6) Ankle joint: there are two degrees of freedom. The neutral position is a 90 degree Angle between the foot and the calf, without varus or valgus. Dorsiflexion is about 20~30°, plantar flexion is about 40~50°, varus is 30°, and valgus is 30~35°.

In this paper, attitude solution refers to the use of existing nine-axis sensor data and relevant theories and algorithms to get attitude Angle information from these data. Attitude solving algorithm belongs to the category of data fusion, that is, attitude solving by fusing multiple sensor data [13]. The commonly used algorithms for attitude resolution include Kalman filter, extended Kalman filter, complementary filter, and gradient descent algorithm.

The model-based linear minimum variance estimation of Kalman filter is a very widely used attitude calculation algorithm. As an important optimal estimation theory, it is widely used in various fields such as automatic control and aerospace [14]. Since discrete Kalman filter algorithm can be directly implemented on computer to estimate multidimensional stochastic processes, it will be introduced in the following.

Let the system noise sequence W_{k-1} act on the estimated state X_k at time t_k and can be described as follows:

$$X_k = \Phi_{k,k-1} X_{k-1} + \Gamma_{k-1} W_{k-1}. \tag{1}$$

The measurement equation is a linear function, as shown in the following equation:

$$Z_k = H_k X_k + V_k, \tag{2}$$

where $\Phi_{k,k-1}$is the one-step state transition matrix from time t_{k-1} to time t_k, Γ_{k-1} is the system noise control matrix, H_k is the observation matrix, V_k is the measurement noise sequence, and w_k is the disturbance noise vector of the system [15].

Assuming that the system noise variance matrix Q_k is nonnegative definite and the observation noise variance matrix R_k is positive definite, the estimator can be solved in the following way:

Single-step state prediction equation is as follows:

$$x'_{k.k-1} = \Phi_{k,k-1} X'_{k-1}. \tag{3}$$

State estimation equation is as follows:

$$x_k' = x_{k.k-1}' + K_k\left[Z_k - H_k X_{k,k-1}'\right]. \quad (4)$$

Mean square error estimation matrix is as follows:

$$P_k = [I - K_k H_k] P_{k,k-1}, \quad (5)$$

where the initial values P_0 and x_0' need to be given in advance, so that the state estimate x_k' at time k can be obtained from the measurement equation Z_k at time k recursively.

2.3. Attitude Feature Extraction Based on Eight-Star Model. The image of the human object is a two-dimensional array. The extracted features of the human object are transformed into a one-dimensional feature vector, which greatly reduces the feature vector's dimension and computational complexity. This article focuses on walking, running, and jumping in three postures for feature extraction and recognition, through the analysis of three kinds of attitude, and the legs move in arm swinging amplitude, arising in the process of adopting the star model to the human body modeling, namely through the calculation of center of mass of human movement target image points and local contour pole and its mutual relations, in order to obtain the attitude. In this paper, an eight-star model is utilized to extract a set of feature vectors containing seventeen feature values to characterize the human pose in each frame [16]. Compared to the six-star model, it can describe the human body's contours, including the head and limbs, more precisely, and it is not redundant.

Eight-star model is an improvement of the traditional star model, which is a feature description model formed according to the eight local contour poles and centroid points of the human object. The human pose model is established as shown in the following equation:

$$Fet = \{D, A, e\}, \quad (6)$$

where D is the distance between the eight local contour poles of the eight-star model and the centroid of the human target. A is the minimum Angle formed by the straight line and horizontal line from the eight local contour poles to the centroid point of the eight-star model; e is the eccentricity of the human target. The specific feature extraction process is as follows:

Calculate the centroid of human object (x_c, y_c):

$$x_c = \frac{1}{N_b}\sum_{i=1}^{N_b} x_i,\ y_c = \frac{1}{N_b}\sum_{i=1}^{N_b} y_i, \quad (7)$$

where N_b is the number of target pixels.

The target is divided into four parts by horizontal lines and vertical lines passing through the center of mass. Based on the overall contour of the target, eight local contour pole coordinates (x_i, y_i) of the rightmost, uppermost, leftmost, and bottommost contour in each part are extracted, respectively.

The Euclidean distances between the eight local contour poles (x_i, y_i) and the centroid point (x_c, y_c) are calculated, which are, respectively, expressed as d_i, and the calculation formula is shown in the following equation:

$$d_i = \sqrt{(x_i - x_c)^2 + (y_i - y_c)^2}, i = 1, 2, \cdots, 8. \quad (8)$$

Then, $D = [d_1, d_2, \cdots, d_8]$. The extraction process is shown in Figure 2.

After feature extraction and fusion, the feature vector of the human pose in the video at frame t is shown in the following equation:

$$Fet_t = \{d_1, d_2, \cdots, d_8, a_8, e\}. \quad (9)$$

The feature vector is a 17-dimensional feature vector constructed from the local contour pole distance feature, local contour pole Angle feature, and eccentricity feature of the human eight-star model, where d_i is the pole distance feature of the eight-star local contour, a_i is the Angle feature of the human local contour pole, and e is the eccentricity of the human body. The computation complexity and memory of the gesture description operator are relatively low, so the system can achieve a good real-time recognition effect.

In practice, the video image will contain some noise and affect the effect of detection and recognition. Therefore, the primary task of video image processing is image preprocessing, and its effect directly affects the subsequent detection and recognition.

2.4. Sports Color Image Grayscale. The color value of the true color image pixel is composed of three components: red R, green G, and blue B. The value of each component has 256 levels of brightness, which is represented by numbers from 0 to 255. Therefore, there are 224 colors, which is relatively complicated to process directly. The gray image is a special color image, whose R, G, and B components are all equal, so there are only 28 colors left, which is convenient for image processing [17]. Therefore, in order to realize the real-time performance of the algorithm, the original image is converted into gray image before the video image processing, so as to reduce the computation amount of the algorithm. In general, the gray-level methods used include component method, maximum method, average method, and weighted average method.

In the component method, one of the three components of RGB is used as the gray value of the pixel, as shown in the following equation:

$$I = R \quad \text{or} \quad I = G \quad \text{or} \quad I = B, \quad (10)$$

where I represents the pixel brightness of gray image, and R, G, and B, respectively, represent the brightness values of RGB components. A gray image can be selected according to the application needs. Taking the 7th frame of LENA_-WALK1 video, the 10th frame of PETS2006 video set, and the 21st frame of test video set in Weizmann database as examples, the grayscale is realized by component method.

The above method is simple to implement but lacks consideration of the importance of different components. According to the importance of components and other needs of images, the weighted average of RGB three

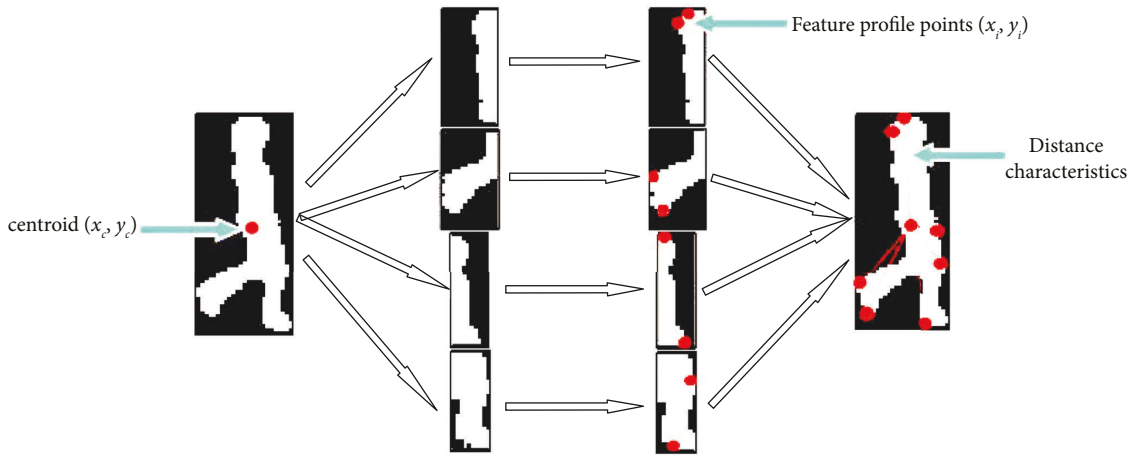

Figure 2: Feature extraction process of pole distance of local contour of human eight-star model.

components can be taken as the gray value of pixels [18]. From the perspective of human physiology, the human eye is sensitive to green and insensitive to blue. Therefore, according to the visual model of human eyes, the weight of G component is set to be large, while the weight of B component is small, and its commonly used formula is shown in the following equation:

$$I = 0.3R + 0.5G + 0.11B. \tag{11}$$

The gray weights adopted by OpenCV open source computer vision library also follow the visual model of human eyes, and the weighted average formula is shown in the following equation:

$$I = 0.212671R + 0.715160G + 0.72169B. \tag{12}$$

From the perspective of theory and practice, the weighted average method is more reasonable and more in line with the needs of practical application, so the weighted average method is the most commonly used method of image graying. In this paper, the weighted average method is used to gray-scale the image [19], and the cvCvtColor function in the OpenCV computer vision open source library is used to complete the gray-scale of the image by setting its third parameter as CV_BGR2GRAY. Or using cvLoadImage function, by setting its second parameter to 0 can realize the color image gray.

3. An Accurate Estimation Algorithm for Sports Posture

3.1. Median Filtering Method for Posture Image Processing. In this method, the arithmetic mean or median of the pixels of the same coordinate in the continuous image frame is taken as the pixel value of the point in the background model, so as to realize the background modeling. The background modeling process is shown in (1314), respectively.

$$B_t(x, y) = \frac{1}{k}\sum_{i=1}^{k} I_{t=i}(x, y). \tag{13}$$

$$B_t(x, y) = \mathrm{med}\left(I_i(x, y)_{i=1,2,\cdots,k}\right). \tag{14}$$

Among them, me d means taking the median operation, $I_t(x, y)$ means the video frame at time t, and $B_t(x, y)$ means the updated background model at time t. However, it can be seen from formula (14) that the memory requirement increases because k frames of images need to be cached for updating the background model. Therefore, in order to reduce memory and computation, the background model parameters are usually updated according to the following equation:

$$B_{t+1}(x, y) = \lambda I_t(x, y) + (1 - \lambda)B_t(x, y), \tag{15}$$

where λ is called the update rate, which controls the update rate of the background model. Through experimental verification, in order to reduce the influence of foreground change on the model, the value of λ is usually small, generally set at 0.05.

3.2. Multifeature Fusion of Human Motion Posture. Multifeature fusion refers to the comprehensive analysis and processing of multisource feature vector information extracted from different feature extraction methods through feature fusion algorithm to form a new fusion feature vector group. In general, it can be divided into two categories: direct feature combination and feature selection combination. Direct feature combination method is to directly synthesize new feature vector groups by all feature vectors according to some simple rules, for example, serial and parallel fusion method. The method of feature selection and combination is to put all the original feature vectors together, and according to some selection rules, select and retain some feature vectors from the original feature vectors as a new combination of feature vectors.

Serial feature fusion method: the feature vectors in the sample space are directly merged into new feature vectors in turn. Assume that A and B are standardized features in sample space Ω, any sample $\xi \in \Omega$, feature vector is expressed as $\alpha \in \Omega$, and $\beta \in \Omega$ fused feature is expressed as

$$\gamma = \begin{pmatrix} \alpha \\ \beta \end{pmatrix}. \tag{16}$$

Parallel feature fusion method [20]: two groups of feature vectors in the sample space are merged into a new feature vector by a complex vector. Assuming that A and B are standardized features in sample space Ω, and any sample $\xi \in \Omega$, feature vectors are expressed as $\alpha \in \Omega$ and $\beta \in \Omega$, and then, the fused features are expressed as

$$\gamma = \alpha + i\beta. \tag{17}$$

In (17), i is an imaginary unit. If the dimensions of features α and β are not equal, feature fusion will be carried out after zero-complementing for features of low dimension.

The serial fusion method is the simplest and most effective method for fusing features. The dimension of the fused feature is increased, all feature information is retained, and there are numerous redundant feature vectors. The parallel fusion method guarantees the invariance of feature dimension, but the use of complex space vectors increases the operation's complexity, which has an effect on the recognition's real-time performance. In order to improve accuracy and real-time performance, the feature selection method generates new features that can ensure the effectiveness within and between feature classes without generating an excessive amount of redundancy. Feature level fusion method is roughly divided into five categories: probability statistical method (Bayesian estimation, Kalman filter, etc.), logic reasoning method (D-S evidence theory, fuzzy logic, etc.), neural network methods, fusion method based on feature extraction (PCA, LDA, etc.), and fusion method based on search (genetic algorithm, particle swarm optimization (pso), etc.).

3.3. Human Pose Estimation in Sports Based on Mixed Gaussian Distribution Model. The method of mixed Gaussian background modeling is to update the parameters dynamically, so that the background model established by it has better adaptability. Its basic principle is to assume that every pixel in the image is independent and can be mixed by K Gaussian distributions, where K is generally 3~5.

At time t, the pixel value at position (i, j) is x_t, and the probability of each pixel value can be represented by the weighted sum of K Gaussian probability density functions, as shown in the following equation:

$$p(x_t) = \sum_{i=1}^{K} \omega_{i,t} \times \eta\left(x_t, \mu_{i,t}, \sum_{i,t}\right), \tag{18}$$

where $\omega_{i,t}$ is the weighting coefficient of the ith Gaussian distribution at time t, the mean and covariance matrix of the ith Gaussian distribution at time t are $\mu_{i,t}$, $\sum_{i,t}$, and $\sum_{i=1}^{K} \omega_{i,t} = 1$, and the probability density function of its Gaussian distribution is $\eta(x_t, \mu_{i,t}, \sum i, t)$. The specific calculation is shown in the following equation:

$$\eta\left(x_t, \mu_{i,t}, \sum_{i,t}\right) = \frac{1}{(2\pi)^{n/2}\left|\sum_{i,t}\right|^{1/2}} e^{-1/2\left(x_t-\mu_{i,t}\right)T\sum_t^{-1}\left(x_t-\mu_{i,t}\right)}, \tag{19}$$

when a new video frame is input, according to (19), the pixel value x_t of each newly input image is successively compared with the K models already established at the current pixel point of this position. Where D is the confidence parameter, usually set at 2.5.

$$\left|x_t - \mu_{i,t-1}\right| \le D \times \sigma_{i,t-1}. \tag{20}$$

If the new input pixel value x_t satisfies (20), then x_t is judged as the background point after successful matching; otherwise, it is the foreground point. After the new video frame input pixel matching is completed, the model parameters of this point are updated and $M_{k,t} = 1$ is taken, and the parameter update method is shown in equations (18) to (20), where α is the learning rate is a fixed value, and the value is $0 < \alpha < 1$, and ρ can be updated through the following equation:

$$\omega_{k,t} = (1-\alpha)\omega_{k,t-1} + \alpha \times M_{k,t}, \tag{21}$$

$$\begin{aligned} \mu_t &= (1-\rho) \times \mu_{t-1} + \rho \times x_t, \\ \sigma_t^2 &= (1-\rho) \times \sigma_{t-1}^2 + \rho \times \left(x_t - \mu_t\right)^T \left(x_t - \mu_t\right), \end{aligned} \tag{22}$$

$$\rho = \alpha \times \eta\left(x_t \mid \mu_k, \sigma_k\right). \tag{23}$$

If no matching is achieved, $M_{k,t} = 0$ is taken, which is only newer (23), and the rest is unchanged. If none of the models is matched successfully, then the model with the lowest weight in the mixed Gaussian model is replaced, and then, the new parameter mean is x_t, the standard deviation is the initial maximum value σ_0, and the weight is the small value ω_0.

In order to obtain the model with good correlation between background and Gaussian model, that is, the model with heavy weight and small standard deviation, all Gaussian models are arranged from large to small according to ω/α^2 value to obtain the sports pose estimation function B, which is expressed as

$$B = \arg\min_b \left(\sum_{k=1}^{b} \omega_k > T\right). \tag{24}$$

In the formula, the parameter T represents the proportion of background. If x_t in the input video frame successfully matches any of the best description model, x_t is judged to be the background point. Otherwise, it is judged as the foreground point. At this time, the obtained sports pose estimation function value is the result of sports pose estimation, so as to achieve accurate sports pose estimation.

4. Experiment

4.1. Experimental Design. The experiment was conducted on two benchmark datasets, JPL First Person Interaction Dataset (tJPL) and DogCentric Activity Dataset (Dogcentric), containing 84 and 209 videos, respectively. The former is the human-computer interaction data set, and the latter is the animal-human interaction data set from the first perspective. The video in both data sets has a resolution of 320 240 and a frame rate of 30 FPS.

In this paper, multiple evaluation indicators are used to evaluate the model, including sample accuracy, sample level category accuracy, sample level average category accuracy, and video accuracy. Sample accuracy, also known as overall accuracy, refers to the proportion of correctly classified samples in the total number of samples and is the simplest and intuitive evaluation index in classification problems. Specifically, assuming that N sample segments are obtained from the video according to the sampling strategy, and the number of segments correctly classified by the model is N^{cor}, and then, the formula for calculating the sample accuracy is as follows:

$$A_{cc} = \frac{N^{cor}}{N}. \tag{25}$$

However, when the proportion of categories is seriously unbalanced, it is not reliable to rely only on the sample accuracy as the evaluation standard. Suppose an extreme case: when the proportion of negative samples is 99% of the total samples, the classifier can also obtain a high accuracy by predicting all samples as negative samples. When the data are skewed, the categories with a large proportion become the main factors affecting the assessment criteria. Therefore, we also use the sample level category accuracy and sample level average category accuracy. Among them, the sample-level category accuracy is to group all sample segments according to categories and obtain the probability of correct prediction in each category. The average category accuracy at sample level is averaged according to the weighted summation of each category accuracy. Specifically, assuming that the number of classes is num_classes (num_classes > 0), each group is grouped according to the category, and the number of samples of num_classes (num_classes > 0) in each group is N_n^{cor} $(0 \le N_n^{\text{cor}} \le N_n)$, and then,

$$\begin{aligned} \text{class}\left(A_{cc}\right) &= \frac{N_n^{cor}}{N_n}, \\ M\text{class}\left(A_{cc}\right) &= \frac{\sum_{n=0}^{\text{num\_class}-1} N_n^{cor}/N_n}{\text{num} - \text{classes}}. \end{aligned} \tag{26}$$

In order to obtain the video level prediction from the prediction metrics of the sample segments, the method described in Section 3.2 is used for voting fusion, that is, the fusion of the maximum number of category predictions, the maximum category scores, and the maximum weighted scores, and the estimation accuracy of sports posture is calculated according to the fusion results.

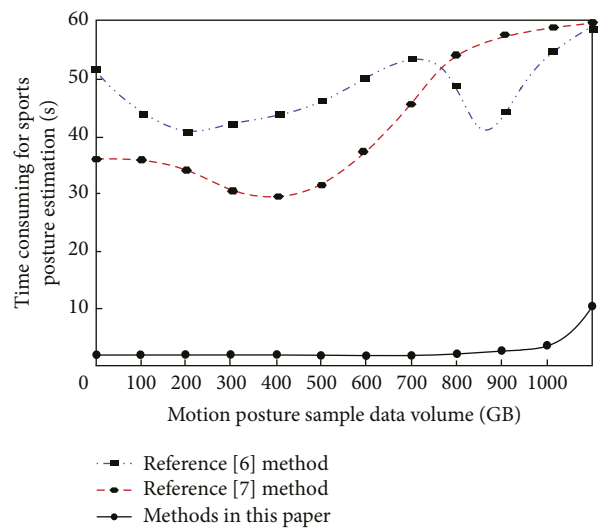

Figure 3: Time consumption for accurate estimation of sports posture.

4.2. Experimental Result

4.2.1. Accurate Estimation of Athletic Posture Takes Time. In order to verify the precision estimation efficiency of the proposed method, the method in literature [6], the method in literature [7], and the method in this paper are used to estimate the precise estimation time of sports posture, and the results are shown in Figure 3.

Analyzing Figure 3 reveals that when the sample data amount of sports posture is 100 GB, the estimation time of the method in reference [6] is 43.5 s, the estimation time of the method in reference [7] is 35.2 s, and the estimation time of this method is 1.5 s. When the sample size of sports posture data is 300 GB, the estimation time of the method in reference [6] is 42.1 s, reference [7] method is 31.6 s, and the proposed method takes 2.3 s. When the sample data amount of sports posture is 900 GB, the accurate estimation time of the method in reference [6] is 46.5 s, the method in reference [7] is 58.3 s, and this method's accurate estimation time is 5.3 s. The posture accuracy of the proposed method is significantly higher than that of other methods, indicating that it can effectively improve the posture accuracy of sports.

4.2.2. Sample Accuracy of Posture Estimation in Sports. In order to verify the sample validity of the proposed motion pose estimation method, literature [6], literature [7] and the methods proposed in the paper are used for comparison, and the results are shown in Figure 4.

According to Figure 4, when the amount of sports pose sample data is 200 GB, the estimation accuracy of the method in reference [6] is 72.5 percent, the method in reference [7] is 48.6 percent, and the proposed method is 95 percent. When the amount of data for the sports pose sample is 600 GB, the estimation accuracy of the method in reference [6] is 69.9%, and that of the method in reference [7] is 71.5%. The proposed method has a 99.9% estimation

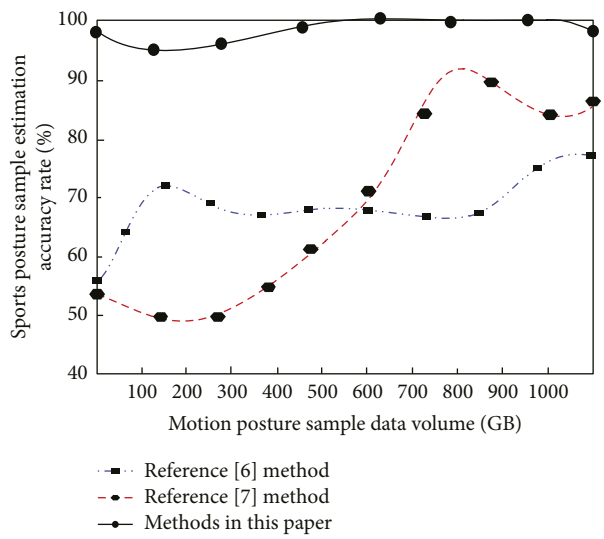

Figure 4: Estimation accuracy of sports posture samples.

precision. The estimation accuracy of the sports pose sample is 69.2% for the method in reference [6] and 89.6% for the method in reference [7] when the sample data size is 900 GB. The estimation precision of the proposed method is one hundred percent. This indicates that the proposed method can effectively improve the estimation accuracy of sports pose samples.

5. Conclusion

In this paper, a human rod model is constructed using a precise estimation algorithm for sports posture based on the fusion of multiple features. Based on the Kalman filter method to estimate the motion posture, determine the degree of freedom and range of motion of the main body joints, use the eight-star model to extract the motion posture features, use the multifeature fusion method to extract the multisource vector information features, and use the mixed Gaussian distribution model to realize the motion body posture. Experimental results indicate that when the amount of sports pose sample data is 900 GB, the accurate estimation time of the proposed method is 5.3 s, and its accuracy is 100 percent. Improve the estimation accuracy of samples of sports posture.

In the future, we will introduce a multihead attention mechanism and more advanced 6D recognition technology to further improve the accuracy of motion gesture recognition.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Retraction

Retracted: Evaluation of Scientific and Technological Innovation Ability of Free Trade Zone Based on Random Forest Weighting Method

Mobile Information Systems

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.

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[1] L. Y. Meng, "Evaluation of Scientific and Technological Innovation Ability of Free Trade Zone Based on Random Forest Weighting Method," *Mobile Information Systems*, vol. 2022, Article ID 8769703, 11 pages, 2022.

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Research Article

Evaluation of Scientific and Technological Innovation Ability of Free Trade Zone Based on Random Forest Weighting Method

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The scientific and technological innovation ability of the economic free trade zone is crucial to the depth and breadth of its economic development. There are too many subjective factors in the evaluation of the scientific and technological innovation ability of traditional economic free trade zones. In order to objectively evaluate the scientific and technological innovation ability of the free trade zone, this paper uses the random forest weighting method and the weighted linear combination to construct the evaluation index system, designs the evaluation model of the scientific and technological innovation ability of the free trade zone, and makes a specific analysis and evaluation based on the operation data of the economic and technological innovation ability of China's four key free trade zones in 2020. The results show that the scientific and technological innovation ability of Guangdong economic free trade zone is the strongest, followed by Guangdong economic and trade zone, Shanghai economic and trade zone, Zhejiang economic and trade zone, and Tianjin economic and trade zone; Guangdong free trade zone has strong scientific and technological innovation ability. Compared with other free trade zones, Guangdong's main advantages lie in the integration and aggregation ability of the industrial chain, strong policy support, and talent attraction. The scientific and technological innovation ability forms a virtuous circle. The analysis of the model example shows that the introduction of the random forest weighting method into the scientific and technological evaluation of the free trade zone can more objectively compare and analyze the scientific and technological innovation ability of the free trade zone, which is of great significance to help the free trade zone find out the problems and shortcomings in the scientific and technological innovation ability and improve the level of scientific and technological innovation.

1. Introduction

There are several definitions of the concept of an economic free trade zone in academic circles. According to the Kyoto Convention (1973), some regions in a certain country and region do not need to be supervised and constrained by the relevant customs system when goods are transported across the border, and these regions can be called free trade zones. This stage took place at the end of World War II. In the second stage, the economic free trade park includes services and investment trade. With the deepening of trade liberalization and the continuous standardization of rules of origin. The third stage of the economic free trade park began with the global financial crisis. With global integration, the main mode of economic free trade park is a transnational trade zone, which gradually moves closer to the form of transnational economic integration, and tariffs and transnational investment barriers disappear. Foreign economic free trade parks have been established for a long time with rich experience, and foreign economists' research on economic free trade parks is also relatively mature. Some scholars believe that the establishment of economic free trade parks will reduce domestic welfare, lack the protection of relevant tariff policies, and the final transaction price of some goods or services produced within the region will decline due to lack of competitiveness, which will damage the relevant interests of the country to a certain extent [1]. The lack of a good business environment and strong government support in developing countries leads enterprises to passively accept the new trade model brought by the

economic free trade park, which is easy to lead to the reduction of business efficiency of the company in the economic free transaction park. The liberalization of intermediate trade brought about by the construction of the economic free trade park will strengthen the transaction relationship between local enterprises and foreign-funded enterprises and increase the purchase of imported parts and components by local enterprises. Due to the strength gap between local enterprises and foreign-funded enterprises, it is easy to lead to a trade deficit in the long run [2]. However, most scholars have expressed positive views on the economic free trade park policy. Different from the trade deficit view of Seyoum, Broda et al. research on Indonesia show that developing countries can improve production efficiency through "importing secondary schools." When the trade liberalization of domestic enterprises is better developed, domestic enterprises will face more intense international competition [3]. The construction of the economic free trade park can bring foreign investment, which will promote the influx of international multinational companies into the economic free trade park for investment and production. The construction of the economic free trade park has reduced the operating costs of enterprises, attracted more foreign investment, increased the opportunities for foreign exchanges of local enterprises, and made the construction of enterprises' international trade network more convenient [4]. After entering the economic free trade park, multinational companies will establish branches or branches in the economic free trade park. These enterprises and institutions will communicate and cooperate with local the company in the economic free trade park. The business of foreign-funded enterprises is concentrated in the technology and service industries. For production weaknesses, local enterprises will choose outsourcing according to their comparative advantages. When intermediate products are professionally divided into different stages of the value chain. Reducing enterprise costs and allocating intermediate products to better enterprises for production can improve the quality of final products so that the market competitiveness of enterprises and the market sales volume of products can be improved [5].

At present, China is building 18 free trade zones, involving 31 countries, regions, and organizations. Among them, 12 free trade agreements have been signed, involving 20 countries and regions, including the free trade agreements between China and ASEAN, Singapore, Pakistan, New Zealand, Chile, Peru, Costa Rica, Iceland, and Switzerland, the closer economic and trade partnership arrangement (CEPA) between Mainland China and Hong Kong and Macao, and the Cross-Strait Economic Cooperation Framework Agreement (ECFA) between Mainland China and Taiwan. Except for the free trade agreements with Iceland and Switzerland, which have not yet taken effect, Others have been implemented; there are six free trade agreements under negotiation, involving 22 countries, regions, and organizations, including China's free trade negotiations with the Republic of Korea, the Gulf Cooperation Council (GCC), Australia and Norway, as well as the China-Japan-Korea free trade area and the regional comprehensive economic cooperation partnership (rcfp). One, in addition, China has also joined the Asia-Pacific trade agreement. [6]. Deepening the reform of the economic free trade park and stimulating scientific and technological innovation in free trade economic parks is a necessary condition for participating in the international industrial division of labor, and inevitable requirements to promote the economic free trade park to play an important role in building a new economic pattern with economic internal circulation as the main body.

1.1. Current Situation of China's Economic Free Trade Park. In 2002, China started the structure process of the free trade area. After more than ten years of development, China has initially formed a network framework of free trade areas based on the surrounding areas and facing the world [7]. It has signed 19 free trade agreements, involving ASEAN, South Korea, Pakistan, New Zealand, Chile, Switzerland, Mauritius, as well as 26 countries and regions such as Hong Kong, Macao, Taiwan, and China, and is cooperating with Norway, Israel, and other countries which carried out negotiations or upgraded negotiations on 11 free trade agreements, and carried out joint feasibility studies or upgraded joint feasibility studies on 8 free trade agreements with Nepal, Canada, and other countries, that part is crucial for expanding foreign economic and political relations, see Table 1. In 2020, with the extended spread of COVID-19, China's economic free trade park construction still made positive progress. In October, China and Cambodia signed a free trade agreement, which is the first free trade agreement negotiated and signed between China and the least developed countries, and also the first free trade agreement to establish independent chapters for the cooperation of the under the background of the "the Belt and Road." In November, 15 member countries of RCEP signed an agreement [8], which will inject strong impetus into regional and global economic growth. From an international perspective, there is still a large gap between the number of China's economic free trade zones and the developed countries such as the United States and Japan. See Figure 1 for details.

In terms of trade volume, the trade between China and its free trade partners (excluding Hong Kong, Macao, and Taiwan) accounted for 27% of China's be-all foreign transactions in 2019. Meanwhile, the trade between the United States and its free trade partners accounted for about 40% of its total foreign trade and about 52% of Japan's total foreign trade. Even after the RCEP agreement came into force, the trade coverage between China and its free trade partners has only increased to about 35%.

In terms of the number of economic free trade parks, as of January 28, 2021, there were 337 regional trade agreements still in force in the world, and the number of negotiations signed by China was only 16 (excluding 3 noneffective free trade agreements), which was far lower than that of the European Union (44), and also lower than that of Singapore (26), Mexico (22), Turkey (23), South Korea (19), Japan (18), and other countries and regions. Japan has also reached the cptpp, signed the economic partnership agreement (EPA) with the European Union, and

Table 1: Average results of index scores of 5 experts on 6 target levels of 4 economic free trade parks.

Free economic and trade zone	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
FTZSH	[9, 9, 8, 7, 8, 10]	[10, 10, 6, 7, 9, 8]	[9, 10, 8, 8, 8, 1]	[9, 10, 7, 7, 8, 8]	[10, 9, 6, 7, 9, 8]
FTZTJ	[9, 8, 7, 6, 6, 10]	[8, 6, 5, 5, 6, 8]	[9, 5, 5, 6, 8, 8]	[9, 5, 4, 4, 7, 8]	[8, 5, 5, 6, 8, 8]
FTZGD	[9, 9, 8, 9, 7, 6]	[8, 10, 8, 10, 6]	[9, 9, 8, 8, 6, 7]	[10, 8, 10, 10, 8, 8]	[9, 10, 8, 10, 7, 7]
FTZZJ	[8, 9, 8, 6, 6, 9]	[7, 8, 8, 7, 5, 10]	[6, 10, 8, 7, 5, 8]	[7, 10, 9, 5, 6, 8]	[8, 8, 8, 8, 8, 9]

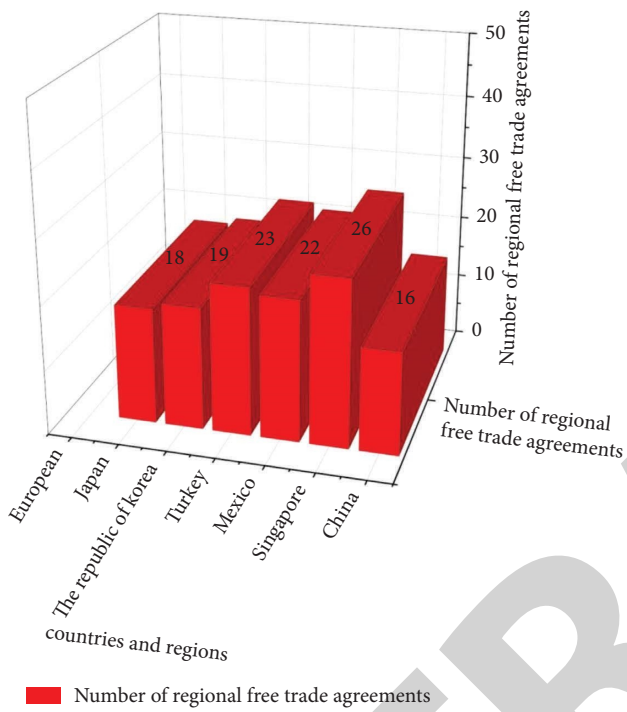


Figure 1: Number of regional trade agreements in some countries.

signed a trade agreement with the United States, while none of China's free trade partners in the agreements that have entered into force are among the world's top ten economies; The degree of liberalization of the economic free trade park is not high. China basically accounts for 90% or even more in terms of the proportion of tariff-free products in the total tax items and the proportion of imports of tariff-free products. The RCEP agreement was signed in November 2020, more than 90% of the commodity trade in these regions will achieve zero tariffs within 10 years so the RCEP economic free trade park is expected to fulfill all the commitments of trade liberalization in goods in a relatively short time. In comparison, the international high-standard free trade agreement can basically reach the proportion of zero tariff products of more than 99%.

1.2. Significance of Evaluation on Innovation Ability of Economic Free Trade Park. In this study, the evaluation index system of scientific and technological innovation capability of the economic free trade park, aiming at the problem of the interweaving and confusion of the index system, this study adopts the random forest weighting method, aiming to clarify the existing core indicators at all levels in an objective statistical and quantitative way, and provide a mainstream model reference for the selection of indicators, to make a theoretical discussion on the evaluation model of the scientific and technological innovation ability of economic free trade park [9]. The maximum utility of evaluation model of the scientific and technological innovation ability of the economic free trade park lies in that the evaluation subject can complete the evaluation of the object with the help of the evaluation index system, and get real and reliable evaluation results, so as to clarify the advantages and disadvantages of the development of the economic free trade park and point out the direction for further improving the scientific and technological innovation ability of the economic free trade park. However, in the process of practical application, there are various evaluation index systems available for selection, and it is sometimes difficult for the evaluation subject to make a scientific judgment, which is easy to cause the same research object to produce different evaluation results due to the selection of evaluation index system [10].

This study uses the random forest weighting method to establish an evaluation model of the scientific and technological innovation ability of the economic free trade park, which helps to provide an operable evaluation index system for the evaluation subjects who study the relationship between the scientific and technological innovation ability of the economic free trade zone and the scientific and technological independent innovation ability of the economic free trade park and explores the development shortcomings of the economic free trade zone. It is important to evaluate the scientific and technological innovation ability of the economic free trade park and to help the economic free trade park develop more stably, it is of great significance to make more contributions to economic development.

2. Main Problems of Scientific and Technological Innovation Capacity Evaluation in Traditional Areas

Up to now, the academic circles have made rich theoretical research achievements in the evaluation of regional scientific and technological innovation ability, mainly in three aspects [11]. The abovementioned research achievements have to build a good theoretical foundation for the formation of the evaluation index model of this study. The evaluation model of regional scientific and technological innovation level constructed by foreign academic circles has become an important measurement standard to measure regional or national scientific and technological innovation, which has a strong representative and provides a basis for the comparison of horizontal scientific and technological competitiveness between different regions [12]. Influenced by

foreign innovation theories, and in recent years, China has introduced a series of macro strategic measures to promote scientific and technological innovation, the research results of Chinese academia are relatively prominent. It is mainly divided into two points: first, the establishment of a regional scientific and technological innovation model is relatively complete, which is mainly divided into 2-3 index levels, most of which are 3 index levels, of which the first level usually involves climate for scientific and technological innovation, innovation foundation input, output and benefit of scientific and technological innovation; on the other hand, the evaluation and analysis method of regional scientific and technological innovation ability is relatively objective, mainly quantitative analysis method, which is conducive to the scientific processing and analysis of data [13].

However, in the process of selecting the evaluation model, the domestic academic circles, generally speaking, it is limited by the research in their respective fields, which makes the constructed evaluation indicator systems show great differences on the whole [14]. First, the indicators are expressed in a similar way, such as the number of scientific researchers and the number of scientific researchers per 10000 people. If we choose to retain more representative indicators, it may be helpful to ensure the reliability of the final evaluation results; second, the definition of indicators is general, such as enterprise technology innovation index, science, and technology human resources training, etc., the specific direction of indicators is vague, which needs to be further refined and explained; third, the level of indicators is misplaced, such as the level of indicators such as R&D investment intensity in different indicator systems is inconsistent; and fourth, the index structure is poor [15]. For example, the construction of some supplements is too simplified, and the construction of some indicators is too cumbersome. For example, if the indicators with a low correlation of forest coverage equal to technological creation l innovation ability are included in the evaluation, it may be detrimental to the key analysis of the final evaluation results, this needs to be selected in the mode of the evaluation model. Therefore, the current domestic and foreign evaluation research of regional technological creation capability has many references, but at the same time, there are also some areas that need to be further improved, which are worth discussing in future research. This paper is based on the above-mentioned research background to re-explore the random forest weighting method to build the evaluation system of technological creation capability of economic free trade parks.

3. Basic Principle of Forest Weighting Method

3.1. Random Forest Principle. Random forest (RF) is a combined intelligent classification algorithm based on statistical learning theory, which mainly includes classification and regression. [16]. This study mainly adopts the radio frequency classification method, RF classification includes various decision tree classification models, A combined distinguish model composed of $\{h(X, \Theta), k = 1, \ldots\}$, and the data set$\{\Theta k\}$set an independent distributed random vector, under the given lambda parameters, each decision tree classification model has to choose the most appropriate voice sorting method.

The fundamental principle of RFC is to extract key indicators from multiple indicator samples. These index samples are from the basic samples, and the data of each sample is the same as the original sample. [17], random forest weighting model is shown in Figure 2.

3.2. Random Forest Weighting Method. Gini index method is used to calculate the random forest weight. If a set t contains k types of data, the Gini index is given as follows:

$$\mathrm{Gini}(T) = 1 - \sum_{j=1}^{k} p_j^2. \tag{1}$$

p_j^2 expresses the frequency of T appearing in j group. When Gini (T) is at least 0, in other words, the information recorded at this node is basically the same, which indicates that useful information can be extracted at this time; at this time, the effective data in the node is evenly distributed in the node, when the value is the maximum, it means that the effective information in the node is the minimum. The set t is divided into m parts, Ti ($i = 1, 2, \ldots, m$). In order to calculate the Gini coefficient conveniently, it is necessary to calculate the reduction of the Gini coefficient of each segmented node. Then calculate the subGini index as follows:

$$\mathrm{Gini}_{\mathrm{split}}(T) = \frac{\sum_{i=1}^{m} \mathrm{Gini}(T_i) N_i}{(N)}. \tag{2}$$

Among them: number of child nodes m; N_i is the number of samples collected from subnode T_i; N is the number of data in the parent node set T. the basic idea of Gini number is: if the minimum Gini spectrum, that is, the maximum purity of impurities, can be provided, it can be used as a criterion for node separation, and the attribute value can be divided into molecular trees, which is the best branch; this is achieved by splitting the corresponding attribute values and creating branches based on the attribute values; the next step is to separate the samples until the stop condition is met. It is usually the purity threshold of a specific leaf node. If the threshold is greater than or equal to, the segmentation ends [18].

If all T samples belong to the same category for regression tree sorting, or there is only one T data, then the T node is an atypical node. If the separator of variable Gini is randomly replaced, the classification of regression tree i is divided by, $\mathrm{Gini}_{\mathrm{split}}\chi_i - Gini_{\mathrm{split}}\chi_{ig}$. Later, the important index of the same category G in the corresponding fractional regression tree can be expressed as. Importance of variable G $\Delta - j$ calculate the average value of element Gini index in the model, namely, the declining value of the average Gini index is given as follows:

$$\overline{\Delta}_j = \frac{\left(\sum_{i=1}^{B}\left(\mathrm{Gini}_{\mathrm{split}}(\chi_i) - \mathrm{Gini}_{\mathrm{split}}(\chi_{ij})\right)\right)}{B}. \tag{3}$$

This study chose to use $\overline{\Delta}_j$ to the importance of analysis of index variables as follows:

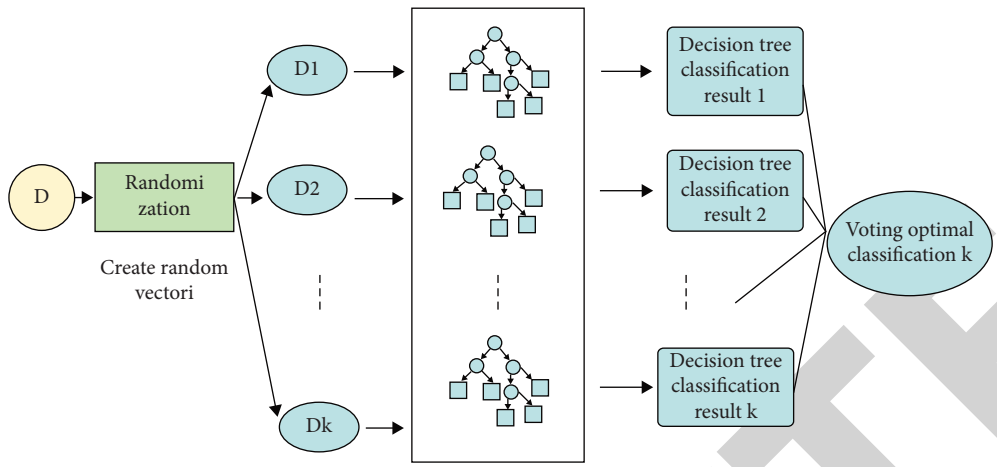


Figure 2: Random forest algorithm model.

$$w_j = \frac{\overline{\Delta}_j}{\sum_{j=1}^{n} \overline{\Delta}_j}. \tag{4}$$

In the formula, n is the number of index elements; W_j is the importance index of the jth index element, right here meets $\sum_{j=1}^{n} w_j = 1$.

3.3. Weighted Linear Combination. Linear weighted combination model also called "addition" comprehensive analysis method or weighted arithmetic average method operator, application of linear computing system for comprehensive evaluation. Its calculation is simple, easy to understand, and easy to combine with GIS technology, and the effect is good because it is widely used [19]. In view of the advantages of the linear weighted combination method, this study uses this method to build a landslide risk assessment system. The specific calculation formula of the weighted linear combination method is given as follows:

$$y = \sum_{j=1}^{m} w_j x_j. \tag{5}$$

In this formula, y is the overall analysis index of the system or the analysis objectives; m is the quantity of indicators variables; w_j is the specific gravity coefficient corresponding to the index variable x_j, which is determined by (4), and needs to meet $0 < w_j < 1$ ($j = 1, 2, \ldots, m$), and $\sum_{j=1}^{m} w_j = 1$; x_j is the normalized value of each index variable. The purpose of normalization is mainly to eliminate the influence of data range and dimension of different index variables. The normalization formula is given as follows:

$$x_j = \frac{x - x_{\min}}{x_{\max} - x_{\min}}, \qquad x_j = \frac{x_{\max} - x}{x_{\max} - x_{\min}}. \tag{6}$$

Where: x is the original value of each index variable, $x_{\min}$ and $x_{\max}$ are the minimum and maximum values of the original values of each index variable, respectively. Formula (6) the former is suitable for improved data, that is, the larger the index, the contribution to risk; the latter is suitable for negative indicators, that is, the smaller the index value, the greater the contribution to the important coefficient.

3.4. Weight Estimation of Eigenvectors. Suppose a random forest consists of a series of trees $h_1(X), h_a(X), \ldots, h_k(X)$, and two random vectors X (input vector) and Y (output vector). $I = (h(X) = Y)$ represents the number of votes of Y that correctly classifies the eigenvector X. The weight estimation link of the eigenvector is as next:

Next link 1: reliability analysis of eigenvector weight estimation.

(1) Convergence estimation of random forest classification tree: define $mg(X, Y)$ as the edge function of sample points (x, y)

$$mg(X,Y) = av_k I(h_k(X) = Y) - \max_{j \neq Y} av_k I(h_k(X) = j), \tag{7}$$

Y represents the clustering vector of content, $I(\cdot)$ represents the special display function, and $av_k()$ averages the take effect of values. This edge function represents the extent to effective equilibrium assignment number classified Y of vector X exceeds that of other votes of the same type. Therefore, the higher the value of edge function, the stronger the reliability of effective classification, and the better the effect of the classifier in the algorithm.

(2) Error rate of weight estimation of feature vector: Let PE^* is the generalization error of classifier in random forest algorithm, which reflects the classification effect of the classifier.

$$\mathrm{PE}^* = P_{X,Y}(mg(X,Y) < 0). \tag{8}$$

It is used to measure the error rate of OOB weight estimation. For the random forest model, if there are enough trees in the forest, the abovementioned equation will satisfy Bernoulli's laws:

$$\lim PE^{*}_{k\longrightarrow\infty} = P_{X,Y}\left(P_{\Theta}\left(h\left(X,\Theta_k\right)=Y\right) - \max_{j\neq Y} P_{\Theta}\left(h\left(X,\Theta\right)=j\right)<0\right). \tag{9}$$

The formula: k represents the number of trees in the forest.

Next link 2 (weight estimation of feature vectors): assume that the formula of OOB estimation in the random forest is given as follows:

$$P_K = \frac{\sum_{(x_i,y)\in O_k} I\left(h_k\left(x_i\right)=y\right)}{\sum_{(x_i,y)\in O_k} I\left(h_k\left(x_i\right)\right)}. \tag{10}$$

P_K is calculated as OOB number of $P(h_K(x)=y)$ according to weight reassessment, and the weight of the feature vector can be selected for the minimum error rate obtained.

4. Development of the Evaluation Model of the Scientific and Technological Innovation Capacity of the Free Trade Area Based on the Forest Weight Method

4.1. Structure of Index Systems. The development mechanism, driven by national innovations in the free trade area, is primarily intended to strengthen the capacity for independent innovation and overcome existing institutional barriers. Promote the development of the free trade area and maximize the great potential of science and technology as a primary productive ability [20]. Due to the particularity of the intellectual property rights of scientific and technological achievements, there is no fully applicable evaluation method. At present, the evaluation results of different evaluation institutions in the intellectual property rights market of scientific and technological achievements are too different, the recognition of the evaluation results is not high, and no normative documents have been issued by relevant departments. In this regard, this paper studies the intellectual property rights of scientific and technological achievements, the characteristics of the value evaluation of intellectual property rights of scientific and technological achievements, the evaluation environment, and the factors affecting its value. On this basis, it studies in detail the application of the income method in its value evaluation, including the determination of parameters such as the prediction of income, contribution rate, income period, and discount rate [16, 21, 22]. Based on the evaluation index selection method, the evaluation index system of 3 primary indexes and 16 secondary indexes as shown in Figure 3 is constructed.

4.2. Establishment of the Empowerment Model. According to the nature of random forest weighting, the algorithm model of a random forest weighting method for establishing the update and development of the science and technology capacity of the economic free trade park is shown in the following Figure 4.

The advantages of the algorithm model designed in this study are given as follows:

(1) By introducing the random forest weighting method, the application scope of the competition model is widened, and the scoring selectivity of experts is more scientific and objective.

(2) Compared with the general method, the scheme designed in this paper can save computation. The combination of expert scoring and historical data makes the calculation results more reliable and provides a valuable reference for decision-makers.

5. Case Analysis of Scientific and Technological Innovation Capacity in the Economic Free Trade Park

This paper takes Shanghai (FTZSH), Tianjin (FTZTJ), Guangdong (FTZGD), and Zhejiang (FTZZJ) economic free trade parks as the research objects to the evaluation of science and technology upgrading ability capacity of these regions. The data are from the 2020 China statistical yearbook and the statistical data bulletins and statistical yearbooks of the provinces and cities of the abovementioned economic free trade parks .

5.1. Analysis of Random Forest Weighting Method

(1) This paper simplifies and optimizes the target level indicators of the scientific and technology update and upgrades the capability of the economic free trade park according to the rough set method, discretizes the 16 indicator data in Figure 3 according to the model established above, and carries out dimensionless quantitative processing. See Figure 5 for specific results.

Rough set Rosetta software is used to calculate the data in Figure 5, and the core of the knowledge system is: {$C1$, $C3$, $C5$, $C7$, $C9$, $C11$}, that is, six indicators [23]. As the target layer for evaluation of science and technology upgrading level of the economic free trade park.

(2) Determine the weight. Input the coefficient data of the target layer of the 4 economic free trade parks that need to be evaluated into the algorithm program of RFW, to the weight of each index of each evaluation project, get the important coefficient of each index of each assessment economic free trade park according to the minimum error rate, and calculate the normalized weighted average value as the important coefficient of each index. See Figure 6 for details.

(3) Determine the average result set (g) of each index score. Experts determine the evaluation index value GJ (AJ) by scoring according to the location of each economic free trade park and the characteristics of the original data of the evaluation index. Among them, $\forall a_j \in K$ is the average score of experts on each project and index. The scoring results of 5 experts on the indicators of 6 target levels of 12 economic free trade parks, see Table 1 for details.

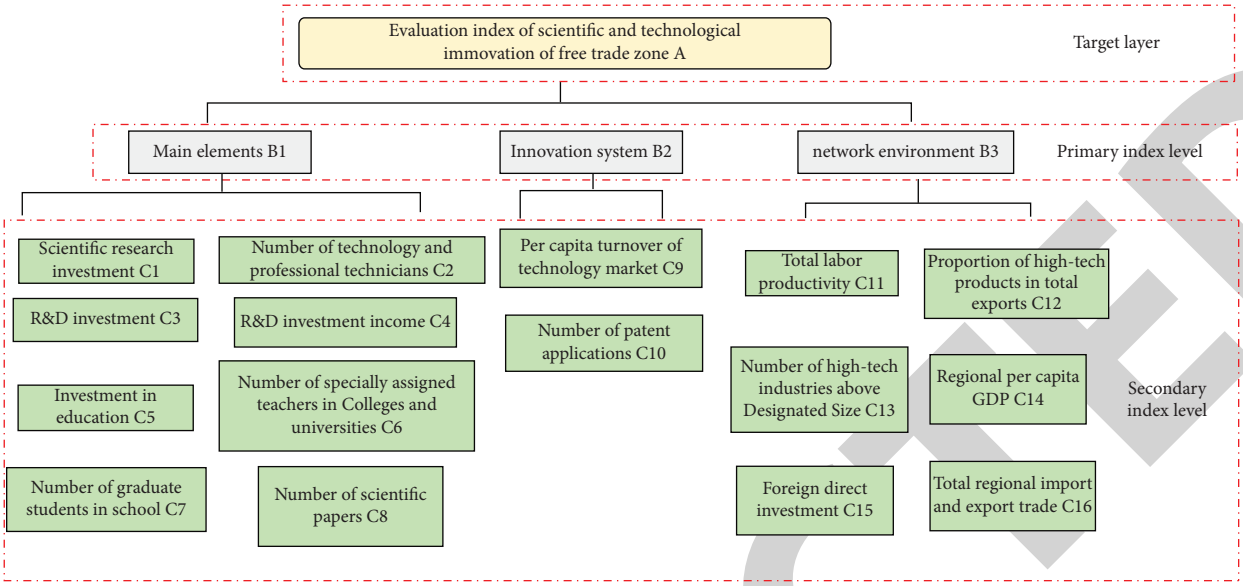


Figure 3: Evaluation index system of the scientific and technological innovation capacity of economic free trade park.

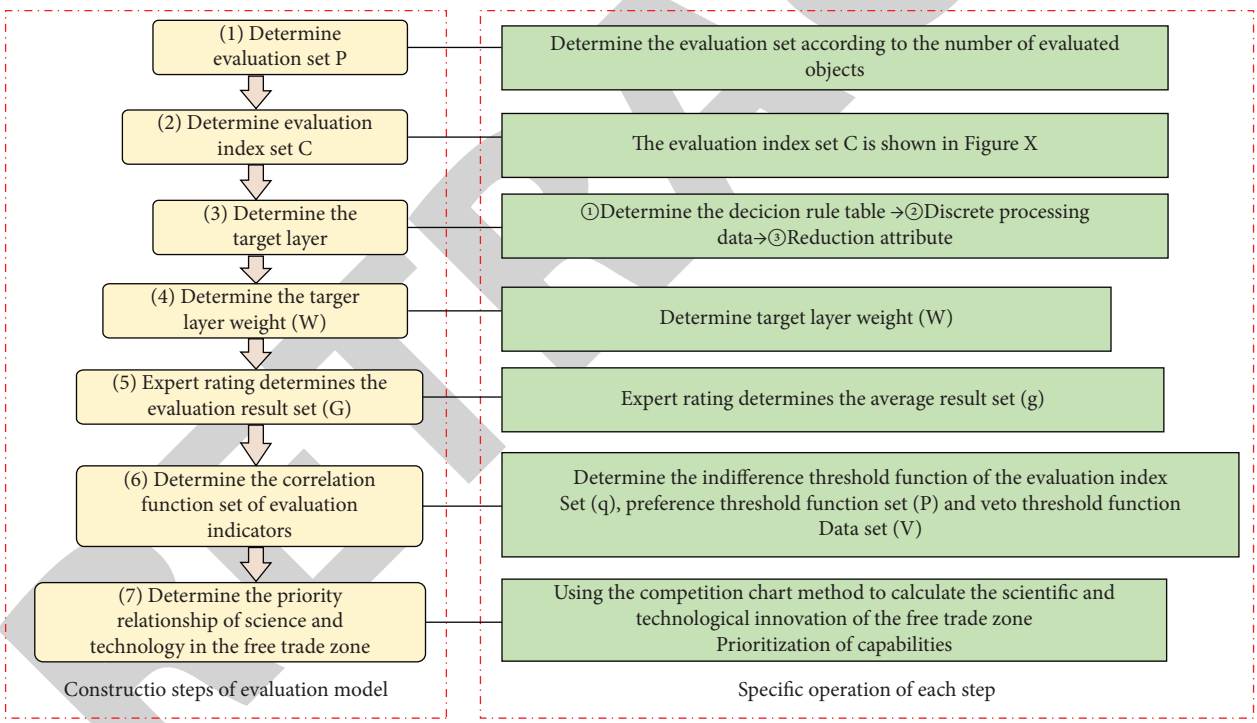


Figure 4: Algorithm model steps of a random forest weighting method for scientific and technological innovation capability of economic free trade park.

(4) Determine the indifference threshold function set Q, preference threshold function set P, and veto threshold function set V. The results obtained by dimensionless quantification of $\{C1, C3, C5, C7, C9, C11\}$, see Table 2 for details.

5.2. Competition Chart Method to Evaluate the Scientific and Technological Innovation Ability of the Economic Free Trade Park. A tournament graph refers to a graph in which any two vertices are connected by a directed edge. The direction of the directed edge refers to the priority relationship between the two vertices, and the priority of the starting vertices is arranged before the pointed vertices, as shown in Figure 7.

The ranking method of bidirectional connected tournaments with the number of vertices ≥4 is as follows: the adjacency matrix of the tournaments $A = (A_{ij})_{n\times n}$ is defined as follows:

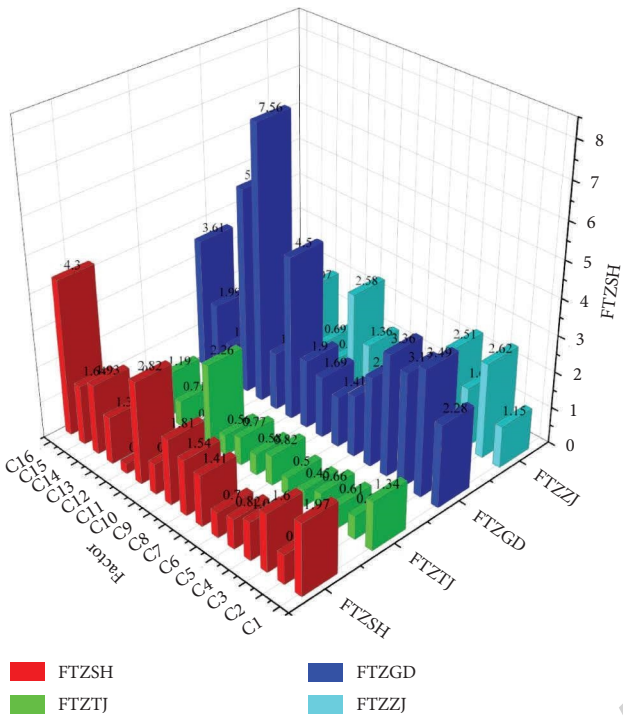


Figure 5: Dimensionless quantitative data diagram.

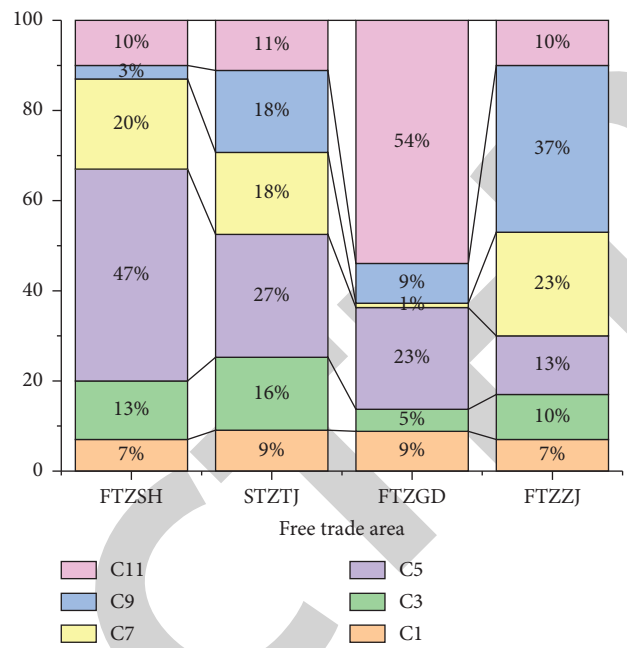


Figure 6: Weight index of minimum error determination.

$$A = \left(A_{ij}\right)_{n\times n} = \begin{cases} 1, \text{Thereisadirectededgefromitoj}, \\ 0, \text{Thereisnodirectededgefromitoj}. \end{cases} \tag{11}$$

Let the score vector of vertex $s = (s_1, s_2, \ldots, s_n)^T$, where s_i is the score of vertex i (that is, the number of directed edges derived from point i). Let:

$$\begin{aligned} \mathbf{s}(k) &= A\mathbf{s}^{k-1} \\ &= A\mathbf{s}^{k}, \end{aligned} \tag{12}$$

Where: $k = 1, 2, \ldots, N$; $e = (1, 1, \ldots, 1)^T$. for a two-way connected graph, there is an integer r. if a satisfies $A_r > 0$, then A becomes a prime matrix. According to peron Frobenius theorem, the maximum characteristic root of a prime matrix is a positive root (λ) When the corresponding eigenvector is s, there are:

$$\lim_{k\longrightarrow\infty} \frac{Ae}{\lambda^k} = s. \tag{13}$$

In formula (13), the normalized level score vector converges to the maximum characteristic positive root (λ_{Max}), whose corresponding eigenvector is used as the basis for ranking the limit score vector. When $k \longrightarrow \infty''$, $s(k)$ converges to a limit score vector, which is used as the basis for reasonable ranking after normalization.

In this paper, this method is applied to the systematic evaluation of scientific and technological upgrading achievements ability of China's economic free trade park. The evaluation indexes representing different aspects of the scientific and technological innovation ability of the economic free trade park are taken as the objectives of the multiattribute decision-making problem, and the importance coefficient (W) of each evaluation index is obtained by the random forest weighting method as the weight of each objective of the multiattribute decision-making problem; then take the upgrading level of science and technology of each economic free trade park as the scheme to be sorted for the multiattribute decision-making problem; finally, the competition chart method is used to calculate the advantages and disadvantages of the scheme, and the scientific and technology upgrading ability of the economic free trade park is ranked.

Substitute the data of table x into equations (12) and (13) successively, and substitute the zik data calculated according to the construction model into equation (24).

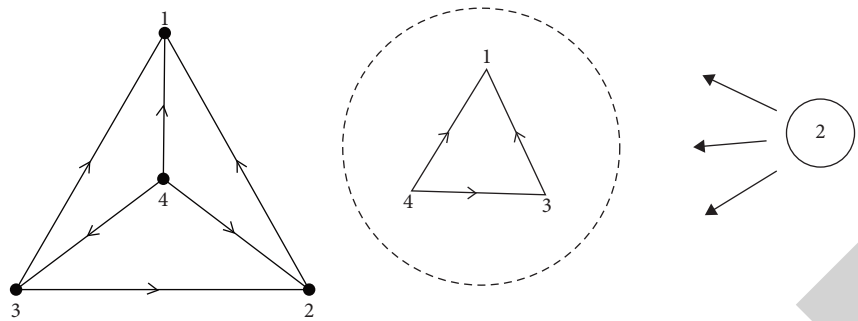
$$\begin{aligned} a &= (x, y), \\ &= \{a \in A \mid f(x, a) \neq f(y, a)\}, \\ \Delta &= \prod_{(x,y)\in U\backslash\backslash U} \sum a(x, y), \\ \omega\left(x_j > x_k\right) &= \sum_{x_i > x_j} \omega_j. \end{aligned} \tag{14}$$

(14)–(16), the values of Qi are respectively 0.15, 0.19, 0.18, 0.16, 0.19, and 0.13, that is, the weight values of the six research objectives. Priority ranking: according to the abovementioned calculation results and modeling, the original data are used as follows:

$$W = \left(w_{ik}\right)_{n\times n}. \tag{15}$$

See Table 3, for details[25].

Calculate the available weight matrix $W = (w_{ij})_{4\times 4^*}$



(a) (b)

Figure 7: Four point competition chart. (a) Four point competition chart. (b) Tournament decomposition.

$$W = (w_{ik})_{4\times4} = \begin{bmatrix} 0 & 1.00 & 0.13 & 0.84 \\ 0.00 & 0 & 0.13 & 0.66 \\ 0.16 & 0.47 & 0.00 & 0.63 \\ 0.87 & 0.87 & 0 & 1 \end{bmatrix}. \quad (16)$$

It can be concluded that the priority relationship of science and innovation capacity in the economic free trade park see Figure 8 for details[26].

The fixed points in the figure represent each economic free trade park, and the arrows between the fixed points indicate the relationship between advantages and disadvantages.

Science and technology upgrading capabilities in the economic free trade park are: Guangdong economic free trade park, Shanghai economic free trade park, Zhejiang economic free trade park, and Tianjin economic free trade park.

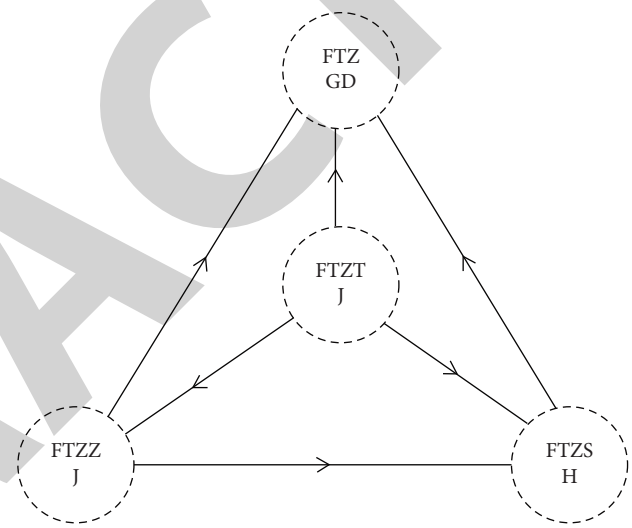


Figure 8: Competition chart of scientific and technological innovation ability in the economic free trade park.

5.3. Result Analysis. The case analysis using the random forest weighting method shows that among the Guangdong economic free trade park, Tianjin economic free trade park, Shanghai economic free trade park, and Zhejiang economic free trade park, Guangdong economic free trade park has the strongest scientific and technological innovation ability, and there are great differences between Guangdong and Shanghai economic free trade parks. The main reasons are given as follows:

(1) The scientific and technological innovation ability of the economic free trade park is more strongly reflected in the industry, which can reflect the objectivity of measurement. The differences in the second economic development of different economic free trade parks have been better complemented [27].

(2) Advantages and differences of the economic free trade park. For example, Zhejiang is adjacent to Shanghai. Shanghai is an international shipping center, international financial center, international logistics center, and manufacturing center under construction, which has great attraction for scientific and technological talents and is very beneficial to the

Table 2: Expert evaluation indicators after dimensionless quantitative processing.

Factor	FTZSH	FTZTJ	FTZGD	FTZZJ
$C1$	1.97	0.57	1.15	0.42
$C3$	0.81	0.84	2.65	1.09
$C5$	1.60	0.72	1.68	0.77
$C7$	1.06	0.47	2.51	0.72
$C9$	0.82	0.81	1.42	1.41
$C11$	0.70	0.73	1.00	1.74

Table 3: Schemes are sorted by objectives.

Factor	Priority of the program to the objectives			
	1	2	3	4
$C1$ (0.17)	FTZGD	FTZSH	FTZTJ	FTZZJ
$C3$ (0.19)	FTZGD	FYZSH	FTZSH	FTZTJ
$C5$ (0.18)	FTZGD	FTZGD	FTZTJ	FTZSH
$C7$ (0.16)	FTZTJ	FYZSH	FTZSH	FTZGD
$C9$ (0.19)	FTZZH	FTZTJ	FTZGD	FTZSH
$C11$ (0.13)	FTZSH	FTZZJ	FTZGD	FTZZJ

development of the region. This reasonably explains the differences in regional GDP and scientific and technological innovation between Zhejiang economic free trade park and Shanghai economic free trade park [28]. The reasons for the abovementioned results are various [29–31], such as the time when the economic free trade park was established, the introduction and implementation effect of policies, science and education investment, infrastructure support, national management and service concept, etc.

6. Conclusion

With the development of the global economy, economic globalization and scientific and technological innovation ability become more and more important. In order to evaluate the scientific and technological innovation ability of the free trade zone, this paper uses the random forest weighting method to screen and establish the evaluation indicators of the scientific and technological innovation ability of the free trade zone, uses the weighted linear combination to determine the evaluation weight and score, constructs the scientific and technological innovation ability evaluation model of the free trade zone, and carries out the actual simulation evaluation for the current mainstream free trade zones in China, The results show that among Guangdong economic free trade park, Shanghai economic free trade park, Zhejiang economic free trade park, and Tianjin economic free trade park, Guangdong economic free trade park has the strongest level of scientific and technological renewal and development, while the indicators of Guangdong economic free trade zone and Shanghai economic free trade park are quite different, which shows that the evaluation model of scientific and technological innovation ability of the economic and trade zone designed this time has strong practicality. The evaluation model designed this time has important pioneering significance for the evaluation research of regional scientific and technological innovation capacity. However, since the number of free trade zones evaluated is still small, the evaluation of other free trade zones will be added in the next study. Through the evaluation, the problems in the model will be found and repaired in time.

Data Availability

The dataset used in this paper can be obtained from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding this work.

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Research Article

Data Science Analysis Method Design via Big Data Technology and Attention Neural Network

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Because of the rapid expansion of big data technology, time series data is on the rise. These time series data include a lot of hidden information, and mining and evaluating hidden information is very important in finance, medical care, and transportation. Time series data forecasting is a data science analysis application, yet present time series data forecasting models do not completely account for the peculiarities of time series data. Traditional machine learning algorithms extract data features through artificially designed rules, while deep learning learns abstract representations of data through multiple processing layers. This not only saves the step of manually extracting features, but also greatly improves generalization performance for model. Therefore, this work utilizes big data technology to collect corresponding time series data and then uses deep learning to study the problem of time series data prediction. This work proposes a time series data prediction analysis network (TSDPANet). First, this work improves the traditional Inception module and proposes a feature extraction module suitable for 2D time series data. In 2D convolution, this solves the inefficiency of time series. Second, the notion of feature attention method for time series features is proposed in this study. The model focuses the neural network's data on the effectiveness of several measures. The feature attention module is used to assign different weights to different features according to their importance, which can effectively enhance and weaken the features. Third, this work conducts multi-faceted experiments on the proposed method.

1. Introduction

With the advancement of IoT and 5G technologies, society has begun to enter an era of mutual sensing and interconnected big data applications. Sensors put on objects can collect information in real time. This information is time series data, which is used to monitor the condition of an object and anticipate its future state. Time series data are a collection of ordered data acquired by the same entity at various times in time. For example, an e-commerce company's total monthly sales volume, the daily change in PM2.5 in a city, and the hourly traffic flow on a specific road. It is widely found in various fields such as industry, medical care, and finance. Usually, time series data contain rich information, mining, and analyzing this information can help people understand phenomena and predict the future. In the field of medicine, medical experts use continuous measurements of a patient's electrocardiogram to classify a patient's possible diseases. In the stock market, time series data consisting of daily closing prices in the history of the stock are analyzed to predict the stock price in the future. In the field of Internet security, network anomalies can be detected by analyzing network traffic data. In supply chain management, sales data for various products are forecasted and categorized. This makes it possible to plan the production and storage of the product in advance, avoiding the backlog of product that leads to additional costs. In addition, by categorical comparison with historical product sales data, a more rational plan for the production and sales of new products can be made. In industrial production, to improve the quality and safety of production, it is significant to monitor and collect data on complex equipment systems in real time. These data record the historical dynamic information of the system, can reflect the operation of the equipment, and play a very good role in improving management efficiency and rapid fault classification and diagnosis [1–5].

Deep learning is now a hot research area in artificial intelligence, owing to its ability to digest data by constructing a system comparable to the human brain. Deep learning models, in particular, process data through numerous hidden layers and map it to a high-level feature space. This can extract more abstract high-level data representation features or characteristics, and then investigate the feature representation of the data's implicit information. In addition to this, since deep learning computes high-level feature representations by directly inputting data. This does not require a lot of effort to do feature engineering and saves time and effort compared to traditional machine learning processes. Deep learning can learn abstract feature representations of data implicit information and can effectively model the correlation between sequence variables and long-term data dependencies. This can better understand and express the implicit information of the data, which improves accuracy. Analysis of time series data mainly includes time series forecasting and time series classification [6–10].

Time series forecasting finds the development trend of time series data by analyzing historical time series data. This can predict the possible value at the next moment or some time later. Traditional time series forecasting methods only perform linearly weighted forecasts based on historical values. This makes it difficult to model the nonlinearity of sequence data, resulting in low prediction accuracy. Traditional machine learning methods make predictions about future values by constructing time series features. Although it has excellent non-linear modeling ability, it does not consider the time dependence of sequence data and the correlation between variables, so it is difficult to achieve high-precision prediction. Not only does deep learning have excellent non-linear modeling skills, but recurrent neural networks and their derivatives can also effectively model long-term sequence dependencies. The self-attention mechanism captures the correlation between sequence data effectively, which is critical for boosting prediction accuracy. Time series classification examines the characteristics, shape, and other properties of the entire time series before assigning it a discrete name. Traditional time series classification methods identify and extract relevant information from sequences. When different patterns appear in sequences, redesign is time-consuming and labor-intensive. In addition, when the model cannot effectively extract different patterns of the sequence due to the preset rule method, the classification accuracy of the sequence will be seriously reduced, resulting in large errors in subsequent tasks. Deep learning can mine the feature representation of the implicit information of the data, which not only saves the complex feature engineering steps. At the same time, the classification accuracy and generalization ability of the model are greatly improved [11–15].

2. Related Work

The authors of reference [16] present a method for multistep forecasting that iteratively creates a model by minimizing the sum of squares of in-sample residuals from one step ahead. When the prediction length is reached, the predicted values are fed back into the same model to forecast the next set of data points. A nonlinear learning ensemble technique for multistep advance forecasting of long-term wind speed time series was proposed in reference [17]. The Ensem LSTM approach is built from an ensemble of LSTM, SVRM, and EO, and it learns time series features using LSTM clusters with varying hidden layers and neurons. The results of the LSTM network predictions are then aggregated into a nonlinear learning regression top layer consisting of SVRM, and the top layer parameters are optimized using the EO algorithm. Reference [18] proposed MARNN for multistep traffic flow prediction. It treats RNNs as dynamic networks for simulating dynamic features in traffic time series like recursive strategies and considers multioutput strategies for reducing accumulated error with increasing step size. Reference [19] proposes a successful prediction of extremely volatile and irregular financial time series data, such as stock market indices, was achieved by using a new self-evolving recursive neuro-fuzzy inference system. When applied to dynamic financial time series data, the method optimizes the model's parameters with MDHS technology, allowing for more accurate predictions than can be made with conventional neuro-fuzzy systems. There was a straightforward approach to multistage time series forecasting proposed in reference [20]. Through the use of historical observations, they constructed a set of predictive models for each horizon and then sought to reduce the squared multistep lead error associated with those predictions. The approach does not rely on the square of the one-step-ahead inaccuracy, and there are several direct-strategy multistep forecasting methods available as well. An ensemble approach involving decision trees, gradient boosted trees, and random forests was proposed in reference [21]. The weighted least squares method is used to obtain the ensemble weights, and a direct strategy is used for multistage time series forecasting of wind speed. In reference [22], a multioutput deep LSTM neural network model for multistep time advance prediction was developed. The dropout approach, L2 regularisation, and mini-batch gradient descent are all model components. This eliminates the error accumulation and propagation problems that are common in multistep forward predictions induced by overfitting during deep network training. Reference [23] proposed a model with a self-encoding-decoder structure for multistep advance prediction of time series. The basic structure of the model is composed of CNN and LSTM. This uses a convolutional network to learn correlations between variables and an LSTM network to learn sequential time series features. Reference [24] proposed a data augmentation model based on C-GAN to improve prediction performance. The method first uses a conditional generative adversarial network to learn a generator model. The model is used to generate new training data and integrate it into the original training data, thereby increasing the diversity of the training set.

The prediction accuracy of a neural network model used to estimate the hourly load value in reference [25] was much greater when compared to previous models. A direct feed of historical time series data is used to train the neural network. A CNN-based convolutional neural network model was

created in the literature to handle the energy consumption time series prediction problem in the industrial production process [26]. By customizing convolution kernels in a number of directions, the model is able to extract the correlation features between input time series variables and the time-dependent characteristics of the same variable. The results of the experiments demonstrate that the model outperforms the neural network using a unidirectional convolution kernel in terms of generalization ability, prediction accuracy, and robustness. In order to make accurate predictions about periodic multivariate time series, the authors of reference [27] created a model called multiple CNN. Multiple CNNs are used to do a periodicity analysis of the time series, to extract proximity and long and short period information of the predictor variables, and to then combine the features of these three sections to produce predictions. Referring to reference [28], a fusion model was presented using CNN and LSTM to forecast immediate power needs. The experimental results demonstrate that the model outperforms a standalone CNN or LSTM in terms of prediction accuracy and robustness. Using a time series network to model long- and short-term dependency patterns in sequence data is proposed in reference [29]. It employs convolutional neural networks and recurrent neural networks to model intermediate-range dependencies in sequences, and it creates a novel recursive structure to capture very long-range dependencies in sequence data. In multivariate time series forecasting, it was proposed in reference [30] that CNN be used to extract time-invariant features from a single time series, and then RNN be used for time series prediction by merging the convolutional features of multiple time series. Two-stage attention was used to provide a model for RNNs in reference [31]. The usual attention approach is used at the decoder's input stage, where unique context vectors are generated at random intervals. The incorporation of an attention mechanism in the encoder's input stage of the two-stage attention model allows for the selection of feature factors and historical long-term temporal relationships. Reference [32] describes a unique focus strategy for multivariate time series forecasting. To get the hidden state output at any given time, the author first applies RNN to the original multivariate time series. The features for the hidden state variables are extracted using several convolution kernels, and then the attention mechanism is utilized to zero in on certain variables for the final prediction.

3. Proposed Method

First, this work improves the traditional Inception module and proposes a feature extraction module suitable for 2D time series data. This overcomes the inefficiency of time series in 2D convolution. Second, this paper proposes the concept of a feature attention mechanism for time series features. The model places the data focus of the neural network on the effectiveness of different metrics. The feature attention module is used to assign different weights to different features according to their importance, which can effectively enhance and weaken the features.

3.1. CNN Algorithm. Local connections, weighted nodes, pooling operations, and a multilayered architecture are all hallmarks of CNN networks. Therefore, the CNN network is better equipped to extract local features thanks to its local connections. Since the goal of the pooling operation is to minimize the dimensionality of the data, the sharing of weights has the additional benefit of drastically reducing the number of network parameters. As a result, the CNN network is also capable of representing time series data in a nonlinear fashion. The convolution kernel connects the preceding hidden layer's local region to the neurons of the convolutional layer. The convolution kernel is made up of weight matrices. When conducting the convolution procedure, the convolution kernel's sliding window travels through each section of the input matrix. It is multiplied by the matching elements of the area and aggregated after flipping to extract characteristics. Typically, many convolution kernels are established in the convolution layer, and distinct convolution kernels gain varied weights through network training, allowing different characteristics to be retrieved from the input. To improve nonlinear representation, the result of convolution operation is usually input into the nonlinear activation function to obtain a feature map. Therefore, multiple convolution kernels perform feature extraction on the previous hidden layer, and a series of feature maps can be obtained. The combination of multiple convolutional layers enables the CNN network to gradually extract more complex features.

$$x_j^k = f\left(\sum_i x_i^{k-1} k_{ij}^k + b_j^k\right). \tag{1}$$

The neurons of the pooling layer are also connected to the preceding hidden layer's local area, and a statistical value of the area is obtained using a specific mathematical procedure. This achieves dimensionality reduction while performing secondary feature extraction and enables the network to obtain a certain invariance to the feature changes of the input samples.

$$x_j^k = f\left(\beta_j^k down\left(x_j^{k-1}\right) + b_j^k\right). \tag{2}$$

Common pooling methods include max pooling, mean pooling, and random pooling. Maximum pooling achieves downsampling by maximizing the local area connected by the pooled kernel. Mean pooling implements downsampling by averaging the local regions of pooled kernel connections. Random pooling determines the probability matrix according to the element values in the local area, and randomly selects the output according to the probability matrix.

After convolution, the features will pass via the activation function layer, which is used to nonlinearly change the feature map formed by the convolution. The ReLU function is commonly employed as the activation function. The objective of the activation function in this case is the same as it is in the fully linked network: to boost the non-linear operation of the network. The ReLU function is generally selected because it has the characteristics of simple operation and easy convergence during training.

$$ReLU(x) = \max(0, x). \tag{3}$$

In the forward propagation process, CNN will randomly select data samples as input to enter the network, and the samples will enter the network in turn to obtain the output of the network. It should be noted that the most important network parameters are randomly initialized, and the initial values of network parameters will be randomly distributed in a small numerical range. Because a big initial value will effect network training, and if the parameters of each network are the same, training will not take place. When the outcome of this forward propagation is acquired, CNN will use the stochastic gradient descent process to update the network's parameters. The concept of minimizing the objective function is central to this method. The loss function determines how far the network's prediction was from the right label. Since the loss function is the objective function optimized by the stochastic gradient descent technique during training, choose the right one is essential. Backpropagation will update the network weights according to the current loss function through the algorithm to complete a round of network training.

3.2. LSTM Algorithm. LSTM is one of the improved models of RNN. As an improved model of RNN, it is mainly used to solve problems such as gradient disappearance. LSTMs, on the other hand, introduce new cellular states into the RNN and hence store long-term states. A gate structure controls the inside of the unit, which is used to increase or decrease the influence of different states on the present unit and to further process the information transmitted at the prior time point. The structure of the LSTM unit is demonstrated in Figure 1.

The forget gate determines which information should be discarded and which should be maintained in the cell unit state. It uses the Sigmoid function to handle the model's input at the present time and output at the previous moment as a vector of [0, 1]. The median of this vector represents the amount of information in the cell state to keep or discard.

$$f_t = \sigma\left(W_f\left[h_{t-1}, x_t\right] + b_f\right). \tag{4}$$

Input gates are primarily responsible for selectively recording new information into the cell state. It consists of two fully connected layers, the first layer decides which input information to retain, and the second layer will generate new candidate cell states based on the input data at this moment. The two layers together form an input gate to control how much of the input at the current moment will be retained to the final cell state.

$$\begin{aligned} i_t &= \sigma\left(W_i\left[h_{t-1}, x_t\right] + b_i\right), \\ \tilde{c}_t &= \tan h\left(W_c\left[h_{t-1}, x_t\right] + b_c\right), \\ c_t &= f_t c_{t-1} + i_{t-1}\tilde{c}_t. \end{aligned} \tag{5}$$

The output gate is responsible for controlling what information in the current cell state can enter the hidden layer of the output layer. It determines the output part of the cell state through a sigmoid layer. Then, go through the tanh layer and finally perform a dot product operation on the two to get the output.

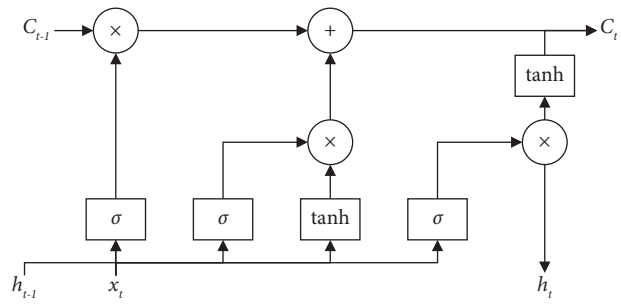

Figure 1: LSTM unit.

$$\begin{aligned} o_t &= \sigma\left(W_o\left[h_{t-1}, x_t\right] + b_o\right), \\ h_i &= o_t * \tanh\ \left(c_t\right). \end{aligned} \tag{6}$$

LSTM networks are all unidirectional. Even if a multilayer recurrent neural network is added, the internal operation process is still only in a forward time sequence. The forward and reverse double guarantees are performed for sequence data to obtain information and improve the accuracy of sequence data prediction. BiLSTM came into being. It is composed of a forward LSTM and a backward LSTM in the horizontal direction. When inputting, BiLSTM will perform pre- and postorder calculations at the same time, and the two jointly determine the output through rules. Each unit of BiLSTM is composed of two LSTM cell units that are calculated in the forward and backward directions, and the horizontal comparison with a single LSTM unit can reflect the influence of the current moment and subsequent states on the current cell unit.

3.3. TSDPANet for Time Series Data Forecast. The TSDPANet model is designed to solve the decline for prediction accuracy due to the complexity of features when the network faces multiple input features. In this work, the attention mechanism is used for feature selection, which assigns higher weights to the features with more important prediction results and lowers the weights of irrelevant variables. In addition, the model is utilized after the input layer, while the feature weighting is calculated. This outputs the different weights the network assigns to each feature after iterative updates. The TSDPANet composite model established in this work is divided into three parts according to their functions: feature extraction module, feature attention module, and time series prediction module. The structure of TSDPANet is demonstrated in Figure 2.

This work proposes a fast feature extraction module for converting 2D feature photos to 3D features. The study integrated a huge number of input variables into the model, and the same type of indicators were placed next to each other once the data was processed. This lays the groundwork for extracting common features from nearby features using convolutional layers. The modified Inception feature extraction module will be used in this paper to be inserted between the input layer and the attention layer. This can

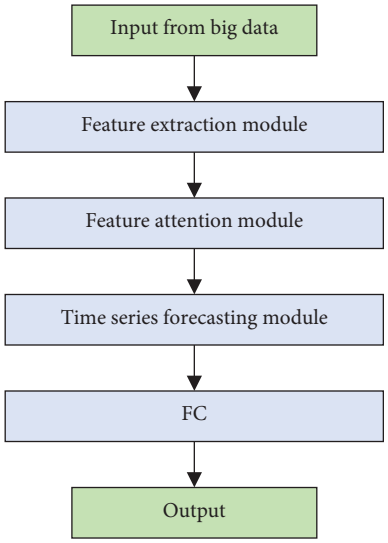

Figure 2: TSDPANet pipeline.

achieve independent extraction of correlated features in two different directions of input variables and time series. The Inception V1 module further extracts the information contained in the local location by computing between adjacent pixels in the data. Unlike image information, time-series data are only correlated at the same time or on the same metric. Therefore, ordinary matrices cannot extract the features of adjacent positions very well. Even add invalid information to the original information due to the participation of irrelevant information, thereby reducing the prediction accuracy. This module expands two-dimensional information into three-dimensional. Different from one-dimensional convolution, the two-dimensional convolution module will only properly blur the original feature matrix, but it will not regenerate the content of the feature direction like the former. Therefore, adding this feature extraction mechanism before the feature attention module will not cause the latter to fail in the feature direction.

The Inception structure must be modified in this work due to the mismatch between time series data and image samples. The optimized Inception's particular structure is shown in Figure 3, which ensures that the original information is not destroyed and allows for the efficient extraction of information between each index variable.

Initially, the attention mechanism assigns various weights to each layer based on the channel direction of different feature images created by convolution. By giving greater weights to feature layers that contain more effective information, SENET achieves efficient feature extraction and better classification accuracy. The CBAM module not only inherits the attention advantage of SENET model channel direction but also establishes the attention mechanism of feature map direction.

The feature attention mechanism in this paper adopts the channel attention module of the CBAM module, which consists of two encoder-decoder structures. The feature map is subjected to global max pooling and global average pooling, respectively, to obtain two different weight vectors whose length is the number of channels. Then, the multilayer perceptron is used to reduce and increase the dimension at a specific ratio, and activate the sigmoid function to jointly realize the nonlinear change of the weight. The two vectors are linearly added and multiplied by the original three-dimensional feature map, and the final output is a feature map that is added to the index by the attention weight. It first employs the Permute layer to transpose the information from the feature extraction module and exchange the feature dimension with the channel dimension. Then, on the spatial plane where the time and convolution layers are located, global max pooling and average pooling are conducted, and two vectors are created based on the order of the indicators. After sorting the Reshape layer into a one-dimensional vector, it is passed to the FC layer for dimensionality reduction, and the next FC layer is used to raise the dimension to the vector with the original number of dimensions. The obtained weight vector is dot-multiplied with the original feature map, and the Permute layer is used to exchange the dimension of the feature and the dimension of the channel back to the original position. It should be noted that the two vectors need to share weights when going through the FC layer for nonlinear transformation to ensure weight consistency.

This work selects BiLSTM to insert the composite model as the last module. This module receives the attention-weighted feature map, calculates it, and passes it to the fully connected layer for processing and outputs the final predicted value. The specific structure of the time series prediction module is demonstrated in Figure 4.

The number of neurons in the two Bi-LSTM layers is 64, which are used to receive feature information, and calculate the time series in both positive and negative directions to achieve the purpose of analyzing time series in a similar context. The dropout layer randomly removes each neuron of BiLSTM with a certain probability, so that every neuron in the BiLSTM layer can participate in the calculation and reduce the risk of overfitting. The Flatten layer reduces the BiLSTM layer's output to one dimension for use in the computation of future fully connected layers. The Flatten layer is utilized instead of the BiLSTM outputting only the last layer since this paper argues that the fully linked layer should have more options. The important information of each time point is obtained by iterative update, and the prediction accuracy is improved. The last two FC layers further extract the output information of the time series to obtain the optimal solution.

4. Experiment

4.1. Experiment on TSDPANet Training. This work first analyzes the training process of TSDPANet, this process is significant and necessary. And, the analysis target is the training loss. Its change process is demonstrated in Figure 5.

When the training epoch increases, the training loss of TSDPANet also decreases gradually. When the training level reaches around 120 epochs, the value of this parameter no longer changes significantly. This shows that TSDPANet has reached convergence at this time.

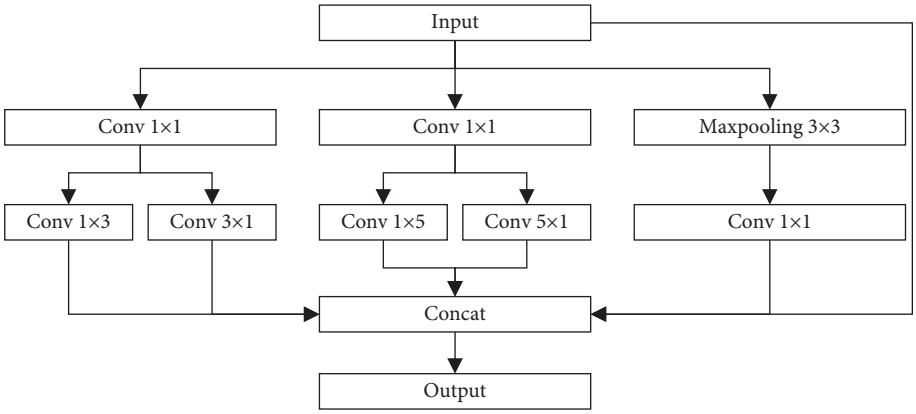

Figure 3: Feature extraction module.

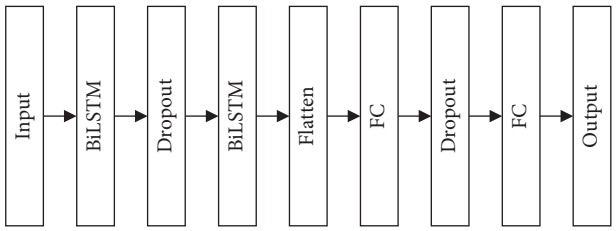

Figure 4: Time series prediction module.

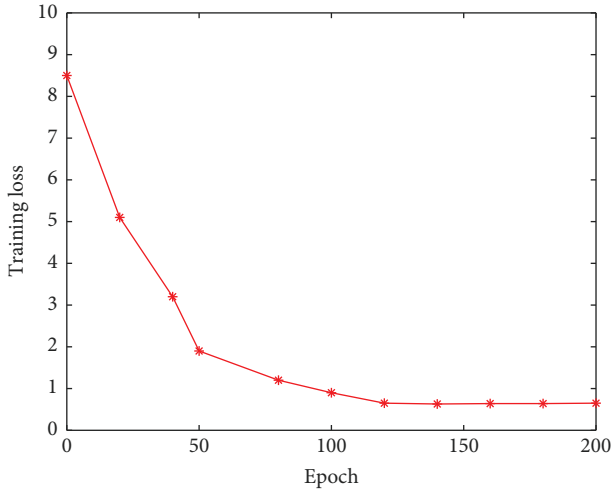

Figure 5: Training loss for TSDPANet.

4.2. Method Comparison. To verify the superiority of TSDPANet for time series data prediction, this paper compares the three methods of RNN, LSTM, and BiLSTM with TSDPANet. The indicators compared are RMSE and MAE, and the comparison data are demonstrated in Table 1.

Compared with other time series data prediction methods, TSDPANet achieves the lowest RMSE and MAE. This verifies the feasibility and superiority of applying TSDPANet to time series data prediction and also verifies the correctness of the method design in this paper.

4.3. Experiment on Feature Extraction Module. TSDPANet utilizes the improved Inception module as the feature extraction module. To verify the superiority of this improvement, this work compares the performance when using the traditional Inception module and the improved Inception module. The data obtained from the experiments are compared in Figure 6.

Table 1: Method comparison.

Method	RMSE	MAE
RNN	25.30	20.20
LSTM	22.70	17.50
BiLSTM	18.20	14.60
TSDPANet	15.60	12.30

TSDPANet can accomplish a certain degree of drop in both RMSE and MAE indicators after employing the upgraded Inception module compared to the standard Inception module. This comparative data verifies the correctness of the improvements to the Inception module.

4.4. Experiment on CBAM. TSDPANet utilizes the CBAM module as the attention module. To verify the superiority of CBAM, this work compares the performance when using CBAM and not using CBAM. The data obtained from the experiments are compared in Figure 7.

Compared with not using the CBAM module, after using the CBAM module, TSDPANet can achieve a certain degree of decline in both RMSE and MAE indicators. This comparative data verifies the correctness of using the CBAM module.

4.5. Experiment on Time Series Prediction Module. TSDPANet mainly uses BiLSTM as the processing module of time series data features. To verify the superiority of BiLSTM for time series data prediction, this work compares the performance of TSDPANet when using LSTM and BiLSTM. The data obtained from the experiments are listed in Table 2.

TSDPANet can achieve a certain degree of reduction in both RMSE and MAE indicators after employing the BiLSTM module in comparison to the standard LSTM module. This comparative data verifies the correctness of the BiLSTM module.

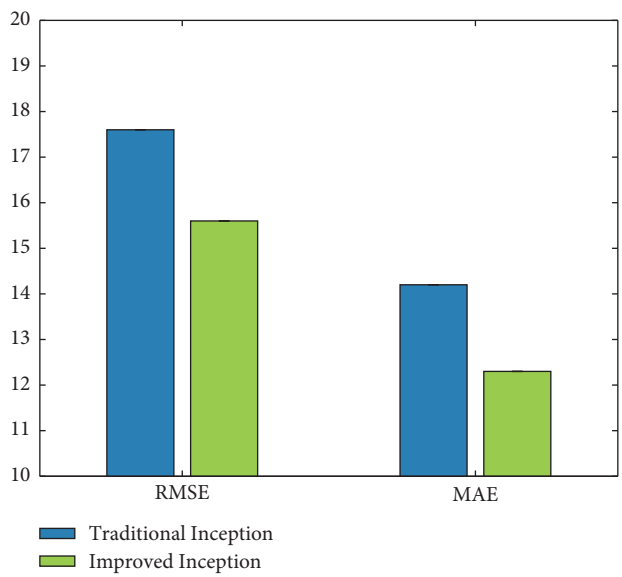

Figure 6: Comparison of Traditional Inception and improved Inception.

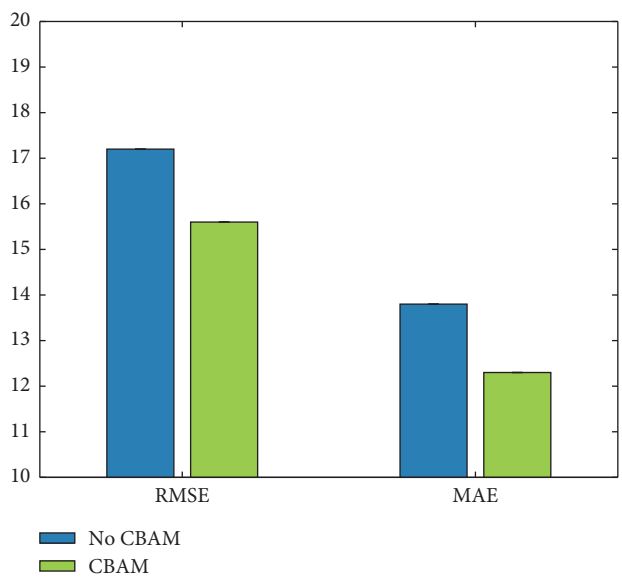

Figure 7: Comparison of using CBAM and not using CBAM.

Table 2: Comparison of using LSTM and BiLSTM.

Method	RMSE	MAE
TSDPANet-LSTM	17.10	13.50
TSDPANet-LSTM	15.60	12.30

5. Conclusion

We are now approaching the age of artificial intelligence, which is defined by increased connection and a greater capacity for shared understanding as a result of breakthroughs in big data and the Internet of Things. The current networked interconnectedness of physical goods and systems promises to provide a deluge of time series data. Decision-makers can direct and assist in making aggregate decisions through a thorough scientific examination of these time series data. As a result, the time series analysis issue piqued the interest of an increasing number of academics. However, most time series analysis problems necessitate custom-built features via traditional machine learning. As computational capabilities increased, deep learning found increasing success in a variety of contexts. Because deep learning can learn high-level feature representations of data's implicit information from beginning to end, it can replace laborious manual processes like feature engineering and extraction. Therefore, this paper will use deep learning methods to scientifically analyze time series data. This paper uses big data technology to collect corresponding time series data and then uses deep learning to study the problem of time series data prediction. This work proposes a time series data prediction analysis network. To begin, this work improves on the classic Inception module and presents a feature extraction module appropriate for 2D time series data. In 2D convolution, this solves the inefficiency of time series. Second, the notion of the feature attention method for time series features is proposed in this study. The model focuses the neural network's data on the effectiveness of several measures. The feature attention module is used to assign different weights to different features according to their importance, which can effectively enhance and weaken the features. Third, this work conducts multi-faceted experiments on the proposed method.

Data Availability

The datasets used during the current study are available from the author on reasonable request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Research on Industrial Structure Transformation and Upgrading of Chinese Tourism Villages Based on Big Data Analysis

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With the rapid modernization of China's economic development, especially urbanization, China's rural economy is clearly lagging behind the overall development level of the Chinese economy, with low industrial efficiency, irrational industrial structure, and unbalanced industrial development. The development of rural tourism brings new opportunities for industrial integration and industrial transformation and upgrading in rural China. This study draws on a case study of Zhonghaoyu village in Shandong province, China, to summarize the important experience of the transformation and upgrading of the industrial structure of Chinese tourism villages by observing and analysing the changes in the industrial structure of Zhonghaoyu village before and during the development of rural tourism. Prior to the development of rural tourism, Zhonghaoyu Village was a mountainous village that relied almost entirely on farming. Through years of rural tourism development, the service industry in Zhonghoayu Village has grown, reflecting the driving effect of rural tourism, but the service industry is small and agriculture still dominates, and its role and position in the overall economic development of the village has not been highlighted. As the transformation of the shareholding system of rural tourism in Zhonghaoyu Village was completed, the original decentralized operation of farmers was replaced by corporate operation, and the service industry led by tourism was developed comprehensively and rapidly, and the development of rural tourism promoted the completion of the transformation and upgrading of the industrial structure of Zhonghaoyu Village.

1. Introduction

China's rural industrial structure transformation and upgrading is an inevitable trend of the era. With the rapid progress of the modernization of China's economic development, especially urbanization, China's rural economy is obviously lagging behind China's overall economic development level. Rural industrial structure development is unbalanced and inefficient, which can no longer meet the new requirements of China's vast rural economic and social development. The complexity and particularity of China's industrial structure problem lies in the coexistence and interweaving of the urban-rural dual structure, the regional gap, and the reform of state-owned enterprises. The dual structure of urban and rural areas is an industrial problem with unbalanced development of agriculture and non-agriculture. The rural industrial structure optimization, high-quality development, and industrial integration have become compelling strategies for the development of China's rural industries. Some studies show that China's rural industrial structure's evolutionary history can be divided into four stages: agricultural industry dominated period, rural industrialization rapid promotion period, rural industry development and structure optimization period, and rural industry integration and high quality development period [1]. The rural industrial structure is the composition and interrelation of various industrial sectors in rural areas. It is an important part of the national industrial structure. It

mainly includes (1) the structure of primary industry, secondary industry, and tertiary industry, (2) the internal structure of each industry, and (3) the production department or industry structure of each industry. This study classifies the transformation and upgrading of China's rural industrial structure into the following three stages. The first stage is the restructuring and upgrading of the internal structure of agriculture. The initial restructuring of China's rural industries began with the upgrading and optimization of the internal structure of agriculture. In other words, it evolved from the cultivation industry, especially the grain industry, which had an absolute proportion in the earliest stage, to the overall development of "big agriculture." In the mid-80s, at the beginning of China's reform and opening up, with the shift from state unified purchase and distribution of agricultural products to market regulation, the main objective of the restructuring of the agricultural industry began to be to meet the diversified demand for agricultural products [2]. The principle of rural industrial structure adjustment is to adhere to the principle of adapting measures to local conditions, the principle of gradual and sustainable development, the principle of combining market regulation with macro-control, and the principle of quality and efficiency. The restructuring of the agricultural industry is to balance the composition and proportional relationship between the various sectors of agriculture, forestry, husbandry, and fishery and to strengthen the development of secondary industries and animal husbandry in addition to food crop production [3]. While achieving a reasonable proportional relationship within agriculture, it also relies on advanced science and technology to transform traditional agriculture and develop new industries [4]. In the late 1990s, the development of China's agricultural industry puts forward new development goals of industrialization and modernization, and the reform of agriculture began to turn towards such as improving quality and added value and began to focus on the sustainable development of Chinese agriculture. The countermeasures and suggestions for the adjustment of rural industrial structure include giving full play to the role of the government in the adjustment of rural industrial structure, relying on scientific and technological innovation, promoting industrial upgrading, comprehensively improving the quality of agricultural products, and realising the common development of leading enterprises and small enterprises. The second stage is the evolution of agriculture towards industrialization. As the 21st century progressed, agricultural value-added growth suffered a slowdown or even stagnation as the development of agriculture in rural China hit a bottleneck and industrialization began to gain importance. Over this period, the restructuring of various industries within agriculture, such as plantation, forestry, animal husbandry, and fishery, brought minimal increase in agricultural output and economic growth to the countryside, with negative effects on rural economic growth [5]. China's rural industries have begun to break away from separate agrarianism and started to vigorously develop industry, thus taking an important step towards the restructuring and upgrading of rural industries, and the industrialization of China's countryside is accelerating rapidly. The third stage is rural tourism development and industrial integration. The role of rural industrialization includes the following: rural industrialization has changed the economic development of rural areas, rural industrialization has promoted the marketization process of rural economy, and rural industrialization has not only cultivated a new growth point of non-agricultural industry for rural economy but also greatly increased the economic income of farmers. Recently, China's rural industrial structure has been transformed and upgraded in the trend of industrial integration. Some studies have concluded that industrial integration is a form of overlapping with agriculture as the main body of integration, with industry supporting the economy and the service industry as the main direction of development [6]. Rural tourism caters to the concept and needs of ecological protection and industrial development in rural areas, bringing new opportunities for industrial integration and industrial upgrading in rural China. The non-agricultural industry has increased farmers' income, and the investment and consumption demand of rural social undertakings have promoted and stimulated the development of rural social undertakings; The non-agricultural industry strengthens the external exchange of rural areas and leads to the progress of farmers' ideas and behavior. It is an important component of China's rural economic development and has significant implications for the transformation and upgrading of China's rural industrial structure. There is a more profound impact on the transformation and upgrading of rural industries from the horizontal and vertical values created by rural tourism [7]. Recreational agriculture is an advanced mode of agricultural production that is different from traditional agriculture [8]. The combination of agriculture and tourism is conducive to the optimization and upgrading of the rural industrial structure and plays a significant role in the rationalization of the rural industrial structure [9]. Rural tourism intervenes in traditional rural production activities in a new economic form and also promotes the non-agricultural of rural industries, drives the transfer of surplus rural labor, and increases farmers' income [10]. Rural tourism takes the natural and cultural objects with rural characteristics as the tourist attractions. Relying on the beautiful landscape, natural environment, architecture, culture, and other resources in the rural area, on the basis of traditional rural leisure tourism and agricultural experience tourism, it expands and develops new tourism modes such as conference vacation, leisure, and entertainment. In this study, we analyse what happened to the industrial structure of Zhonghaoyu village before, during and after the development of rural tourism, and summarize the important experience of the transformation and upgrading of the industrial structure of Chinese tourist villages.

2. Research Case and Methodology

In this study, we take Zhonghao Yu village in Shandong, China as a research case, analysing the function and influence of the development of rural tourism in the transformation and upgrading of the rural industrial structure of China's tourism villages in the process of developing rural

tourism. Meanwhile, we summarize both experiences and challenges of rural tourism for modernizing China's rural industrial structure and provide insights into new issues that have emerged in the industrial restructuring and upgrading of China's tourism villages. The development trend of rural tourism is to promote the construction of a new socialist countryside, agricultural production, rural scenic spots, farmers' multi-industry, and resource production. The rural style becomes the background of tourism, the concept of landscape is used to build the countryside, the concept of tourism is used to manage agriculture, the concept of talents is used to cultivate farmers, and the countryside is decorated as a tourist resort hinterland. Exploring the path of transformation and upgrading of China's tourism village industrial structure as a result of rural tourism, in order to better promote the industrial economy of China's tourism villages.

Zhonghaoyu Village is located in Zhishang Town, Zibo City, Shandong Province, China, in the vicinity of the main peak of Lushan Mountain. One hundred and thirteen households and 268 people are registered in the village, which covers a total area of 2,800 mu. This village has developed from a poverty-stricken village based solely on agriculture to one that is famous for its wealth, in which the development of rural tourism has played a crucial role, enabling the village to achieve economic revitalisation, industrial prosperity, and the removal of poverty and wealth for its inhabitants. The production and living materials in rural areas should be transformed into tourism products with sightseeing, experience, and leisure value, and differentiated development should be carried out in certain areas. There are rural agricultural tourism, folk custom tourism, agritainment tourism, village and township tourism, leisure tourism, popular science education tourism, and other modes. In 2003, Zhonghayu Village was a mountainous village that relied almost entirely on farming, with a total output value of less than 900,000 yuan, with agricultural output accounting for 95% of the total. As a mountainous village that relied almost entirely on farming, arable land, and forest and fruit land were the most important means of production in Zhonghaoyu village at that time. Because of its geographical location, the land available for production in Zhonghayu was severely limited. There are only 108 mu of cultivated land in the village, with a per capita cultivated area of about 0.4 mu and an average household farmland area of 0.96 mu. The total area of woodland in the village is 285 mu, with a per capita area of 1.06 mu and an average household area of 2.52 mu. In 2004, Zhonghayu Village launched the leisure agriculture and rural tourism project, but after a few booming years at the beginning, the rural tourism industry has gradually decreased, and its development has been slow or even stagnant. The village's total output value was 1.3 million yuan up to 2011, with agriculture still occupying the main position, accounting for 79% of the total. After eight years of rural tourism development, the tertiary industry in Zhonghaoyu Village has expanded, reflecting a positive effect of rural tourism development, but the relatively small volume of the tertiary industry, accounting for only 18%, has not been highlighted in the overall economic development of the village. The village's productivity still comes mainly from farming in agriculture, with no improvement in industry and an increase in services mainly from tourism. In general, the unreasonable industrial structure of Zhonghaoyu Village has led to slow economic development. The development of rural tourism in Zhonghaoyu Village has not formed a certain scale, and the economic effect is not obvious. Zhonghayu Village's real ascendancy began with the shareholding reform in 2011, when the village set up Zibo Boshan Yuyu Valley Tourism Development Co Ltd, which, through the shareholding reform, achieved corporate operation and standardized management, and the development of the rural tourism industry entered the fast lane. By 2019, the total output value of Zhonghaoyu village also increased from 1.3 million yuan in 2011 to over 40.7 million yuan, of which the service industry, mainly tourism, achieved an output value of 34.7 million yuan, accounting for 86%. Through the development of rural tourism, Zhonghaoyu Village has achieved the transformation and upgrading of its industrial structure.

This study is based on a research method using survey and comparative and inductive methods. The industrial data and information in this stud are mainly obtained from the official statistics of the village committee of Zhonghayu Village. In order to more clearly observe and comparatively analyse the changes in the industrial structure of Zhonghaoyu village and to provide insight into the objective pattern of transformation and upgrading of the industrial structure of Zhonghaoyu village and the mechanism of the role of rural tourism, three observation points were set in this study: 2003, 2011, and 2019. The year 2004 was the initial year of rural tourism development in Zhonghaoyu village, 2003 was the year before the development of rural tourism, 2012 marked the completion of the transformation and corporatization of rural tourism, 2011 was the milestone before the transformation of rural tourism, and 2019 was the year when the tourism industry completed its normal operation before the outbreak in China. Industrial transformation and upgrading is defined as the upgrading of industrial structure, that is, the development in the direction more conducive to economic and social development. Industrial transformation and upgrading includes technology upgrading, market upgrading, and management upgrading. Most of the personnel think that the key is technological progress, and on the basis of introducing advanced technology, they should digest and absorb it and conduct research, improvement, and innovation to establish their own technological system. Furthermore, we also conducted in-depth interviews with the main village cadres, managers of tourism companies, business operators, practitioners, and some villagers so as to analyse the internal dynamics of the development of rural tourism and to conclude the important experience of the transformation and upgrading of the industrial structure of Zhonghaoyu village.

3. The Development of Rural Tourism in Zhonghoayu Village

3.1. The Early Stages of Spontaneity and Exploration. Zhonghaoyu Village has gone through two main stages in the development of rural tourism. The early stage was one of

spontaneity and exploration, while the later stage was one of rising and rapid development. In 2003, Zhonghaoyu Village began to emerge as a rural tourism operation, with only a few villagers participating, carrying out tourism operations such as farm caravans, and catering mainly on a spontaneous basis, each operating independently, with income going to individual villagers. Since 2004, the village collective has started to get involved in rural tourism activities, taking the initiative to explore the path of rural tourism development and guiding and mobilizing villagers to take the initiative to participate so that the number of farmers operating rural tourism began to increase, and the service content and scope of business expanded. However, farmers still operate independently and the income is owned by individuals. At first, the impetus for the development of rural tourism activities in Zhonghaoyu Village stemmed from the poor village's instinct. In fact, the core of the "transformation" in the transformation and upgrading of the industrial structure is to change the "type" of economic growth, that is, to transform high input, high consumption, high pollution, low output, low quality and low efficiency into low input, low consumption, low pollution, high output, high quality, and high efficiency and to transform the extensive type into intensive type, rather than simply changing industries. Zhonghaoyu Village develops rural tourism only following the trend of the rural tourism boom, without much vision at the beginning. As a result, the development of rural tourism in Zhonghaoyu Village gradually encountered difficulties, with a confused tourism market, vicious competition between villagers, and low quality tourism products. It was only 225,000 yuan in 2011, and the development of rural tourism was in the process of groping, and the transformation and upgrading of the industry encountered difficulties and faced failure.

3.2. The Late Stage of Rising and Rapid Development

3.2.1. Implementing a Shareholding System and Establishing a Benefit-Sharing Distribution Model Has Mobilized Villagers to Participate. In 2011, Zhonghaoyu Village established the Youyougu Tourism Development Company, which officially operated in 2012 and began to try the shareholding system reform of rural tourism operation, opening up the company operation mode under the collective leadership, breaking through the bottleneck and the rapid growth of rural tourism business [11]. The village has achieved a relative separation of ownership and management by setting up a joint-stock tourism company, breaking the operational limitations of rural tourism operators on their own and strengthening the unified management and administration functions of rural tourism. Zhonghaoyu village valued the resources available to the whole village as shares. These include all kinds of unused houses, such as the offices of the two village committees, schools, health rooms, and villagers' houses. Villagers' contracted land, such as gardens, mountain forests, ponds, and vegetable fields, economic trees on contracted land, such as peach and chestnut trees, and even labour, which are assessed for the value. All categories of contracted land are calculated at the total price of the original contract fee for 20 years. Villagers have the possibility to invest their own resources in the company, with no restriction on the form of shareholding. The joint-stock system reform is to establish a standardized corporate governance structure, raise funds, optimize the allocation of resources, and establish the property rights of legal persons. In addition, the villagers can participate in the shares progressively from year to year, and the tourism company is constantly absorbing new resources [12]. As of 2013, Zhonghaoyu Village finally realized the participation of all villagers, the oldest being 94 years old and the youngest only 2.5 months old. The village resources integration, joint-stock reform, and the integration of various kinds of assets totaling 6.416 billion yuan of equity, as the start-up capital of Yuyugu Tourism Development Company, are also the basis for the rise of Zhonghaoyu Village's rural tourism industry. Up to 2019, the Yuyugu Tourism Development Company's assets have increased from less than 6.5 million yuan initially to 210 million yuan now. With the transformation of the shareholding system of rural tourism in Zhonghaoyu Village, villagers have taken shares and become shareholders, which has not only enabled the reasonable and effective allocation and utilization of limited tourism resources but also effectively mobilized the enthusiasm of all villagers to develop rural tourism under the incentive and drive of their own interests. A governance structure that meets the requirements of a joint stock limited company must be established. For example, the general meeting of shareholders shall be established as the power organ of the company, and the board of directors and the board of supervisors shall be established. The board of directors shall appoint the manager as the operation and management of the company in accordance with the provisions of the articles of association. The manager shall preside over the production and operation management and organize the implementation of the resolutions of the board of directors. As the internal supervision organization of the company, the board of supervisors exercises the supervision power over directors, managers, and other senior management personnel. One of the keys to the success of the shareholding system transformation in the village of Zhonghayu is the distribution of benefits, ensuring that the distribution of benefits is fair and equitable, attaching importance to the practical interests of villagers, realising benefit sharing, collective income generation, and enrichment of villagers. In the share system transformation, the share composition of the Yuyu Valley Tourism Development Company includes three parts: proportional shares account for 80%, collective shares account for 17%, and welfare shares account for 3%. All proceeds from the collective shares of the company, which is used to finance the company's operations and the construction of tourism infrastructure. In addition, the welfare share is used for the welfare of the elderly. Twenty percent of the proportional shares are used as head shares for dividends, a fixed income enjoyed by all villagers, while the remaining 80% of the proportional shares are used for secondary dividends, which are distributed according to the proportion of villagers' shares, forming a distribution

mechanism of "minimum income + the second dividends." Villagers' income can include share dividends and share of business income and wage income, reflecting the fact that those who can work more, earn more. It not only protects and increases the income of villagers but also better mobilizes them to make concerted efforts to improve rural tourism. Zhonghaoyu Village, based on household registration, protects all villagers in the village to enjoy the rights and interests of the shares, enjoy the proceeds of collective assets and dividends, and enjoy the right to elect and be elected to the board of directors of the tourism company. The main business must have a certain high-tech content. The main business must have enough market space. The main business must have continuous innovation ability and high-added value. The main business must have high growth. Following the establishment of the Yuyugu Tourism Development Company, a shareholder's certificate was issued for all Zhonghaoyu villagers, and the shares held by the villagers can be circulated and transferred within the village collective, and the shares can be inherited by the designated heirs, fully protecting the interests of the villagers.

3.2.2. Implementing Corporatized Operations and Standardized Management Has Improved the Efficiency of Tourism Operations and the Quality of Products. Zhonghaoyu Village explores the innovative model of rural tourism industry development, undergoes the transformation of shareholding system, establishes the modern enterprise system, draws up the Zhonghaoyu Village Development Plan, explores the advanced management model, and realizes the corporatization of operation, standardized management, and project development, which is of great significance for the development of Zhonghaoyu village rural tourism [13]. The company is responsible for development and management as well as market development, while the farmers are responsible for service and reception, with a clear division of labour and responsibilities. It is responsible for the development and operation of all tourism projects in the village, including lodging, catering, commerce, and amusement. In addition, the company is also in charge of the development and operation of all tourism projects in the village, including lodging, catering, business, and entertainment. All visitors to the village are received and distributed by the tourism company, and the prices of tourism products are also set by the tourism company, and fees for tourism activities are collected uniformly, which well avoids vicious competition among farmers. In this way, the tourism company contracts the operation to the farmers, who are responsible for the reception and service according to the prices and operation standards set by the tourism company. In order to safeguard and enhance the quality of rural tourism products and services and to ensure a good sense of experience for tourists in rural tourism activities, the tourism company has developed the "Standards for the Management of Accommodation Services," which provides training on tourism services and hospitality to villagers involved in tourism services throughout the village, in order to achieve standardized management. In order to be able to rationalise the operation, the tourism company is taking charge of the overall planning of the village's business activities, and at the end of each year, statistics and analysis of the village's tourism business situation are carried out to guide and plan the tourism development for the next year, such as quantitative planning of the village's planting industry and rational planting to avoid oversupply, or market shortage, in order to achieve a balance between supply and demand for tourism business activities.

Zhonghaoyu Village has gained significant success in the practice of rural tourism development. By summarising the development experience of rural tourism, Zhonghaoyu Village has formed a replicable and replicable "Haoyu Model." By 2019, more than 1000 villages across the country have visited Zhonghaoyu Village to study the advanced experience of rural tourism development. Yuyu Valley Tourism Development Company began to progress towards a new goal of group development and exporting its business model. Model of Zhonghayu in Shandong, Hebei, Inner Mongolia, Chongqing, and other 27 villages around the country cooperation operation, such as the Inner Mongolia Autonomous Region Chifeng City Lei Yingzi village, Gushan village, Shandong Weihai City, Be Cao Kou village, Dezhou City, before the Yang village, Chongqing Youyang County Che Tian village, and Shizhu County Huaxi village. Leiyingzi Village in Chifeng City, Inner Mongolia Autonomous Region, is a successful case of implementing the "Haoyu Model." Through the analysis of the background, current situation, context, geographical context and objective image of rural tourism development and the horizontal and vertical analysis, the problems in its development are diagnosed, the overall thinking of rural tourism development is determined, including rural tourism image planning, development direction and layout, and development planning, and the planning objectives are determined. According to information, in 2016, the village still had 29 poor households; after replicating the rural tourism business model in Haoyu Village, vigorously developing the rural tourism industry, by 2019, Lei Yingzi Village's poor households achieve all out of poverty; the village's per capita annual income also reached 14,000 yuan. Lei Yingzi Village has become a model for the development of rural tourism in Inner Mongolia and has been selected as a "National Rural Tourism Key Village." Yuyugu Tourism Development Company has sent a management team to join the tourism village for business guidance, guide training, the establishment of study teams and market operations, and the implementation of unified training and management of the local B&B. According to the general manager of the Youyu Valley Tourism Development Company, Zhao Shengjian, the tourism company will lay out 100 tourism villages in the country in the "Haoyu model" operating company to help backward areas to develop rural tourism industry.

3.2.3. Building Product Features and Forming Its Own Advantages with Its Unique Tourism Resources. Zhonghaoyu village is located in the hinterland of the mountainous region of Luzhong, in the shade of the main peak of Mount Lushan,

and their geographical disadvantage turns out to be their greatest advantage. The village is surrounded by mountains, streams, green water, and green hills, the scenery is extremely beautiful, and the village is planted with peach trees, ten miles of peach blossoms, and the flavor of the paradise, coupled with the simple and rich peasant style, very suitable for leisure, holiday, and other tourism activities. Outstanding natural resource endowment and local humanities have laid a good foundation for the development of rural tourism industry in Zhonghaoyu Village. Since its establishment in 2011, the Yuyugu Tourism Development Company has started to make use of its own superior natural conditions and cultural customs to explore its own unique tourism resources and create unique rural tourism products with its own characteristics. Regarding the development of the basic elements of rural tourism, it relies on the natural and humanistic features of the villages, pursues original ecology, and takes the path of specialization. First is building characteristic rural lodges, positioning ecological and cultural leisure and residential functions, renovating and transforming villagers' houses, and building unique farmhouses, with designs focusing on local styles. Services are based on unified norms, highlighting the characteristics of family hospitality. In the past few years, there have been eight kinds of local food for visitors to experience and taste, namely, the Zhangmuniang big bowl of tea, the Poxiyuanbao, the Xiucaihezi, the ma Madaniang's bean curd, the Sishenzi cake and noodles, the Erjinzi, the Shanzuihouzi, and the Laoliang's pancake. The food development not only reflects the local style of Boshan Mountain Village but also contains the local village folk culture. Compared with traditional sightseeing tourism, experiential tourism focuses on the process of tourists' feeling, experience, and enjoyment of tourism products, rather than blindly pursuing the tourism results of "visiting here." To some extent, it emphasizes psychological perception and understanding. Secondly, the tourism company has developed more than 30 kinds of experiential leisure and entertainment projects, which are unique and adaptable to the rural leisure and study needs of foreign visitors, such as the Yuyugu Farm Ranch, the Living Gallery of Farming Culture, the Real CS, the Suspension Bridge, the Village Memory Hall, and the Yuyugu Wonderland. Thirdly, it attaches importance to the development of traditional rural handicraft experience activities and has established eight traditional folk handicraft workshops, where folk handicraftsmen demonstrate on-site and visitors can visit and enjoy the fun of handicraft making, such as pottery, weaving, carpentry, masonry, rattan weaving, blacksmithing, and woodblock printing. Fourth is the construction of an ecological recreation base, highlighting the characteristics of ecological recreation, giving full play to the ecological advantages of the mountainous area of Zhonghaoyu village, with a forest coverage rate of 96% and an average summer temperature of less than 26°C, which has suitable conditions for recreation and summer vacation, focusing on the construction of recreation supporting facilities, and increasing and improving the functions of the elderly activity centre, recreation, and leisure, as well as medical services, to create a national forest recreation demonstration base [12].

3.2.4. Grasping Market Opportunities, Precise Market Positioning, and Forming a Good Market Effect. Zhonghaoyu Village's rural tourism development attaches importance to market demand, product development is guided by market demand, and the business strategy of "short, flat, and fast" and "fast, accurate, and active" is proposed to accurately grasp the rural tourism market demand and achieve accurate market positioning. In line with the long-term development plan of Zhonghaoyu Village, the company follows the tourism market situation, analyses customer needs, and stands at the forefront of the rural tourism demand market. In the business activities, tourists' suggestions are actively adopted and encouraged to put forward their needs, and the tourism company carries out statistics, makes analysis and selection, and implements them quickly, and puts forward the positive response strategy of "chasing the stars, chasing the trend, chasing the fashion" in the market, cultivates rural tourism products with its own characteristics, and makes rural tourism products that can meet customers' preferences. In addition, the company has built an excellent marketing team, which is responsible for marketing, product promotion and promotional activities, collecting feedback on the consumer experience of the products in the tourism market, and providing suggestions for the design of new tourism products. For example, Yuyugu Tourism company has successfully created a group study tour product, using a personalized programmer customization strategy, through the word-of-mouth marketing approach, project-based and theme-based study products, red culture study tours for one day, three-day, and two-night study tours, parent-child study tours, etc., and designed various types of summer camps, with the form and content of the product constantly pushing the envelope. The research team is received by the company's specially trained research coaches and life instructors to ensure the quality of research and is popular with primary and secondary school students. In 2017, Zhonghaoyu Village was awarded the first batch of "Shandong Primary and Secondary School Students' Research and Practice Teaching Base" and "Shandong Primary and Secondary School Research and Tourism Destination."

3.2.5. Bringing the Advantages of the Collective Economy into Full Play to Maximize the Benefits of Resource Utilization. The success of Zhonghaoyu Village in developing rural tourism is to explore a new model for the development of rural collective economy. The joint-stock system and corporate operation will give full play to the advantages of collective ownership. The company will make unified planning and use of various resources in the village, manage and coordinate the tourism service reception work of the whole village, improve efficiency, and ensure tourism quality. By strengthening the collective economy and serving the production and livelihood of the villagers, the company also maximises the interests of the villagers. As the backbone

of rural tourism development, the overall environment and conditions of Zhonghaoyu Village have been improved and enhanced, reflecting the advantages of the collective economy. Collective economy is a form of public ownership owned by workers (members) within a certain range and obtains the right of control. The right of control of workers (members) is the main symbol that is different from private ownership and state ownership. Workers have individual property rights in the enterprise as well as common property rights of workers (members). The collective economy embodies the combination of labor and capital elements, the distribution according to work, and the sharing of benefits by various factors of production. First is the improvement of public facilities and infrastructure. Zhonghaoyu Village has set up a special construction team, using idle labour to build public facilities and infrastructure in the village, investing more than 2 million yuan to redesign and build roads in the village, investing 4.2 million yuan to renovate and improve the river, building a 5,000 square metre car park, constructing a leisure square for villagers, carrying out courtyard renovation, old house renovation and house appearance beautification, and installing street lights, and greatly improved the village appearance of Zhonghaoyu Village. Secondly, it improved the hygiene and environmental conditions. In the village of Zhonghaoyu, agricultural toilets have been renovated and a special hygiene and cleaning team has been set up to carry out daily environmental cleaning and sanitation and to maintain the hygiene and environmental conditions in the village. Thirdly, the tourism landscape has been improved. It has built a 5.6 km sightseeing road around the mountain, constructed two water storage dams on the natural river in the village to create a water body landscape, and implemented greening projects to achieve a greening rate of over 80% in the village, to construct road landscapes and tourist signs, and to beautify old houses, stone walls, stone roads, old trees, ponds, and streams in the village to create a tourist atmosphere. Fourthly, it will enhance the quality of life and security for all villagers. The development of the collective economy has ensured that all villagers are able to escape poverty and common prosperity. Zhonghaoyu Village Yuyugu Tourism Company has achieved universal shareholding, with all villagers participating in the business activities of rural tourism, realising the common prosperity of all villagers, a great practice in the development of China's rural social undertakings. The 20% of the company's proportional shares are used for capitation dividends, a fixed income for the whole village, and some of the special groups of the elderly, the sick, and the disabled can enjoy the capitation income even if they have no assets to share. Part of the welfare shares of the tourism company is used for elderly welfare dividends and also gives all villagers a unified purchase of cooperative medical care and pension insurance and other welfare benefits and, in June 2018, began to achieve all villagers free three meals throughout the year; the village also had set up a nursing home, the elderly aged 70 years or older moved voluntarily into the nursing home, all living expenses were borne by the company. In order to protect the interests of all villagers, villagers do not need to care about and participate in the development of village commerce. In view of the difficulties and problems faced by the collective ownership economy in the reform and development, we should base ourselves on the long term, focus on the present, adhere to the scientific concept of development, and conscientiously solve them by means of reform and development. Therefore, it has become an inevitable requirement to focus on clarifying property rights, deepen collective reform, and develop various forms of collective economy.

4. Transformation and Upgrading of the Industrial Structure of Zhonghaoyu Village

4.1. Rural Tourism Has Promoted the Diversification of Agricultural Categories in Zhonghaoyu Village. Firstly, agriculture in Zhonghaoyu village as a whole has shown continuous growth driven by the development of rural tourism. From 2003 to 2011, the increment of the total agricultural output value in Zhonghaoyu village was relatively small and the growth rate was slow, and the impact of rural tourism was not significant. From 2011 to 2019, as the development of rural tourism in Zhonghaoyu Village entered the fast track, the development of agriculture, driven by the tourism industry, has significantly accelerated. From 2003 to 2011, the total agricultural output value of Zhonghaoyu Village grew from RMB850,000 to RMB1.03 million, an increase of 21%, with an average annual growth rate of 2%, a relatively slow growth rate. In terms of the increase in the output value, the largest increase in the output value was in fruit cultivation, which increased by 117,500 yuan, while the output value of grain cultivation showed negative growth, decreasing by 0.73 million yuan. In terms of growth rate, the largest growth rate was in vegetable cultivation, with an average annual growth rate of 27%, while the average annual growth rate in food cultivation showed a slight decline, with an average annual decrease of 1%. In general, from 2003 to 2011, fruit in Zhonghaoyu Village had the largest volume and the largest increment in the primary industry, vegetable had a large development and the fastest development, and grain cultivation showed negative growth. From 2011 to 2019, with the rapid development of rural tourism, the development of Zhonghaoyu Village's primary industry also had a significant speed up, with the total output value increasing from 1.03 million yuan to 1.77 million yuan, an increase of 72%, with an average annual growth rate of 7%, which is 5 percentage points higher than the growth rate from 2003 to 2011, and more than three times the growth rate from 2003 to 2011, with a significant increase in growth rate. This is mainly due to the rapid development of the farming industry, which has been driven by the demand for tourist meals due to the breakthrough development of rural tourism in Zhonghaoyu Village. From the perspective of incremental output value, the largest incremental output value was in the farming industry, which grew from nothing to something like 460,000 yuan, and the smallest incremental output value was in vegetables' cultivation, which grew by 70,000 yuan. In terms of growth rates, both grains' cultivation and vegetable cultivation grew at an average

Table 1: Agricultural production value, proportion, and increase in each sector in Zhonghaoyu Village, 2003, 2011, and 2019.

Type	2003		2011		2003–2011		2019		2011–2019	
	Output value	Proportion (%)	Output value	Proportion (%)	Increment	Average annual growth rate (%)	Output value	Proportion (%)	Increment	Average annual growth rate (%)
Grain	74874	9	67600	7	−7274	−1	152300	9	84700	11
Vegetables	12500	1	86000	8	73500	27	156000	9	70000	8
Fruit	762500	90	880000	85	117500	2	1000000	56	120000	2
Cultivation	—	—	—	—	—	—	460000	26	460000	—
Total	849874	100	1033600	100	183726	2	1768300	100	734700	7

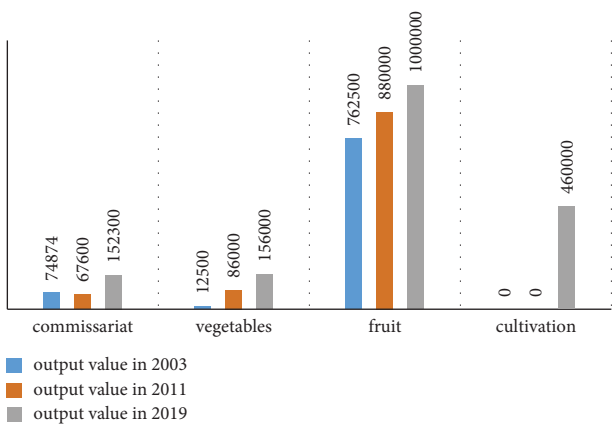

Figure 1: Output value of agricultural departments in Zhonghaoyu Village in 2003, 2011, and 2019.

annual rate of around 10%, while the smallest growth rate was in fruit cultivation, which grew at an average annual rate of only 2%. Overall, from 2011 to 2019, fruit cultivation in Zhonghaoyu Village still has the largest volume in the primary industry, but the rate of development has slowed down significantly, while the largest increment is in the emerging livestock farming industry, and the development of grain cultivation and vegetable cultivation is stable (Table 1 and Figures 1 and 2).

Secondly, under the development of rural tourism, the agricultural categories in Zhonghaoyu Village have developed in a diversified direction. In terms of the internal structure of agriculture, in 2003 and 2011, there were mainly three types of industries: grain, vegetable, and fruit cultivation, while fruit held an absolute proportion, accounting for 90% in 2003 and 85% in 2011, while grain production and vegetable had a smaller proportion, accounting for less than 10%, and the development of various categories within agriculture was extremely uneven. Since 2011, with the rapid development of rural tourism and driven by the market demand for tourist consumption, the internal structure of agriculture in Zhonghaoyu Village began to adjust. By 2019, the main production sectors of agriculture, apart from the original grain cultivation, vegetable cultivation, and fruit cultivation, livestock farming became an important growth point for agriculture in Zhonghaoyu Village, with fruit cultivation dropping to 56%, although still accounting for the largest share, but the balance of the internal structure of agriculture has been greatly improved, with the rapid rise of the farming industry, accounting for 26%, and the share of both grain production and vegetable cultivation approaching 10%. in following the rapid development of rural tourism, the internal structure of agriculture in Zhonghaoyu village has become more balanced, with a richer range of industrial categories, and has begun to develop in a diversified direction (Table 1 and Figures 1 and 2).

However, as a result of the development of rural tourism, the basic position of agriculture in Zhonghayu Village is no longer the same, and agricultural production is relatively weak. Due to the limitations of the arable land and the quality of the farmland, it has been difficult to make a breakthrough in food cultivation in the mountainous area of Zhonghaoyu Village, and growth has been slow. Until the development of rural tourism, fruit tree cultivation had been the most important source of economic income for the farmers in Zhonghaoyu Village, but the varieties of fruit tree cultivation were relatively homogeneous, mainly planting chestnut and peach trees. Agricultural production of vegetables in Zhonghaoyu Village has not been very large, and livestock breeding has only been developed in recent years. At present, the production of these agricultural products is mainly used to meet the consumption needs of tourists in the rural tourism market, and the agricultural and rural tourism industries in Zhonghaoyu Village are necessarily complementary. Agricultural production in Zhonghaoyu Village is relatively weak, and agriculture is no longer a fundamental position, but the rapid development of rural tourism does not mean that the development of agriculture is abandoned; the core of what makes the countryside a countryside lies in agriculture, which is indispensable in the countryside, but that agriculture should be pushed towards higher directions and goals, and ecological agriculture and high value-added agricultural products should be vigorously developed with the opportunity of the development of rural tourism. Initially, rural tourism originated from leisure farming, agricultural farming, and the countryside in the fields, and its attraction lies in the enjoyment of the tourists' participation in farming or harvesting, and the experience of the countryside, known as "Nongjiale." Even though rural tourism is now beginning to develop in a cultural connotation direction, the cultural attributes of rural tourism are still agrarian and everything is based on agriculture. The development of agriculture in tourist villages must abandon the original rough and tumble model of rural development and give full

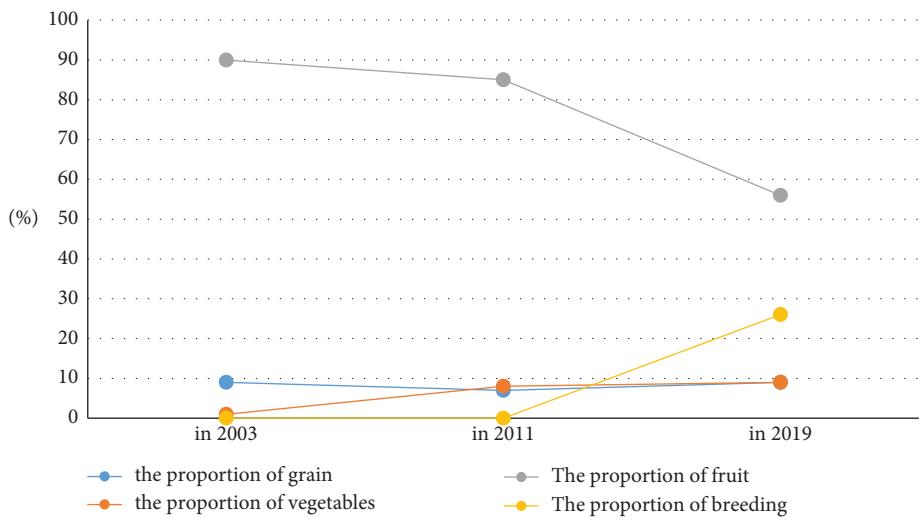

Figure 2: Schematic diagram of the development and change of the output value of the primary industry in Zhonghaoyu village in 2003, 2011, and 2019.

play to the role of agricultural technology to improve quality and efficiency. To make good use of the huge tourist flow brought by the development of rural tourism, we cater to the current consumer philosophy of "environmental protection, health, and green," produce green ecological and organic agricultural products, develop modern agriculture with high added value, and take the road of quality and branding of agricultural products. For example, Zhonghaoyu Village should do more in the production of peaches and chestnuts. New modes of agricultural production and new businesses should also be constantly explored. The tourist villages can make good use of the important offline advantages of tourists in the production of agricultural products to develop new forms of agricultural production such as shared agriculture, adventure agriculture, and creative agriculture. It is also possible to further explore a large number of new business models such as central kitchens, direct agricultural business supply, smart agriculture, contract farming, and personal customization. In addition, in the marketing of agricultural products, market development and sales can be carried out through a combination of online and offline and virtual and physical organic means, with the benefit of the enormous visitor groups' spreading and the utilization of great marketing techniques.

4.2. Rural Tourism Drives the Industrialization of Zhonghaoyu Village. Above all, as a result of the development of rural tourism, the industrial sector in Zhonghaoyu Village has grown from scratch. Early industrial development in Zhonghoayu Village was rather fragile, and from 2003 to 2011, industry in Zhonghaoyu Village was confined to a few artisanal workshops making and selling steamed buns and bean curd, and although the growth rate was rapid and the relative value of the increment was large, the absolute value of the increment was small due to the small total value of the output, and the impact of rural tourism was not significant during this period. From 2011 to 2019, the development of industry has been enhanced owing to the rapid development of rural tourism and the establishment of a construction team in Zhonghaoyu Village in order to meet the needs of the village's infrastructure construction and the renovation of the residential accommodation, etc. From 2003 to 2011, the total output value of industry in Zhonghaoyu Village grew from 0.5 million yuan to 43,000 yuan, an increase of nearly eight times, with an average annual growth rate of 31%. The growth rate is very fast, but the total output value is limited. In terms of the incremental output value, the handicraft workshop was the only industry in Zhonghaoyu Village at the time, and the output value increased by 38,000 yuan; although the relative amount of the added value was large, the absolute amount was small. Judging from the growth rate, the growth rate was high, with an average annual increase of 31%. Overall, from 2003 to 2011, the volume of industry in Zhonghaoyu Village was small and, despite the high growth rate, was less influential in the village's economic development. 2011 to 2019 saw the rapid rise of rural tourism in Zhonghaoyu Village, which provided a good boost to the development of industry in the village. The total output value grew from 43,000 yuan, a huge increase to 4,248,000 yuan, an increase of nearly 98 times, with an average annual growth rate of 78%, a significant increase of 47 percentage points compared to the growth rate from 2003 to 2011. The construction industry in Zhonghaoyu Village, from scratch, developed an annual output value of 3 million yuan in 2019, and the number of handicraft workshops increased dramatically, as did the incremental output value, which grew by 1.205 million yuan, a 28-fold increase, with an average annual growth rate of 52%. Overall, industry in Zhonghaoyu Village has seen a significant increase in volume from 2011 to 2019, with relatively large growth rate figures. This is mainly due to two reasons: firstly, the industry in Zhonghaoyu Village was extremely weak before 2011 and the volume of the total output value was very small, and secondly, due to the huge traction formed by the breakthrough development of rural tourism in

Table 2: Output value, share, and growth of industrial sectors in Zhonghayu Village in 2003, 2011, and 2019.

Type	2003		2011		2003–2011		2019		2011–2019	
	Output value	Proportion (%)	Output value	Proportion (%)	Increment	Average annual growth rate (%)	Output value	Proportion (%)	Increment	Average annual growth rate (%)
Manual workshop	5000	100	43000	100	38000	31	1248000	29	1205000	52
Building	—	—	—	—	—	—	3000000	71	3000000	—
Total	5000	100	43000	100	38000	31	4248000	100	4205000	78

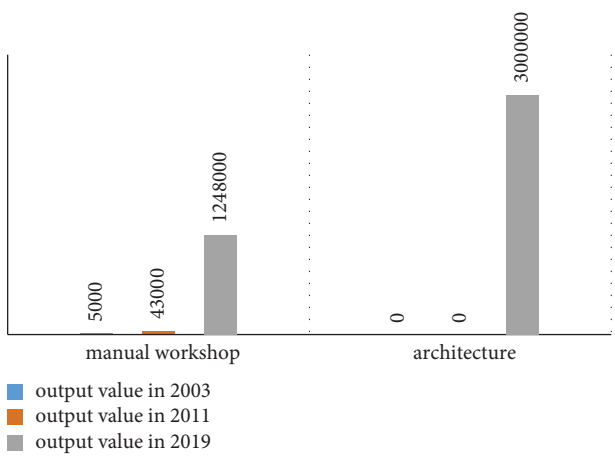

Figure 3: The development of the output value of the industrial sectors in Zhonghaoyu Village in 2003, 2011, and 2019.

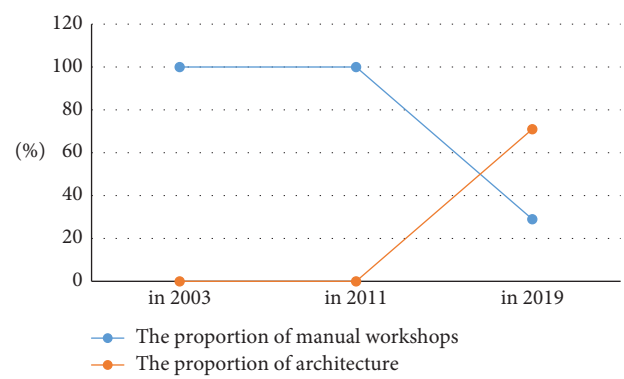

Figure 4: Trends in the share of industrial sectors in Zhonghayu Village in 2003, 2011, and 2019.

Zhonghaoyu Village, the number of handicraft workshops increased dramatically and the output value grew significantly, as well as the construction demand of rural tourism drove the construction industry to grow significantly (Table 2 and Figures 3 and 4).

Furthermore, through the development of rural tourism, the industrial sector in Zhonghaoyu Village has developed from a single category to a richer category. According to the internal structure of the industry, in 2003 and 2011, there was only one type of industry in Zhonghaoyu Village, mainly producing steamed buns and bean curd, and the industrial structure was homogeneous. After 2011, a special construction team was set up by the Village Youyugu Tourism Company to serve the construction and renovation of tourism infrastructure and reception facilities, and the construction industry became an important industrial sector in Zhonghaoyu Village. The internal structure of the industry in Zhonghaoyu village has been restructured. In 2019, among the industrial sectors in Zhonghaoyu Village, the output value of the construction industry was 3 million yuan, accounting for 71%, while the output value of handicraft workshops was 1.248 million yuan, accounting for 29%. Overall, the internal structure of industry in Zhonghaoyu village has been optimised to some extent following the breakthrough development of rural tourism, which is a good example of the driving effect of rural tourism (Table 2 and Figures 3 and 4).

Nevertheless, Zhonghaoyu Village's industrial development as a whole has been slow and the shortcomings are yet to be fulfilled. In 2003, there was only one traditional handicraft workshop making and selling bean curd, and in 2011, a steamed bread workshop was added, leaving the village's industry largely in limbo. Even in 2019, when Zhonghaoyu Village saw the great development of rural tourism, industrial development was still seriously inadequate. In order to meet the requirements of rural tourism development, the village has set up a construction team to serve the construction and maintenance of rural tourism landscapes, residential accommodation, and infrastructure such as roads, and no modern agricultural processing and manufacturing industries have emerged. A large number of traditional handicraft skills have been tapped for the diversification of rural tourism products and services, but not enough large-scale operations. Drawing on the development opportunities of rural tourism, Zhonghaoyu village should vigorously promote traditional handicraft skills and the processing industry of agricultural products. By leveraging the rural tourism industry, the tourism industry chain is extended towards the upper reaches, which can promote the development of tourism village industries. A huge consumer base of tourists and a market diffusion effect give the development of tourism village industries an inherent market advantage, the key to which is the ability to produce products with local characteristics and excellent quality. The industrial development of tourist villages can form a breakthrough from two aspects: the processing of agricultural products and the production of traditional handicrafts. Agricultural products have the characteristics of freshness, originality and taste, etc. Villages of tourism put out primary agricultural products in the local consumption activities of

tourists, and these original fresh agricultural products, with their unique local flavour and local characteristics, can make tourists produce good consumption experience and enhance the image of the place of origin of tourism villages. It is an important feature of tourism consumption for consumers to capitalise on the fact that they conduct their consumption activities in the places where tourism products are produced. However, primary agricultural products also suffer from problems such as unsuitability for storage, inability to achieve taste enhancement, inconvenience in carrying, and poor health protection conditions. In terms of operating profit, primary agricultural products are generally less expensive, have simple packaging and no brand image promotion, etc. Therefore, it is necessary to vigorously promote the processing industry of agricultural products, combining deep processing and moderate processing according to the characteristics of agricultural products by combining coarse as appropriate. Moreover, we should strengthen the extension of the agricultural industry chain, improve the storage, processing, packaging, and logistics, express delivery and transportation of agricultural products, attach importance to innovation-driven and green production, and constantly increase the added value of agricultural products production. The production of traditional handicrafts is another important growth point for the development of industry in tourist villages, fitting the need for shopping and consumption of souvenirs for tourists in rural tourism, and making comprehensive use of processing of rural agricultural resources to achieve multiple levels of depth of use. Zhonghaoyu village has a rich variety of traditional handicraft making workshops, such as pottery, carpentry, masonry, rattan weaving, weaving, blacksmithing, and woodblock printing, which are popular with tourists. In the development of traditional handicraft-making industry, we should pay attention to local characteristics and bring into account our own advantages. For example, as Zhonghaoyu Village has a tradition of peach tree planting, we can make full use of peach tree resources to develop handicrafts with local characteristics such as peach wood carving and peach kernel ornaments and promote the characteristic development of handicraft skills.

4.3. Rural Tourism Boosts the Continuous Growth of the Service Industry in Zhonghaoyu Village. On the whole, along with the development of rural tourism, the service industry in Zhonghaoyu village has continued to grow, especially after the shareholding system transformation in 2011, to achieve explosive development; the impact of rural tourism development is obvious. From 2003 to 2011, the volume of the output value of the service industry is relatively low and steady growth and can reflect a certain countryside tourism driven role, but the role and status in the village's overall economic development has not been highlighted. From 2011 to 2019, following the completion of the transformation of the shareholding system of rural tourism in Zhonghaoyu Village and the realization of the company's operation, the countryside tourism has been developed by rapid progress, and the service industry led by rural tourism has been developed comprehensively and rapidly. Between 2003 and 2011, the total output value of the service industry in Zhonghaoyu Village increased from 35,600 yuan to 225,000 yuan, an increase of more than five times, with an average annual growth rate of 26%. Before the development of rural tourism in 2003, the service industry in Zhonghaoyu only consisted of the traditional supermarket and catering sectors, but after the development of rural tourism, the residential business sector was added. In terms of incremental output, the residential sector saw the largest increase in output, from nothing to something like 110,000 RMB, followed by the catering sector with an increase of 68,000 RMB, while the shop sector saw a smaller increase of 11,400 RMB. In terms of growth rates, supermarkets had an average annual growth rate of 20% and restaurants had an average annual growth rate of 15%. In general, from 2003 to 2011, rural tourism brought about the development of service industries such as farm caravans and residential accommodation for Zhonghaoyu Village, and the growth rate of service industries was relatively high, and the relative value of the increment was relatively large, but the total output value of service industries was still not very large, the volume was small, and the absolute value of the increment was relatively small. From 2011 to 2019, with the transformation of the shareholding system and the corporatization of rural tourism, the Zhonghaoyu Village's service industry has seen a breakthrough development, with the total output value increasing dramatically from 225,000 yuan to 34.7 million yuan, an increase of 153 times, with an average annual growth rate of 88%, which is 62 percentage points higher than the growth rate from 2003 to 2011 and 3.5 times the average annual growth rate from 2003 to 2011, with a huge increase in growth rate. In terms of incremental output value, catering, B&B, and leisure projects all achieved incremental output value of over RMB10 million, leisure projects went from strength to strength, achieving operating income of RMB11.5 million in 2019, while supermarkets, convalescent residences, and hospitality services achieved relatively small incremental output value, also achieving incremental output value of RMB1.489 million, RMB600,000, and RMB436,000, respectively. In terms of growth rates, the three operating sectors of supermarkets, restaurants, and B&B, which have comparable calibers, all grew at an average annual rate of nearly 80%. Overall, from 2011 to 2019, the service industry in Zhonghaoyu Village has achieved explosive development, with huge growth in both incremental output value and average annual growth rate, fully reflecting the significant role of a good rural tourism development model in promoting the great development of the service industry (Table 3 and Figures 5 and 6).

Secondly, as a result of the development of rural tourism, the economic sector of the service industry has become increasingly diversified. However, before the launch of rural tourism, the service sector in Zhonghaoyu Village was rather traditional and homogeneous. There were only two types of service sector in 2003, namely, supermarkets and restaurants, both of which had relatively low revenues and mainly met the consumption of local villagers, with restaurants accounting for 90% and supermarkets for only 10%. In the

Table 3: Production value, share, and growth of the services sector in Zhonghaoyu Village, 2003, 2011, and 2019.

Type	2003		2011		2003–2011		2019		2011–2019	
	Output value	Proportion (%)	Output value	Proportion (%)	Increment	Average annual growth rate (%)	Output value	Proportion (%)	Increment	Average annual growth rate (%)
Supermarket	3600	10	15000	7	11400	20	1504000	4	1489000	78
Catering	32000	90	100000	44	68000	15	10160000	29	10060000	78
Residential accommodation	—	—	110000	49	110000	—	10500000	31	10390000	77
Health home	—	—	—	—	—	—	600000	2	600000	—
Leisure projects	—	—	—	—	—	—	11500000	33	11500000	—
Hospitality	—	—	—	—	—	—	436000	1	436000	—
Total	35600	100	225000	100	189400	26	34700000	100	34475000	88

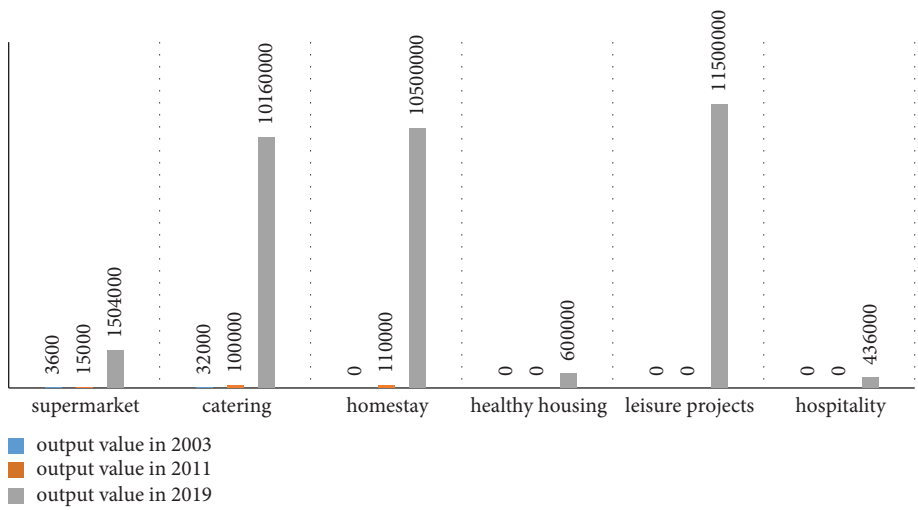

Figure 5: Development of the output value of the service sector in Zhonghaoyu Village in 2003, 2011, and 2019.

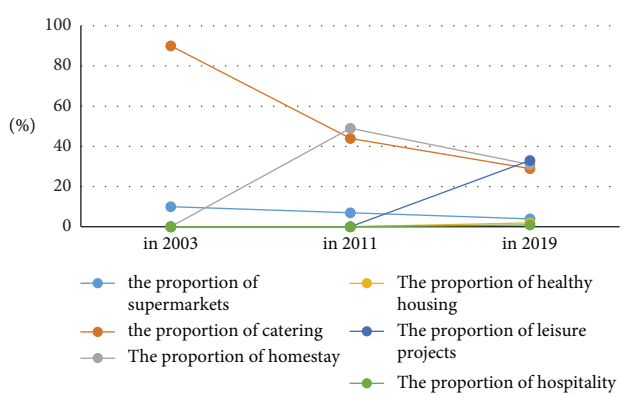

Figure 6: Trends in the share of service industries by sector in Zhonghaoyu Village, 2003, 2011, and 2019.

early stages after the development of rural tourism, the internal structure of the service sector in Zhonghaoyu Village did not change much with the development of rural tourism, as the main forms of rural tourism were low-level products such as farmhouses and residential accommodation. In 2011, only one category of residential accommodation was added to the service sector in Zhonghaoyu Village, with supermarkets, catering, and residential accommodation accounting for 7%, 44%, and 49%, respectively, which were among the important business sectors. Since 2011, the internal structure of the service industry has changed dramatically with the successful transformation of the shareholding system and the corporatization of the operation of rural tourism. In 2019, the main sectors of the service industry, apart from the original supermarket, catering, and residential accommodation, leisure projects have become an important sector of the service industry, and other sectors such as recreational housing and hospitality services have also been added, with an increasingly rich industrial sector. The service industry is developing in a diversified direction with the rural tourism industry as the mainstay. The service sector has developed in a balanced way, with restaurants, lodges, and leisure projects, being the three pillars of the service sector, accounting for 29%, 31%, and 33%, respectively. Although the proportion of recreational housing is relatively small, accounting for only 2%, it is an important attempt to develop the service industry in a pioneering way (Table 3 and Figures 5 and 6).

However, Zhonghaoyu Village is dominated by tourism in the service sector, and further industrial development is necessary, with an emphasis on enhancing the sustainable

development of the village. In 2003, agriculture dominated the industrial economy of Zhong Hao Yu village, with agriculture dominating the economy, accounting for more than 95% of the total, and the economy was backward and a poor mountain village well-known nearby. After a decade of development of the rural tourism industry, it has been constantly transformed into a service industry, gradually getting rid of the homogeneity of agriculture. In 2019, the proportion of tourism-dominated service industry rose to 85% and was transformed into a rich village with a strong village and rich people. Rural tourism is developing rapidly and tourism has become the dominant economy, occupying an absolute share. However, the development of rural tourism in the village still mainly relies on the six elements of traditional tourism, such as food, accommodation, transportation, tourism, shopping, and entertainment industries, and the industrial categories are basically complete, but the lack of new industries and new forms are bigger and stronger, and there is still a lot of room for development. In addition, besides these traditional forms of the tourism industry, other service industries, such as public services such as health care, education, and culture, are still missing and not fully developed. Firstly, the innovation and development of the rural tourism industry is properly carried out. The current rural tourism product structure is single, the quality varies, homogenization is serious, and the supply of quality products is insufficient, which seriously restricts the healthy and sustainable development of rural tourism. Rural tourism should focus on deepening reform from four aspects, production factors, product structure, industrial structure, and consumption environment, effectively carry out product optimization and industrial structure adjustment, and improve the quality and efficiency of the supply system, so as to realize the sustainable development of rural tourism [14], promoting the further development of the service industry by relying on the traditional rural tourism industry. This is followed by the integrated development of the wellness, health, culture, and tourism industries. Crucial to the further development of the service industry in tourist villages is the outreach of the industry and the diversification and expansion of the service industry, with rural tourism as the core. We should expand the concept of rural tourism, which is all the activities carried out by foreign tourists and all the phenomena arising from it, in order to give full play to the economic driving effect of rural tourism. In summary, these can cover the four main industrial sectors of "wellness, health, culture, and tourism." Health: health can be defined as the health elements that rural areas can provide to the outside world. It can include ecological agriculture and ecological environment, green ecological agriculture, such as organic agriculture, green agriculture, and ecological environment, such as fresh air, green vegetation, and many rural and agricultural elements that can be processed, produced, and manufactured to affect people's health. Health: it can be understood as "health," which means relaxing, releasing pressure, and cultivating health. It also highlights its other main value, "retirement," whether it is to return to their farms or their hometown, which is also a phenomenon. People in cities are willing to go to the countryside to take care of themselves. The countryside has natural environmental advantages, and the rural retirement industry will become a new driving force for the development of rural industries. The rural retirement industry is bound to become a new dynamic force in the development of rural industries. Culture: culture is the elements in rural society, especially those that can be transformed into productive forces, such as traditional culture, folk customs, local customs, theatre, folklore, festivals, crafts, or buildings, objects and artefacts that can carry these cultures, either as objects for sightseeing or as cultural souvenirs, or even as daily necessities. These rural traditional cultures, which are themselves a factor of production, such as local specialties such as food and handicrafts, still have a large market and a certain influence, and are even a golden signboard for the industrialization of folk culture. Tourism: tourism is an important driving force for rural areas to be able to bring their various advantages of resources to industrial effectiveness; it can bring a large number of consumer groups, relying on the strong spending power of tourists and health; the cultural industrial value will be able to give full play to drive the development of various industries in rural areas; rural tourism will certainly contribute to the prosperity of rural industries. In addition, the tourism industry also has an important cultural propaganda role, which can bring these resources of the countryside to the world and become a free propagandist. The four industrial forces of "Wellness, Culture, and Tourism," both traditional and new industries, are an important expression of the modern value of the countryside and agriculture. The development of the four industries of "Wellness, Culture, and Tourism" will be the key to promoting the development of the rural service industry.

4.4. Rural Tourism Promotes the Transformation and Upgrading of the Overall Industrial Structure of Zhonghaoyu Village. During the development of rural tourism, the industrial economy of Zhonghaoyu Village has been transformed and the industrial structure has been adjusted, transformed, and upgraded. The transformation and upgrading of the industrial structure of Zhonghaoyu Village has experienced three important stages. The first stage is the agricultural era; in 2003 and before, Zhonghaoyu Village was a typical agricultural mountain village, with agriculture accounting for 95% of the total, and industry and services nearly absent, accounting for 1% and 4%, respectively. From 2003 to 2011, agriculture was still the mainstay of the village's economy, while industry was still poor, but the service sector was developing rapidly. In terms of incremental output value, agriculture and service industries both had almost 200,000 yuan of incremental output, while industry had only 38,000 yuan of incremental output. Judging from the growth rate, industry and services grew rapidly, with an average annual growth rate of 31% and 26%, respectively, while the average annual growth rate for agriculture was only 2%. However, the volume of the service sector remains small, reflecting the inadequate development of rural tourism. Up to 2011, the share of agriculture decreased to 80%, industry accounted for 3%, which was only a slight increase, and

service industry accounted for 17%, showing a significant increase, and the industrial structure showed a diversified development trend. The third stage, which is the advanced stage of rural tourism development; since 2012, with the completion of the shareholding system transformation, the company began to operate, the development of rural tourism in Zhonghaoyu Village entered the fast track, and the tourism industry has been developed rapidly. From 2011 to 2019, agriculture in Zhonghaoyu Village's output value growth rate is growing slowly and the proportion is declining. The main position of agriculture gradually lost, while industry developed steadily and its position has been developed steadily and its position was upgraded, and the development of service industry emerged and took the leading position. Based on the increase in output value, the service industry achieved a huge increase of 3,445,000 yuan, while the increase in industrial output value was 4,205,000 yuan and the agriculture only 735,000 yuan. From a growth rate perspective, both services and industry achieved high growth rates, averaging 88% and 78% per annum, respectively, while agriculture achieved a slow growth rate of only 7% per annum. As of 2019, the village has seen a significant decline in the share of agriculture to just 4% and a further increase in the share of industry to 10%, with the rise of the service industry, mainly tourism, which has risen to 86% and become the dominant industry. Overall, through the development of the rural tourism industry, Zhonghaoyu Village has achieved a transformation and upgrading of its industrial structure, with a more rational industrial structure and a more diversified industrial sector (Table 4 and Figures 7 and 8).

However, there is still plenty of opportunity for industrial integration in Zhonghaoyu Village, and there is still a need to focus on the balanced development and diversity of industries, while avoiding the phenomenon of a monolithic rural tourism industry. As the rural tourism industry develops rapidly and deeply, the industrial structure has undergone significant changes. Traditional agriculture no longer exists, and the industrial economy of Zhonghaoyu Village is developing in the direction of diversification and industrial integration. Nevertheless, with the continuous and in-depth development of rural tourism, the industrial economy has a new tendency towards industrial mono-industry and the mono-industry of tourism. In 2019, the proportion of agriculture in Zhonghaoyu Village dropped rapidly from 95% before the development of rural tourism to 4%, and the proportion of industry was only 11%, while the proportion of tourism was as high as 85%. This is threatening the healthy and stable development of the industrial economy. Seasonality, vulnerability, and instability are characteristics of the tourism industry itself, and the off-peak season is an inescapable topic for tourism, as well as the fact that tourism is susceptible to natural disasters, the economic environment, and political and cultural conditions and is sensitive and fragile, such as the current outbreak, which has hit China's rural tourism industry hard, and over-reliance on the rural tourism industry is not conducive to the stable and healthy development of the rural industrial economy. Preventing the industrial economy of tourism villages from moving from one monolithic industry to another and reasonably avoiding industrial risks is another important issue for tourism villages after they have achieved greater development in their tourism industrial economy. Firstly, agriculture is the basis of rural areas, and agriculture in tourist villages should be based on leisure agriculture and ecological agriculture, which are mutually dependent and complementary to the rural tourism industry. Secondly, using industry as an auxiliary, relying on agricultural resources, vigorously developing the processing industry of agricultural products and traditional handicraft manufacturing, taking the road of boutique and specialization, enriching the content of tourism products, and increasing the depth of rural tourism activities, furthermore, with a focus on tourism and the overall development of the service industry, the development of "tourism+" and "agriculture+" is emphasized, as is the integration of agriculture industry and the service industry. In addition to the cultural experience, health and wellness, and elderly care services mentioned above, there are many other industries that are closely related to the foreign tourist community and have great potential, such as farmhouse rental, education, health and wellness, medical and health care, leisure and sports, and exhibitions and fairs. Tourism information technology has arrived, and rural tourism should also pay attention to the development of tourism information technology industry, using modern information technology to achieve digitalization, networking, and intelligence of rural tourism, to achieve the integration of digital economy and rural tourism, to carry out short video marketing with the help of new media platforms such as Tik Tok and Kuaisho to conduct online experience, and to use the Internet to live-stream rural local products, so that rural tourism's operation, production, purchase, and consumption are more convenient and fast.

5. Summary

Zhonghaoyu Village's rural tourism development is a clear demonstration of the impact of rural tourism industry on the industrial structure adjustment and transformation and upgrading of tourism villages. From 2003 to 2011, Zhonghaoyu Village's rural tourism development was at a primary stage, and although the industrial structure had changed compared to before the development of rural tourism, it did not undergo substantial transformation, and the impact of rural tourism was relatively feeble; therefore, rural tourism development does not always lead to the transformation and optimization of the industrial structure of tourist villages. From 2011 to 2019, following the transformation of the shareholding system and the realization of corporatised operations, rural tourism in Zhonghaoyu Village has achieved a breakthrough and entered a brand new stage of development, where the driving effect of rural tourism has been highlighted and the industrial effect has been fully reflected, and the village's industrial structure has been fully transformed and optimised and upgraded. Zhonghaoyu Village has also developed from a traditional and backward

Table 4: Agricultural, industrial and service output, share, and growth in Zhonghaoyu Village, 2003, 2011, and 2019.

Sector	2003		2011		2003–2011		2019		2011–2019	
	Output value	Proportion (%)	Output value	Proportion (%)	Increment	Average annual growth rate (%)	Output value	Proportion (%)	Increment	Average annual growth rate (%)
Total agricultural output	849874	95	1033600	79	183726	2	1768300	4	734700	7
Total industrial output	5000	1	43000	3	38000	31	4248000	10	4205000	78
Total service sector output	35600	4	225000	18	189400	26	34700000	86	34475000	88
Total	890474	100	1301600	100	411126	5	40716300	100	39414700	54

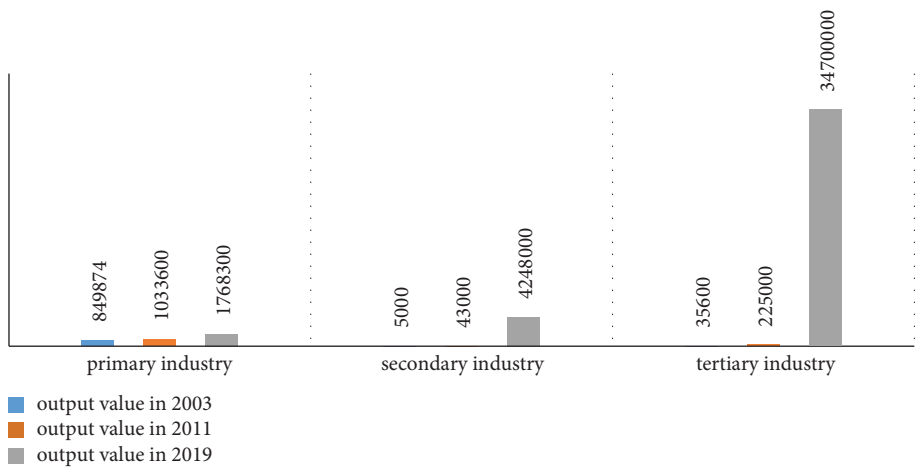

Figure 7: Development of agricultural, industrial, and service output in Zhonghaoyu Village in 2003, 2011, and 2019.

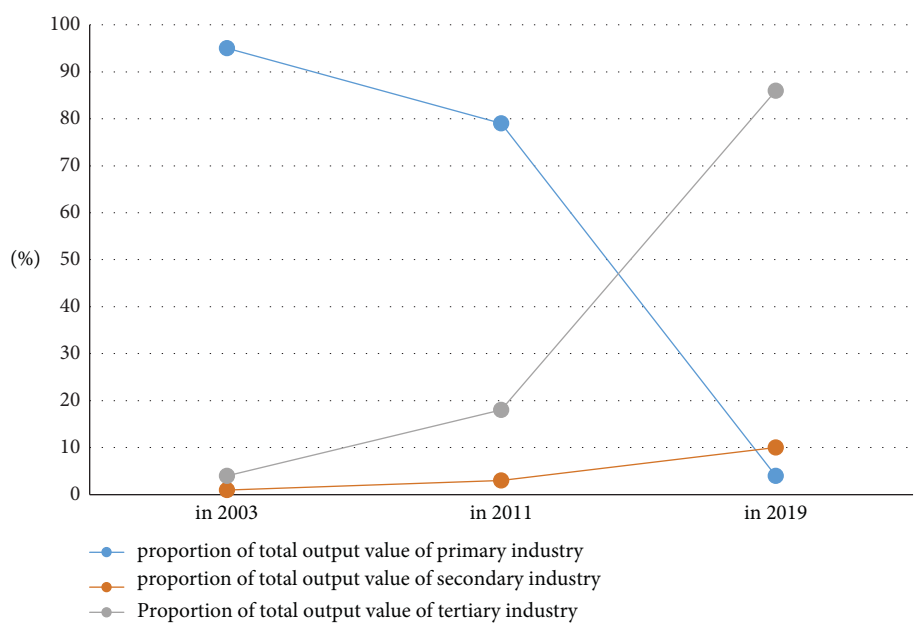

Figure 8: Trends in the share of agriculture, industry, and services in Zhonghaoyu Village in 2003, 2011, and 2019.

agricultural village to an affluent village with tourism-led and multiproduct integration.

Data Availability

The data underlying the results presented in the study are included within the article.

Disclosure

The author confirms that the content of the manuscript has not been published or submitted for publication elsewhere.

Conflicts of Interest

The author declares that there are no potential conflicts of interest in this study.

Authors' Contributions

The author has seen the manuscript and approved to submit to the journal for publication.

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Research Article

Resource Sharing Method of Basic Computer Education Based on Mixed Gaussian Model

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This study developed a computer-based basic educational resource sharing method based on a mixed Gaussian model in order to improve the effect of educational resource sharing. Initially, the challenges of educational resource sharing are examined. Then, the basic sharing platform, consisting of the index layer, the computer basic education resource library, and the data layer, is designed. After collecting information about basic computer education resources to be shared, the education resources are clustered using the Gaussian mixture model and then configured based on the results of the clustering. Depending on the number of configuration factors, computer basic education resources can be shared in accordance with their design. The experimental results indicate that this method has high resource sharing efficiency, the ability to update resources in real time, and a good teacher and student evaluation system. Compared to traditional sharing methods, the proposed method has the benefits of a shorter sharing time and greater resource clustering precision.

1. Introduction

The rapid advancement of computer and network technology hastened the arrival of the information technology revolution and propels social development into the information age. Computer information technology belongs to the category of high and new technologies, and as a result of its rapid development and complex knowledge of two major characteristics, its development level, application level, and education level have become crucial indicators of social progress [1]. Because computer technology encompasses a variety of fields and only when combined with all walks of life, it can have vitality. The most important objectives of noncomputer major computer basic education for general undergraduate colleges and universities are to popularize computer culture and improve the level of computer application.

Currently, as a result of "big expansion," the demand for basic computer education in domestic general undergraduate colleges and universities is increasing, as are teacher stress and the contradictions of school compression; moreover, the rapid development of computer technology and its teaching content updates must be adopted as soon as possible to solve this problem [2]. Faced with the new situation and new things, we must maintain sensitivity, increase the intensity of all aspects of investment, and make practical efforts to familiarize future college graduates with their major and enable them to master compound computer information technology skills. In order to achieve this training objective, there are a number of issues that must be studied and resolved, including but not limited to, training objectives, teaching systems, curriculum design, teaching content, teaching methods, teacher construction, equipment conditions, resource construction, etc. Solving these problems should be the starting point for undergraduate colleges and universities seeking to improve the computer education of noncomputer majors.

How to realize the reasonable development and effective use of basic computer education resources is the foundation for improving the quality of basic computer education work as well as a significant factor in enhancing the quality of education. How to realize the sharing of high-quality teaching resources is still one of the most difficult issues to be resolved [3, 4], despite the fact that many schools have reached a high level of maturity in the independent development of computer education for basic skills.

A cloud-based educational course resource sharing platform has been designed in reference [5]. The platform includes cloud infrastructure, cloud system services, cloud applications, and cloud client layers. The business management system in the cloud system service layer implements the platform's business logic. According to the difference in user rights, the platform divides user functions into two functional modules: teacher and student. The teacher functional module can manage students/teams/courses/live broadcast, edit, review, and approve papers; create/assign/count student assignments; and upload teaching materials, among other capabilities. The student function module enables the download of teaching materials, online homework, online examinations, and discussion and communication functions. A method for sharing educational resources based on a wireless broadband connection is designed in reference [6]. In this method, the ant colony algorithm is used to optimize the focused crawler, which is then used to capture educational resource data and extract the semantic features from the captured data. The K-means clustering algorithm is then applied to all the data to cluster it. According to the results of network centrality and network density calculations, the wireless broadband connection is utilized to schedule and complete the sharing of educational resources. In reference [7], a blockchain-based educational resource-sharing platform has been designed. According to the research, due to the rapid development of the Internet, the construction and sharing of educational resources have become an increasingly important aspect of modern distance education. Creating a blockchain-based platform for sharing educational resources has also become a social consensus. This study discusses the history development and practical issues of educational resource-sharing analyzes the role of an educational resource sharing platform based on blockchain in the construction of a credit bank and proposes the system design scheme for an educational resource sharing platform based on blockchain.

In practice, however, it has been discovered that the aforementioned traditional methods have the drawbacks of a time-consuming sharing process and poor resource clustering accuracy. This study designs a new resource-sharing method for basic computer education based on the Gaussian mixture model to address these issues.

The following is the structure of this work: the first chapter is an introduction that describes the motivation, significance, and contribution of this work. The second chapter is related work, which introduces and summarizes previous work on this topic. "Methods" is the third chapter, and it describes the method used in this paper in detail. The fourth chapter discusses the experimental results, which demonstrate the superiority of this method. The final chapter is the conclusion, which summarizes the work of this paper and discusses its shortcomings as well as future work.

2. Analysis of Difficulties in Educational Resource Sharing

First, the resource management platform has a strong ability to control resources. On the one hand, the resource management platform has a strong ability to control resources, and teachers cannot change the contents of the resource database at will, which leads to the difficulty of updating some old teaching resources in time. On the other hand, each school has its own teaching resources and there is no unified standard to manage these resources, which are only used by teachers and students in the school. Each school has abundant resources inside, but they are not open to the public, which makes it difficult to share teaching resources. Moreover, it is impossible for all teaching resources to give full play to their value in the teaching work of the school, leading to the waste of teaching resources [8].

Second, is the blindness and standardization of basic computer education. A lot of teaching resources are done by numerous companies' cooperation, prone to blindness in the process of construction. This leads to the lack of standard teaching resources construction, resources classification, content, form diverse and complicated, cause some resources appeared repeatedly and the situation of the old, did not get the timely update and check. For self-learning students, these resources are easy to mislead, as they fail to identify useful resources. Meanwhile, they also add difficulties to the management of teaching resources for schools, which is not conducive to the sharing of resources between schools [9].

Third, the utilization rate of basic computer education is too low. The resources of each school are still in the self-sufficiency stage, and some teaching resources have been eliminated before being used, which leads to the low utilization rate of teaching resources. This is mainly because the school has not realized the unified standard requirements for the resource management platform, and the management and use are not coordinated, which leads to the low utilization rate of teaching resources [10, 11].

3. Design of Sharing Methods of Basic Computer Education Resources

3.1. Design of Basic Sharing Platform

3.1.1. Index Layer. In order to deal with the connection search problem of a massive computer basic education resource set, the domain index method is used to reformulate the computer basic education resource set.

Definition 1.

Domain: A particular attribute or combination of attributes of a dataset is described as a domain [10]. If the primary key of the basic computer education resource table can form a domain, the domain is described by the value set of the domain, and the symbol R is used to describe it. If the symbol Ω represents the complete set of values of a domain, then the formal definition of a domain can be described as follows:

$$R = \{x | x \in \Omega\}. \tag{1}$$

The resource set S of basic computer education reformulated by the field is as follows:

$$S = \{R_1, R_2, \cdots, R_n\}. \tag{2}$$

Definition 2.

Domain association degree: For query domain D_1 and index domain D_2, the domain association degree can be formulated as follows:

$$t(D_1, D_2) = \frac{|D_1 \cap D_2|}{D_1}, \tag{3}$$

where $|\bullet|$ stands for the basis of the set. The correlation degree of domains is $(D_1, D_2) \in [0, 1]$, and the greater its value, the better the linkage between domains. Similarly, if two resource sets have domain pairs with a higher degree of linkage, the resource sets will be more related.

Definition 3.

Domain search: According to the query domain D_1, index domain D_2 and the correlation degree threshold $t^* \in [0, 1]$, the process of searching the correlation degree more than t^* from the domain set D_2 is described as domain search, and its formalization can be expressed as:

$$X\colon t(D_1, X) \geq t^*, X \in D_2, \tag{4}$$

where X represents the target of domain search, that is, beyond the set of computer basic education resources with high linkability.

3.1.2. Computer Basic Education Resource Library. A distributed resource library is a resource library in which the resources are stored and distributed across multiple computers and nodes. It consists of connections between computer networks. The physical distribution of each resource storage node is referred to by the Distributed Resource Library Module. Logically, these nodes constitute a complete resource library module, and a distributed resource library is equivalent to a centralized management and partially connected resource library cluster [12]. The distributed resource library module utilizes the computer P2P network as its medium, connects a number of geographically dispersed independent resource libraries, creates a global logical view, and transforms these distributed centralized resource libraries into a unified resource library module for control and management. All the node resource library modules can independently support local applications and provide resource sharing capability to other nodes [13] in the distributed resource library module.

According to the concept of centralized resource library management, distributed resource library modules can be classified as either homogeneous or heterogeneous. As shown in Figure 1, both heterogeneous and homogeneous distributed resource libraries can be abstracted into a four-layer schema architecture.

The distributed resource library is divided into four layers of patterns: global external pattern, global conceptual pattern, local conceptual pattern, and local internal pattern. There is a corresponding inter-layer image between each adjacent layer mode, and the switch between modes is completed through the inter-layer image. The four-layer distributed resource library module is also suitable for the same configuration as the distributed resource library module formed by the same kind of resource library and the heterogeneous distributed resource library module formed by different kinds of resource libraries [14].

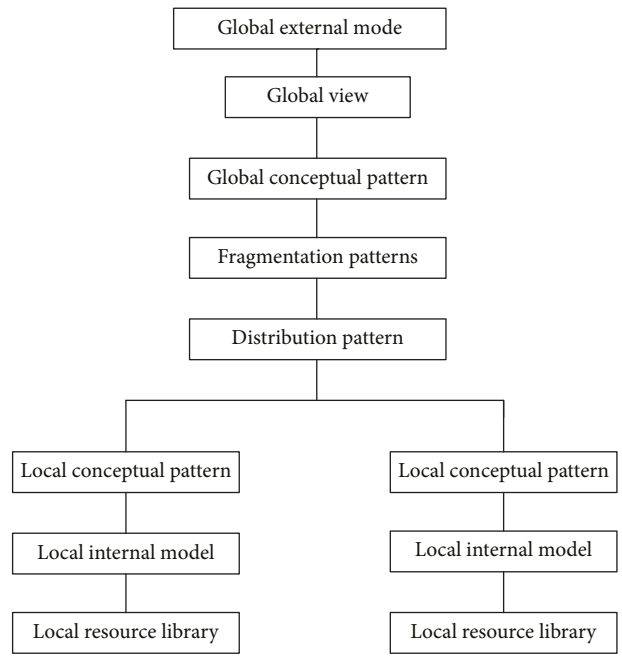

Figure 1: Distributed resource library module architecture.

3.1.3. Data Layer. The main purpose of building a data layer is to ensure the stability and security of the output and input of basic computer education resources. Taking association computation as an example, the implementation of selection and sort computation is described in detail below.

Firstly, it is considered that in the two computations of linkage and sorting, the selection calculation only involves the computation of monomer association, and the latter two computations satisfy the commutative and associative laws. Assume that X_1, X_2, X_3 represents an association, then the link and sorting calculation meet the properties shown in (5) and (6):

Commutative law:

$$R_1 \leftrightarrow R_2 \equiv R_3 \leftrightarrow R_1. \tag{5}$$

Associative law:

$$(R_1 \leftrightarrow R_2) \leftrightarrow R_3 \equiv R_1 \leftrightarrow (R_2 \leftrightarrow R_3). \tag{6}$$

It can be seen that the secure multicomputing problem can be transformed into secure two-party computing.

Data linking refers to the process of combining records with the same keyword in different sets of computer basic education resources. The model completes data linking in the form of a subquery, which means that the shared resources are transmitted among all parties to achieve the final

link operation. The general process of link operation is as follows:

All shared computer basic education resources are formulated as T_i, k_i represents the primary key column of the resource set, and the equivalent link data shared by all input parties is formulated as T^*, Shuffle the respective teaching resource set T_i, and use T_i^* to describe the shuffled resource set, and k_i^* represents the shuffled primary key column. The random permutation function is selected based on the shared access control key s between the parties. In order to query the primary key column by permutating function evaluation, the value $\pi_s(k_i^*)$ is transferred to the subsequent calculating party in turn, and the subsequent calculating party is linked with the results transmitted by the previous calculating party, until finally the result table T^* is produced.

The essence of the ranking is a vague ranking. If the vector $X_1, X_2, \cdots, X_n$ of basic computer education resources shared by n computing parties is drawn up, then the shared vector can be described as $X_1, X_2, \cdots, X_n$, The goal of the ranking is to determine the order of vectors according to specific comparison principles, and its general process is as follows:

The encrypted shared vector of each computation method is drawn as X_i, and the input vector of each computation method is randomly selected. When $1 \le i \le j \le n$, $g_{i,j} = X_i \le X_j$ is calculated in parallel, and the sorting vector X' can be obtained by using $g_{i,j}$ to sort the vector X.

The concrete structure of the data layer can be built based on the above two computations. The cover layer can not only ensure the security of basic computer education resources but also provide automatic arrangement and keyword selection services for resource sharing.

3.2. Collected Information about Basic Computer Education Resources to be Shared. In the database of basic computer education resources, there are many users who provide shared information. In order to ensure the reasonable distribution of shared resource information, it is necessary to collect and classify shared information resources according to different providers and define the information resource sharing process of information providers as follows:

$$\begin{aligned} \frac{\mathrm{d}n_A}{\mathrm{d}t} &= v_A n_A \left(1 - \frac{n_A}{N_A} - \frac{\alpha_{AB} - \beta_{AB}}{N_B} n_B\right) \\ \frac{\mathrm{d}n_B}{\mathrm{d}t} &= v_B n_B \left(1 - \frac{n_B}{N_B} - \frac{\alpha_{BA} - \beta_{BA}}{N_B} n_A\right), \end{aligned} \tag{7}$$

where, v_A and v_B represent the speed at which providers upload resources, α_{AB} and α_{BA} represent the inhibitory effect coefficients between different information providers caused by resource sharing, and β_{AB} and β_{BA} represent the promoting effect coefficients between resource providers.

The overlap of digital resource information is shown in Figure 2. Where, A and B, respectively, represent the information of computer basic education resources uploaded to the shared platform by the provider.

As can be seen from Figure 2, there are three scenarios for resources shared by different providers:

① The resources provided by different providers do not overlap, as shown in Figure 2(a);

② Different providers provide parts of the same or overlapping resources, as shown in Figures 2(b)–2(d);

③ Different providers provide the same or similar resources, as shown in Figure 2(e).

According to the representation in Figure 2, R_{AB} is defined as the information overlap degree of resource information A and B. Therefore, if the value of R_{AB} is 0, the configuration factor can be defined directly. If the value of R_{AB} is not 0, it is necessary to reduce the weight of the collected basic computer education resource information and eliminate the repeated resource information.

3.3. Clustering of Basic Computer Education Resources Based on Gaussian Mixture Model. The Gaussian distribution, also known as the normal distribution, is a very important probability distribution in statistics and has significant applications in the computer field [15, 16]. If there are n -dimensional joint Gaussian random variables, then: is still Gaussian random variable after any linear transformation; any $m(m \le n)$ -dimensional marginal distribution is Gaussian; after linear transformation (or linear system processing), it is still a Gaussian signal.

Consider the case of a mixed Gaussian model with a mean of 0 and a standard deviation of 1. The cross section parallel to the horizontal plane is a circle, and the center of the circle is where the mean of each dimension lies. In practice, by changing the standard deviation, the probability distribution density curve can become an ellipse, and the ellipse can be tilted at any angle to achieve any aspect ratio, or it can be moved to any position in the plane. The cross section defines a specific distribution, and the mixed Gaussian model adjusts the ellipse so that it can achieve the best match with the cluster data, and the final ellipse parameters can generate the data in the cluster with the maximum probability [17].

It can be said that the mixed Gaussian model clustering is a basic data probability density distribution clustering method, and many widely used algorithms have good applicability to the data distribution conforming to the mixed Gaussian model. The clustering process based on Gaussian mixture model is shown in Figure 3.

Step 1. Input the initial number of clusters C_0 to obtain the overlap threshold T of Gaussian distribution;

Step 2. Let C be the result of each iteration clustering, which is consistent with the initial clustering number C_0, to form the initial partition area and determine the initial kernel;

Step 3. Set the normal kernel function of iterative clustering result C as F_k, and then run the dynamic clustering process;

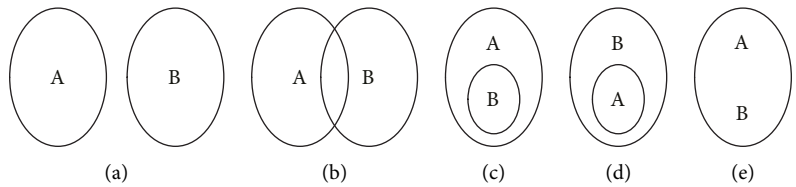

Figure 2: Diagram of shared resource overlap.

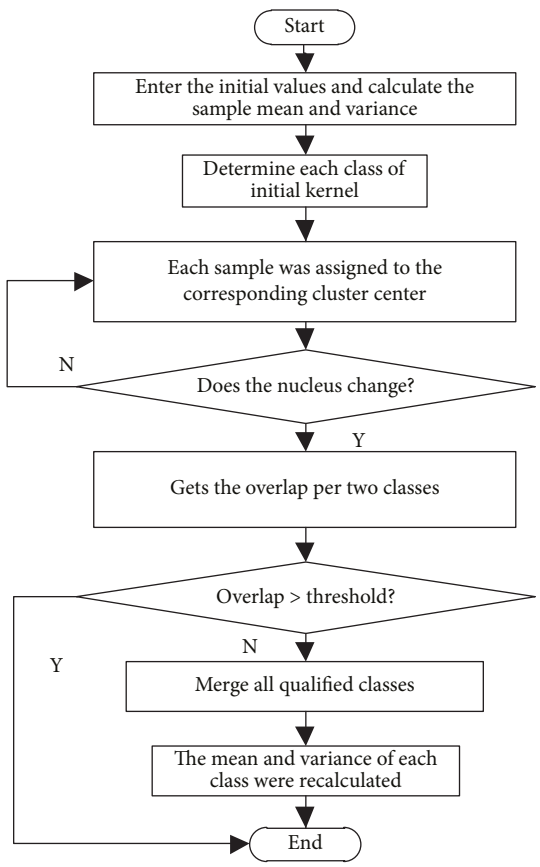

Figure 3: Resource clustering process based on gaussian mixture model.

Step 4. Distinguish overlapping regions and scattered regions according to Step 3, and then calculate the overlap degree $DO(1 \le i < j \le C)$ of several Gaussian distributions into groups;

Step 5. Select the Gaussian distribution results of all load conditions:

(1) The formula of overlap degree threshold meeting the conditions is:

$$T < DO. \tag{8}$$

If the overlap threshold meets the above conditions, the cluster point (i, j) is randomly selected.

(2) The overlap degree of several Gaussian distribution groups meets the conditions and the formula is:

$$DO = \max_{F_k \ge j, l \le i}\left\{DO_{i,k}, DO_{l,j}\right\}. \tag{9}$$

If the overlap degree of several Gaussian distribution groups meets the above conditions, then randomly selected cluster point (i, j) will be merged.

(3) All selected cluster points were normalized to form a new cluster center, and then the mean and covariance of the cluster center were calculated.

Step 6. Update the iterative clustering result. If the result meets > 2, then it needs to jump to Step 3; otherwise, stop updating and output the clustering result X_{AB}.

3.4. Configure Basic Computer Education Resources Based on Clustering Results Evolution. When the information overlap degree of shared information uploaded by different information providers is 0, it means that information resource sharing reaches balance and information demanders' reception degree of information resources tends to be saturated. Then the equilibrium condition shown in (10) holds:

$$\begin{aligned} \frac{n_A}{N_A} &= v_{AB}\frac{n_B}{N_B} + 1 \\ \frac{n_B}{N_B} &= v_{BA}\frac{n_A}{N_A} + 1. \end{aligned} \tag{10}$$

Therefore, the equilibrium condition of information resource sharing is transformed into variable representation, as follows:

$$\begin{aligned} \chi(n_A, n_B) &= X_{AB} + v_{AB}\frac{n_B}{N_B} - \frac{n_A}{N_A} \\ \delta(n_A, n_B) &= X_{AB} + v_{BA}\frac{n_A}{N_A} - \frac{n_B}{N_B}. \end{aligned} \tag{11}$$

The coordinate satisfying the equilibrium condition can be obtained by solving the equilibrium condition. When the information resource sharing level of A and B is equal, the information resource sharing can be realized within a certain range [18].

3.5. Design Configuration Factor. Assume that the number of samples of basic computer education resource information configured by equilibrium evolution is, the factor index of configuration is h, and the j -th configuration factor of the i -th sample in the configuration information is defined as ε_{ij}. $i \in [1, g]$, $\in [1, h]$, then the initial matrix composed of all

sample values of basic computer education resource information can be expressed as follows:

$$\varepsilon = \left|\varepsilon_{ij}\right|_{g\times h}. \tag{12}$$

Before calculating the initial matrix of the sample, the data in the matrix should be standardized. The average value of the j -th column data can be calculated by formula (13) as follows:

$$\overline{\varepsilon_j} = \sum_{j=1}^{g} \frac{\varepsilon_{ij}}{g}. \tag{13}$$

After the data in the initial matrix are averaged, the new matrix is obtained as follows:

$$\overline{\varepsilon_{ij}} = \frac{\varepsilon_{ij}}{\overline{\varepsilon_j}}. \tag{14}$$

Then, normalize the mean results according to formula (15):

$$\phi_{ij} = \frac{\overline{\varepsilon_{ij}} - \min\overline{\varepsilon_{ih}}}{\max\overline{\varepsilon_{ih}} - \min\overline{\varepsilon_{ih}}}. \tag{15}$$

The construction matrix obtained after a series of processing can be expressed as formula (16):

$$\phi = \left|\phi_{ij}\right|_{g\times h}. \tag{16}$$

The relevant data of the collected computer basic education resource information is substituted into the matrix, and the relevant matrix, eigenvalue and eigenvector of the matrix are calculated, so as to obtain A uniform eigenvector corresponding to the configuration eigenvalue of the matrix, in which the characteristic polynomial composing the eigenvector is marked as γ_j. Finally, the number of allocation factors can be further determined through the cumulative contribution rate of allocation factors of basic computer education resource information [19]. The cumulative contribution rate of the first μ factors is as follows:

$$d_\mu = \sum_{1}^{\mu} \left(\frac{\gamma_j}{\sum_{j=1}^{h} \gamma_j}\right), \tag{17}$$

When the eigen root of the eigenvector is not less than 1, the number of configuration factors n_d can be determined. Thus, the sharing of basic computer education resources can be realized [20]. The process is as follows:

$$Z = \frac{n_d \times X_{AB}}{\chi(n_A, n_B) + \delta(n_A, n_B)}. \tag{18}$$

4. Experiment and Result Analysis

In order to verify the practical application performance of the computer basic education resource sharing method based on Gaussian mixture model, the following experimental test process is designed.

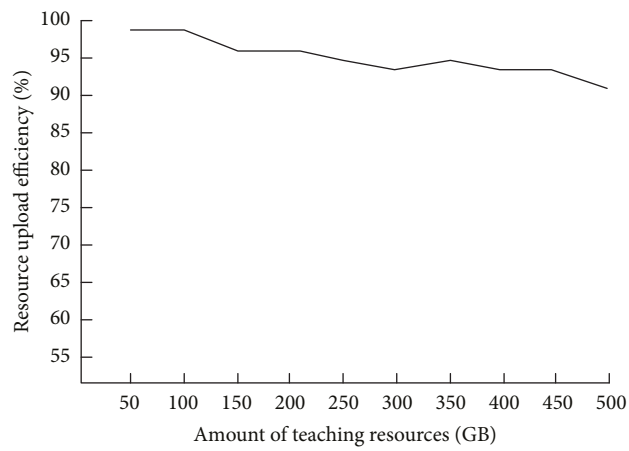

Figure 4: Resource sharing efficiency of basic computer education based on this method.

4.1. Basic Inspection. The method proposed in this paper is used to conduct a sharing experiment on basic computer education resources in a university, and the sharing efficiency of this method is tested by taking the uploading efficiency of resources as an index. The experimental results are shown in Figure 4.

As can be seen in Figure 4, as the total amount of computer basic education resources continues to grow, their upload speed will gradually decrease. Although the efficiency of resource uploading will decrease when basic computer education resources are shared in this paper, the rate and range of this decrease are small, indicating that the efficiency of resource sharing in this paper is high. The reason for this result is that the method described in this paper designs the index layer, which can construct the domain with specific attributes or a combination of attributes and complete the rapid clustering and data uploading of teaching resources using the domain index.

Assuming there are 1,000 resources for computer basic education that need to be shared, divide them into six groups. Likewise, each group has a distinct update upper limit. Figure 5 illustrates the real-time resource update capability when the proposed method is used to share basic computer education resources.

As shown in Figure 5, when the proposed method is used to share the resources for basic computer education, the update amount of the resources does not exceed the update upper limit, indicating that the proposed method has superior real-time update performance. This is due to the fact that after configuring basic computer education resources based on the evolution of clustering results, the proposed method also designs the allocation factor of educational resources, so that after generating new educational resources, the proposed method will locate the newly generated resources and integrate them with the original resources, thereby achieving the update and sharing of real-time educational resources.

The method is therefore applied to college teaching. After 60 days of application, a questionnaire is used to assess teacher and student satisfaction and the application's

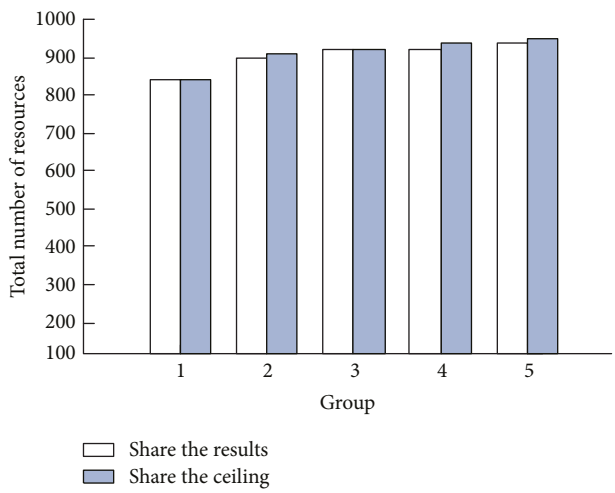

Figure 5: Real-time resource update performance analysis of the proposed method.

Table 1: Evaluation of the application effect of the teaching method by teachers and students.

	Preapplication prediction	Postapplication evaluation	Value of t	Value of p
Learn about educational resource sharing	2.20 ± 0.48	2.60 ± 0.44	−10.258	0.001
Awareness of educational resources	2.52 ± 0.50	2.66 ± 0.57	−3.142	0.002
Understand the role of communication in educational resources	1.88 ± 0.51	2.54 ± 0.51	−10.865	0.001
Recognize the method of sharing educational resources	2.84 ± 0.30	2.80 ± 0.59	0.698	0.487
Contact education educational content	2.93 ± 0.36	2.85 ± 0.44	1.881	0.063
Characteristics of educational resource sharing methods	3.19 ± 0.45	3.06 ± 0.40	2.625	0.010
Improve signal literacy	3.39 ± 0.56	3.27 ± 0.51	1.941	0.054
Autonomy of learning	3.30 ± 0.54	3.17 ± 0.56	2.047	0.046
Information interactivity	3.22 ± 0.62	3.18 ± 0.52	0.536	0.595
Students' concentration	3.17 ± 0.55	3.04 ± 0.53	1.866	0.061
The improvement of interest in learning	2.75 ± 0.69	2.54 ± 0.61	3.224	0.003

impact. In both surveys, 300 questionnaires were distributed and 300 were returned, for a total of 297 valid responses. The SPSS software package was utilized for the analysis and statistics of the collected data. Pearson's correlation, relative number analysis, and multiple stepwise regression methods were utilized for the two questionnaires, respectively, and statistics were utilized for the final result analysis, as shown in Table 1.

After the application of this method, the degree of interest and cognition of teachers and students significantly increased, and the difference was statistically significant ($P < 0.01$). The difference between students' learning autonomy and interest in learning was also statistically significant ($P < 0.05$). As can be seen from Table 1, the evaluation results of teachers and students before and after the application of this method have obvious changes. This also shows that a reasonable method of sharing educational resources has a positive role in promoting both teachers and students.

4.2. Contrast Test. In order to avoid the demerit being too single, the traditional education curriculum resource sharing platform based on the cloud platform (method A) and the education resource sharing method based on wireless broadband connections (method B) as contrast method, respectively, to share process takes, resource clustering accuracy as an index, and complete the performance verification together with the method in this paper.

First, verifying the sharing process of different methods is time-consuming, and the results are shown in Table 2.

According to Table 2, the sharing process of the proposed method takes 5.55 minutes, method A takes 8.74 minutes, and method B takes 9.45 minutes during the tenth experiment. On the 30th experiment, the sharing process time for the proposed method was 5.32 minutes, 8.68 minutes for method A, and 9.58 minutes for method B. On the 50th experiment, the proposed method's sharing procedure takes 5.46 minutes, compared to 8.55 minutes for method A and 9.54 minutes for method B.

In the experimental process, the proposed method has a maximum sharing time of 5.78 min and a minimum sharing time of 5.32 min, indicating that, compared to the two traditional methods, the proposed method is more time-efficient.

The accuracy of different resource clustering methods is then evaluated, and the results are depicted in Figure 6.

Table 2: Time consumption comparison of different methods of educational resource sharing (min).

Number of experiments/time	Method of this paper	Method A	Method B
10	5.55	8.74	9.45
20	5.78	8.63	9.62
30	5.32	8.68	9.58
40	5.34	8.74	9.69
50	5.46	8.55	9.54

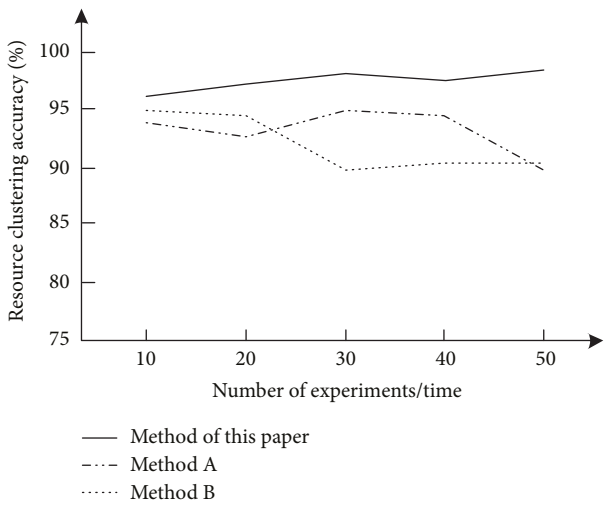

Figure 6: Comparison of the resource clustering accuracy of different methods.

According to the results shown in Figure 2, at the 10th experiment, the resource clustering accuracy of the proposed method was 96.2%, the resource clustering accuracy of method A was 94.1%, and the resource clustering accuracy of method B was 94.8%. At the 30th experiment, the resource clustering accuracy of the proposed method was 97.5%, the resource clustering accuracy of method A was 95.0%, and the resource clustering accuracy of method B was 89.9%. At the 50th experiment, the resource clustering accuracy of the proposed method was 97.9%, the resource clustering accuracy of method A was 89.7%, and the resource clustering accuracy of method B was 89.4%. In the whole experimental process, the resource clustering accuracy of the proposed method can reach 97.9%, indicating that the proposed method has a good effect on the processing of basic computer education resources.

5. Conclusion

In tandem with the acceleration of the education informatization process, the quantity of basic computer education resources is growing. The ability to supervise the basic computer education resources effectively is growing in significance. Increased requirements for the cocreation and sharing of educational resources have been prompted by the expanding types and quantities of basic computer education resources and the diverse learning needs of users.

Based on a mixed Gaussian model, this study develops a method for sharing basic computer education resources. Following the design of the basic sharing platform, information regarding the basic computer education resources to be shared is gathered. The education resources are then clustered using the Gaussian mixture model, and the clustering results are used to configure the education resources. Depending on the number of configuration factors, computer basic education resources can be shared in accordance with their design.

According to experimental results, the proposed method has high resource sharing efficiency, the ability to update resources in real time, and positive teacher and student ratings. Compared to conventional resource sharing methods, the proposed method reduces sharing time and improves resource clustering precision.

In the future, we will further reduce the time of educational resource sharing methods and improve the clustering accuracy.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Research on Multitarget Detection and Intelligent Tracking Technology Based on Computer Vision

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With image analysis as the core for multitarget detection and intelligent tracking, mostly applying the Faster R-CNN or YOLO framework, the MOTA score for multitarget tracking is low in the face of complex working environments. Therefore, further research into computer vision techniques is carried out to design new multitarget detection and intelligent tracking methods. Based on the small-aperture imaging model, the principle of lens distortion was analyzed, and a camera calibration and image calibration scheme was designed to obtain effective environmental images. The attention mechanism is introduced to optimise the structure of deep learning networks, and a computer vision detection algorithm based on this is applied to complete regional multitarget detection. The distance between each target and the body is then measured in combination with binocular vision principles. Finally, the spatiotemporal context algorithm is applied to perform simulation calculations to obtain the multitarget intelligent tracking results. The experimental results show that the mean MOTA score of the proposed technique is 0.87 in the night environment, which is 24.14% and 28.374% better than the neural network-based and machine vision-based tracking methods, respectively; in the daytime environment, the mean MOTA score of the multitarget tracking results of the technique is 0.94, which is 28.72%, and the mean MOTA score of 0.94 for the multitarget tracking results in the daytime environment was 28.72% and 22.34% higher than the other two methods.

1. Introduction

The progress of modern technology has led the automotive industry towards an intelligent trend [1], and it can be said that the level of development of multitarget detection and intelligent tracking technology directly determines the degree of intelligence of the vehicle. As urban traffic scenarios become more and more complex [2], the technical requirements for intelligent driving are becoming higher and higher. To ensure the stability and safety of automated vehicle driving, it is necessary to first detect targets in the driving area and track their movement trends in order to generate highly intelligent driving decisions [3]. At the same time, a key aspect of smart driving vehicle operation is environmental perception. Only a clear enough knowledge of the road environment around the driving area can ensure that smart driving vehicles are integrated into the traffic environment. However, existing multitarget detection and intelligent tracking technologies can be affected by good or bad lighting and weather conditions, resulting in target detection and intelligent tracking effects that do not meet intelligent driving requirements.

With the in-depth research of computer vision technology, computer vision technology with deep learning as the core has started to be applied in various fields. The paper takes this as the research direction and introduces an attention mechanism to further optimise the current computer vision technology by adding a subregion feature library and an aspect ratio feature library to the original detection model to improve the feature representation capability of the computer vision-based multitarget detection model and obtain accurate localisation recognition results.

On this basis, a new multitarget detection and intelligent tracking technique is established to stably and quickly track the movement trend of multitarget objects in the vehicle's surrounding environment. The experimental validation results show that the application of the proposed technique for multitarget tracking results in more accurate tracking.

This paper consists of four chapters. The first chapter is the introduction. The second chapter introduces the design of multitarget detection and intelligent tracking based on computer vision. The third chapter is the empirical analysis, and the designed multi-target detection and intelligent tracking algorithm is tested. The fourth chapter is the conclusion.

2. Multitarget Detection and Intelligent Tracking Technology

2.1. Camera Calibration and Image Calibration Programme. The first step in tracking is identification. A binocular camera with a wide-angle lens is mounted on the front of the smart driving vehicle as the main device for sensing the smart driving environment. Considering that radial and tangential aberrations exist when the camera captures images [4], a camera calibration and image calibration scheme is established with the objective of reducing the position errors caused by lens aberrations as a fundamental part of computer vision-based multitarget detection and intelligent tracking [5]. Most of the imaging of the camera relies on the small-aperture imaging model, in three-dimensional space and the camera imaging plane, respectively, to determine a target point with a corresponding relationship between the two can be expressed as follows:

$$I\left[a'\ b'\ 1\right] = \left[a\, b\, c\, 1\right]\begin{bmatrix} R \\ T \end{bmatrix}, \tag{1}$$

$$\left[g\, h\, 1\right] = \left[a'\ b'\ 1\right]\psi. \tag{2}$$

In the formula, (a, b, c) represents the coordinates of the target point in the world coordinate system, (a', b') represents the coordinates of the target point in the camera coordinate system, (g, h) represents the coordinates of the target point in the image pixel coordinate system, I represents the scaling factor, R represents the rotation matrix, T represents the translation matrix, and ψ represents the internal parameter matrix.

$$\psi = \begin{bmatrix} d_1 & 0 & 0 \\ \tau & d_2 & 0 \\ u_0 & v_0 & 1 \end{bmatrix}. \tag{3}$$

In the formula, d_1 and d_2 represent the scale factor on the x and u axes, respectively, (u_0, v_0) represents the coordinates of the origin, and τ represents the axis inclination parameter. With (1) and (2), the imaging principle of the camera is described directly, but in practice, a nonlinear aberration model needs to be added to describe the imaging point shift.

$$\begin{bmatrix} \overline{\varepsilon} \\ \overline{o} \end{bmatrix} = \left(1 + \varphi_1 r^2 + \varphi_2 r^4 + \varphi_3 r^6\right)\begin{bmatrix} \overline{\varepsilon_1} \\ \overline{o_1} \end{bmatrix} + \begin{bmatrix} 2k_1\overline{\varepsilon_1 o_1} + k_2\left(r^2 + 2\overline{\varepsilon_1}^2\right) \\ 2k_2\overline{\varepsilon_1 o_1} + k_1\left(r^2 + 2\overline{o_1}^2\right) \end{bmatrix}. \tag{4}$$

In the equation, $(\overline{\varepsilon}, \overline{o})$ represents the ideal coordinate value of the target point, $(\overline{\varepsilon_1}, \overline{o_1})$ represents the actual distortion coordinate value of the target point, φ_1, φ_2, and φ_3 represents the radial distortion factor, r represents the radius, and k_1 and k_2 represents the tangential distortion factor. Based on the exact and distorted coordinates, the camera calibration process is completed and reasonable parameter values are obtained.

In practice, it is necessary to combine the Zhang Zhengyou calibration method with a calibration plate composed of black and white squares to take images, build a library of photos for calibration, apply the optimization method to iteratively solve the camera parameters with the minimum error as the goal [6], determine the optimal internal and external parameters and aberration parameters of the camera, and after the camera calibration is completed, calculate the aberration pixel coordinates of the actual photos taken, as well as the ideal coordinates to complete the image calibration.

2.2. Computer Vision Multitarget Detection Algorithms. A calibrated camera is applied to capture images of the smart driving surroundings, and then computer vision techniques are applied for multitarget detection. Considering the computer vision detection technology based on deep learning, it can be influenced by external factors in practical applications, making the detection results biased. The paper applies computer vision principles and introduces attention mechanisms in conventional deep learning networks [7] to establish the multitarget detection framework shown in Figure 1 for feature extraction, feature pooling, and classification regression of camera acquisition images.

According to Figure 1, it can be seen that applying convolutional neural network for computer vision multitarget detection requires first acquiring image convolutional features for classification and regression analysis. In the paper, the subregion feature attention module and aspect ratio feature attention module [8] are introduced into the original multitarget detection model to obtain the computer vision target detection block diagram shown in Figure 2. Introducing subregion feature attention module and aspect ratio feature attention module into the original multitarget detection model can help distinguish single target in multitarget better. Therefore, higher recognition accuracy can be obtained for target recognition.

According to Figure 2, the updated computer vision target detection model contains the attention module, which mainly plays a role in the ROI feature extraction process, extracting features for regular patterns for further processing and combining them with the original ROI pooled features to generate high-quality ROI classification features.

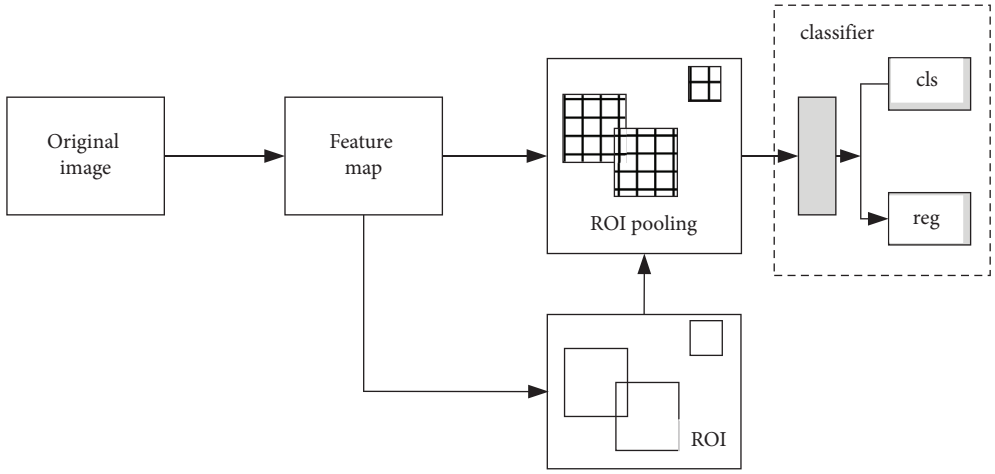

Figure 1: Block diagram of multitarget detection.

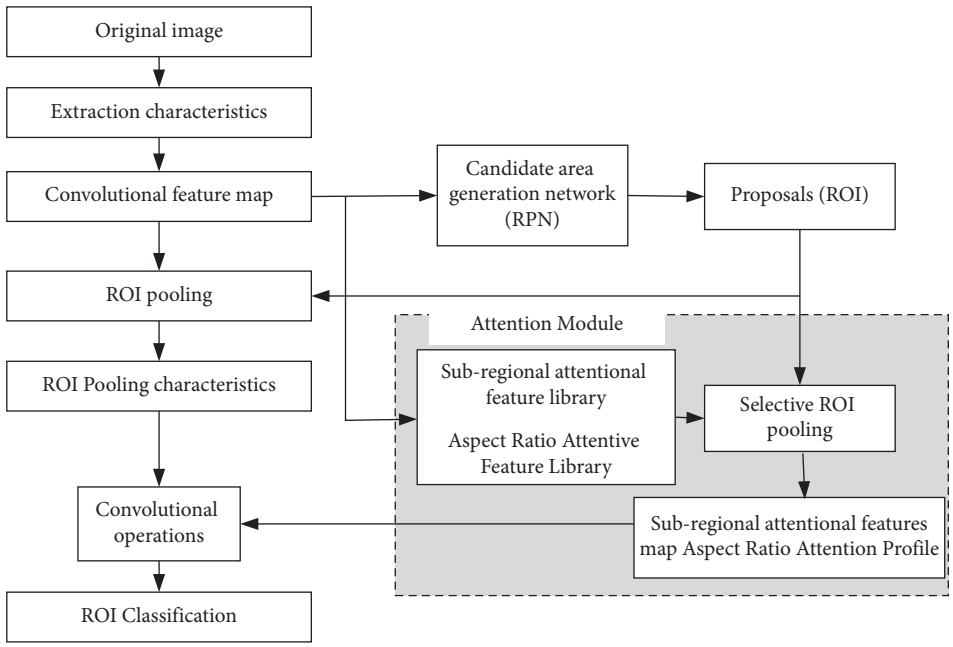

Figure 2: Block diagram of computer vision target detection with the introduction of an attention module.

$$\xi B_p = B_p \bullet (M_1 + M_2). \tag{5}$$

In the formula, p represents ROI, B_p represents ROI pooling features, ξ represents ROI classification features, M_1 represents subregion attention feature maps, and M_2 represents aspect ratio attention feature maps.

The new attention module contains two attention feature bases, each of which holds the corresponding attention feature activation relationships. Among them, the features displayed within the subregion attention feature library are associated with spatial location information [9], and based on the location of each feature point in the ROI subregion, the formula for calculating the subregion attention salience value is expressed as follows:

$$\mu_\beta(i, j) = \phi U_{ij}. \tag{6}$$

In the formula, (i, j) denotes a point in the convolutional feature map, β denotes a subregion, μ denotes an attentional salient, U denotes a feature vector, and ϕ denotes an attentional feature extractor.

The features saved within the aspect ratio attention feature library describe actual feature attributes that directly describe the observed viewpoint and pose morphology of the target object, extracting horizontal and vertical scale differences in the target detection framework and better determining target class differences. A deep learning network structure incorporating attention mechanisms is applied to run computer vision techniques to obtain multitarget detection results during intelligent driving.

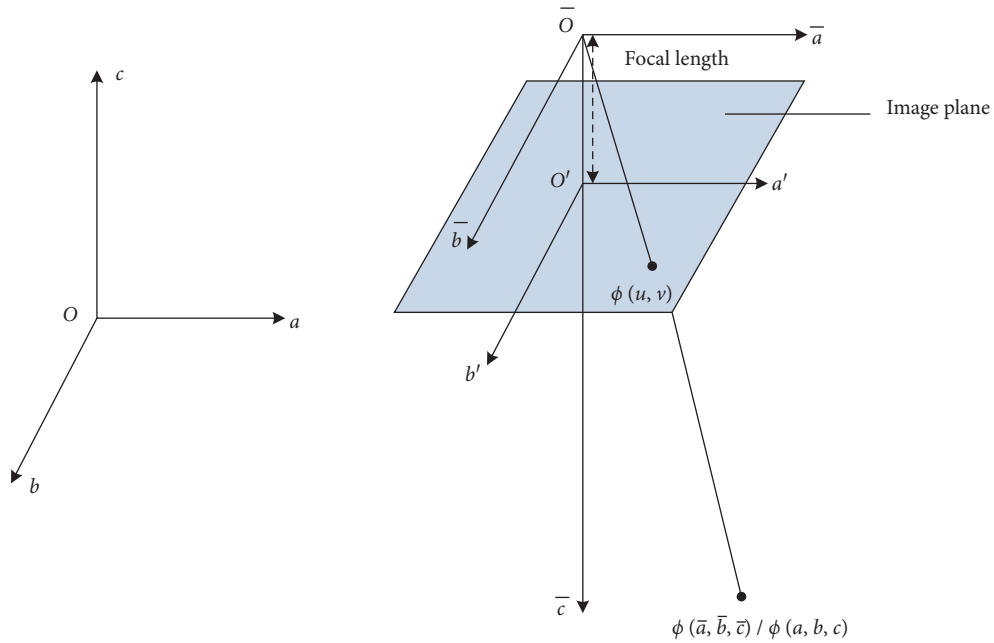

Figure 3: Diagram of each coordinate system of the pinhole model.

2.3. Target Distance Measurement Programme. After the target detection is over, the target distance measurement method is designed based on the binocular vision principle to locate the distance between each target point and the vehicle body. Applying the pinhole model imaging principle [10], image acquisition is carried out during intelligent driving, and each coordinate system of the pinhole model is shown in Figure 3.

In Figure 3, ($Oabc$) represents the 3D world coordinate system, ($\overline{O}\overline{a}\overline{b}\overline{c}$) represents the camera coordinate system, ($O'a'b'$) represents the image plane coordinate system, $\phi(u, v)$ represents the plane coordinate points, and $\phi(\overline{a}, \overline{b}, \overline{c})\phi(a, b, c)$ represents the 3D coordinate points.

Setting up the existence of a target point in space and the known coordinates of the image point of the target point in the two calibrated camera coordinate systems, combined with the projection matrix, the perspective projection matrix transformation relationship can be expressed as follows:

$$\overline{c}_A \begin{bmatrix} u_L \\ v_L \\ 1 \end{bmatrix} = \chi_1 \begin{bmatrix} \overline{a}_L \\ \overline{b}_L \\ \overline{c}_L \\ 1 \end{bmatrix}, \tag{7}$$

$$\overline{c}_A \begin{bmatrix} u_A \\ v_A \\ 1 \end{bmatrix} = \chi_2 \begin{bmatrix} \overline{a}_A \\ \overline{b}_A \\ \overline{c}_A \\ 1 \end{bmatrix}. \tag{8}$$

In the formula, L denotes the left camera, A denotes the right camera, χ_1 denotes the projection matrix of the left camera, and χ_2 denotes the projection matrix of the right camera. Based on the left and right camera perspective projection matrix transformation relationships shown in (7) and (8), the spatial coordinates of the target can be deduced from the known image point coordinates and the distance measurement results can be obtained by comparing the coordinate information. It is important to note that camera images in complex environments can contain a lot of noise, which can affect the accuracy of the distance measurement results. In this case, the least squares method can be combined with further solutions to obtain more accurate spatial coordinates of the measured point.

2.4. Multiobjective Intelligent Tracking. Relying on computer vision technology, the correlation between the target object and the local scene needs to be analysed for intelligent tracking of multiple targets for detection and localisation [11], and the spatiotemporal context algorithm based on Bayesian framework is applied in the paper for simulation and calculation to clarify the intensity and location correlation of the target region in the image of the local context, and then the maximisation confidence function [12] is applied to achieve the target location of real-time tracking. In which, the confidence function can be expressed as follows:

$$e(X) = \Gamma \times \mathrm{E}^{-\left(\frac{|X - X''|}{\partial}\right)^{\Theta}}. \tag{9}$$

In the formula, X is the target position, X″ is the target region centre position, e is the confidence level, Γ is the normalisation factor, E is the bias function, ∂ is the scale parameter, and Θ is the shape parameter.

Faced with a multiframe image acquired in real time, the local contextual feature set of the target region it contains can be represented as follows:

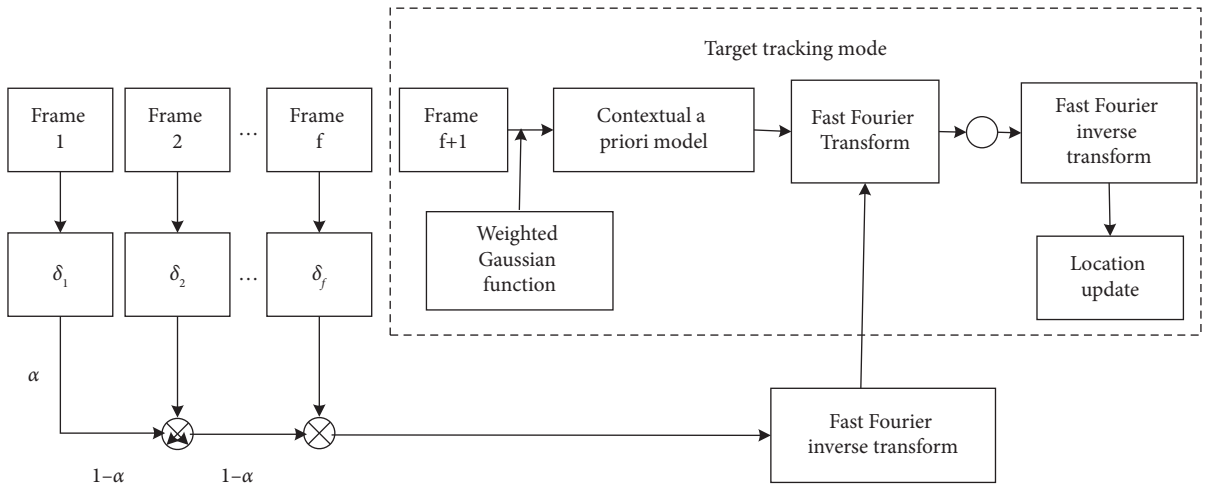

Figure 4: Multitarget intelligent tracking model.

$$D = \{e(\Upsilon) - G(\Upsilon), \Upsilon \in \Omega\}. \quad (10)$$

In the formula, D represents the local context feature set, Υ represents the selected location, G represents the image intensity, and Ω represents the local context region around the selected location. Based on the concept of local context analysis [13], the multiobjective intelligent tracking model can be described as Figure 4.

According to Figure 4, the STC algorithm-based multitarget intelligent tracking model is essentially a multitarget intelligent tracking task through a maximum confidence function search. The target image frame is analysed to obtain its corresponding spatial context model, and the spatiotemporal context model of the next image frame is represented as follows:

$$H_{f+1}(X) = (1-\alpha)H_f(X) + \alpha\delta_f(X). \quad (11)$$

In the formula, f denotes the number of image frames, H denotes the spatiotemporal context model, α denotes the learning rate factor, and δ denotes the spatial context model. According to (11), it can be seen that the spatiotemporal context model of the next frame can be derived by weighting the spatiotemporal context model for the current frame of the photo and the spatial context model [14]. Therefore, the confidence function calculation formula can be updated as follows:

$$e_{f+1}(X) = Q^{-1}\left(Q\left(H_{f+1}(X)\right) \otimes Q\left(G_{f+1}(Y)w_\partial(X - X'')\right)\right). \quad (12)$$

In the formula, Q denotes the Fourier transform, Q^{-1} denotes the Fourier inverse transform, $\otimes$ denotes the convolution operation, and w denotes the weighted Gaussian function. Based on the results of the maximum confidence calculation, the position of the target point within each frame is determined. Considering the application of the STC algorithm, it is only possible to describe the change in the target position of a single pixel and obtain the actual displacement of the pixel. To obtain more intuitive target tracking results, it is also necessary to fuse optical flow algorithms [15] to specify the subpixel displacement in consecutive image frames and obtain multitarget intelligent tracking results.

3. Experiment

The design of a multitarget detection and tracking technique is based on computer vision technology, and an experimental analysis is carried out to verify the effectiveness of the technique in practice. A binocular camera is mounted on an ordinary car to perform multitarget detection and tracking in night and day scenes. Based on the detection and tracking results, the validity of the research content in the paper is reflected.

3.1. Camera Calibration. The implementation of computer vision technology needs to be image-based. During the experiments, a camera calibration process is carried out before the camera is fixed to the car in order to capture a more realistic image. First, create a $13 * 14$ black and white checkerboard visual calibration grid, each measuring $20\,\text{mm} * 20\,\text{mm}$, as shown in Figure 5. Print out the calibration grid and paste it onto a flat horizontal board to form a visual calibration board.

When applying the binocular camera to capture images, it is necessary to constantly adjust the angle of the visual calibration plate to obtain multiple calibration plate images, as shown in Figure 6.

The calibration plate images captured by the cameras shown in Figure 6 were loaded simultaneously into the MATLAB software and manually processed through the Calibration Toolbox to extract the corner points contained within each calibration plate image, and the optimum internal and external parameters for the left and right cameras were calculated based on the image corner point information, as shown in Tables 1 and 2.

Among them, η_x, η_y indicates the camera focal length parameter, (u_0, v_0) indicates the camera principal point

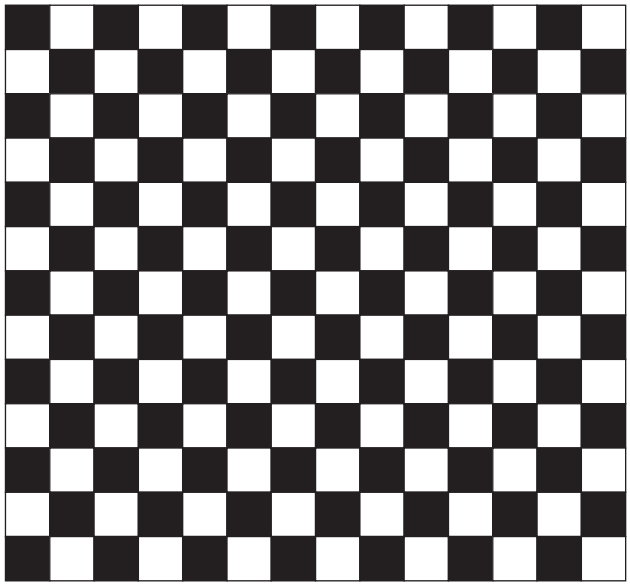

Figure 5: Schematic diagram of the visual calibration grid plate.

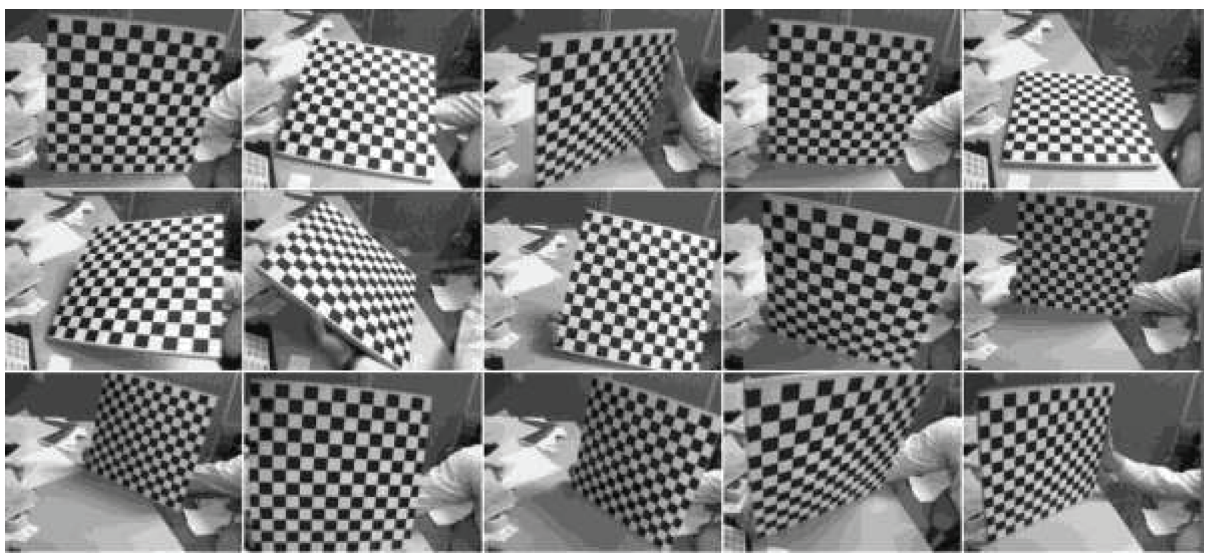

Figure 6: Image information of the calibration plate captured by the camera.

Table 1: Statistics of in-camera parameters.

Internal parameter	Left camera calibration result	Right camera calibration result
η_x	5523.45	5528.86
η_y	5523.57	5512.53
u_0	775.98	774.43
v_0	631.52	543.78
l_1	−0.137	−0.162
l_2	3.454	0.338
s_1	0.006	−0.001
s_2	−0.001	0.008

position, (l_1, l_2) indicates the radial aberration, and (s_1, s_2) indicates the tangential aberration. Through the camera calibration process, in addition to the intracamera parameters shown in Table 1, the external parameters of the right camera relative to the left camera were also obtained, as shown in Table 2.

Table 2: Statistics of off-camera parameters.

External parameter	Calibration result
x-Axis rotation matrix *(Rx)*	$[0.98\ 0.07\ 0.03]^T$
y-Axis rotation matrix *(Ry)*	$[-0.07\ 0.98\ -0.02]^T$
z-Axis rotation matrix *(Rz)*	$[-0.03\ 0.02\ 0.98]^T$
Translational variables *(T)*	[−303.02 −0.54 6.63]

After the parameters inside and outside the camera have been adjusted, it is fixed to the vehicle and continuous image acquisition is carried out while the vehicle is in motion as the data required for multitarget detection and intelligent tracking.

Figure 7: Night multitarget tracking results.

3.2. Evaluation Indicators. In order to demonstrate the reliability of the design technique in the paper, the Multi-Objective Tracking Accuracy (MOTA) should be selected during this experiment to assess the consistency between the intelligent tracking results and the actual trajectory of the target. The intelligent tracking result output from the application of the techniques in the text is first obtained to form a tracking path containing multiple nodes, and then the true position of each target is investigated to generate an actual running path containing multiple nodes. Comparing the degree of matching between the two paths and analysing the false detections, misclassifications, and incorrect matches that occur during the tracking process, the MOTA score is calculated by expressing the formula as follows:

$$MOTA = 1 - \frac{(m + n + \gamma)}{N}. \tag{13}$$

In the formula, m represents the number of false targets detected during tracking, n represents the number of false targets, γ represents the number of false match targets, and N represents the number of all targets that appear in the image frame.

3.3. Visual Analysis of Tracking Results. Firstly, a complex scene with high footfall was selected as the experimental scene. The experimental vehicle is controlled to drive through the scene and take video in a night environment, and several images are captured within the video sequence to form a multitarget tracking dataset. Using the multitarget detection and intelligent tracking techniques proposed in the paper, the dataset was analysed to obtain the multitarget tracking results shown in Figure 7.

Figure 7 shows frames 3, 10, 15, and 25, from which it can be seen that the scene contains a large number of pedestrians and that the pedestrian trajectories are not identical, while the tracking technique proposed in the text, when applied, detects essentially all the pedestrians, except in cases where the occlusion is too severe. The comparison of the four frames shows that the position of the pedestrian changes within each frame, but the colour of the detection frame does not change, which indicates a better result for multitarget tracking. The above experiments show that the tracking technique designed in the paper can detect and track multiple targets accurately in complex scenarios.

Afterwards, a weather day with good lighting conditions was selected to conduct a multitarget detection and intelligent tracking experiment on a relatively secluded street. The vehicle is set to drive through the street at an even speed and the binocular camera captures images of the surrounding scene as it moves to form a second experimental dataset. This dataset is processed by applying the techniques in this paper to obtain the multitarget tracking results shown in Figure 8.

As can be seen from Figure 8, there are only a small number of vehicles moving in the area and no pedestrians passing by. Therefore, the car can be considered as a detection target, and the illustration captures frames 18, 26, 32, and 40 to visualise the tracking results of a moving vehicle. Overall, the proposed technique can be applied to quickly detect other vehicles from the moment they come into the camera's range and mark them with different coloured detection boxes and then keep track of the vehicle's movement until it leaves the camera's range. In addition, although the experiment was conducted during daylight hours with few targets, the lighting conditions were complex, containing both shaded and brightly lit areas. However, the detection and tracking results of the techniques designed in the paper were not affected by the light and showed that the application of computer vision techniques based on deep learning networks with the introduction of attention mechanisms ensures the reliability of multitarget detection and tracking.

Figure 8: Daytime multitarget tracking results.

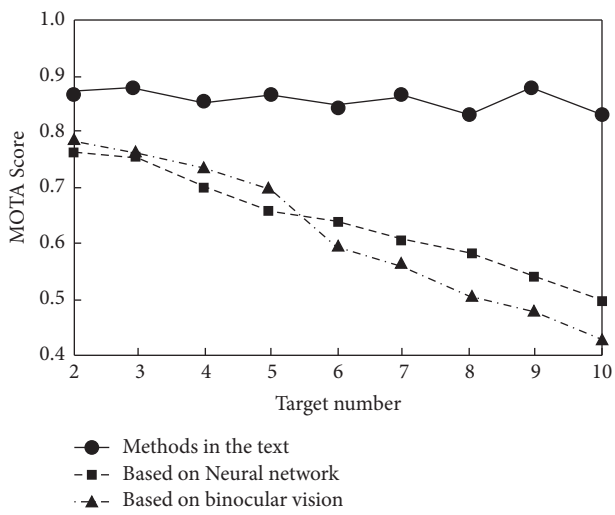

Figure 9: Comparison of MOTA scores for different methods in the night environment.

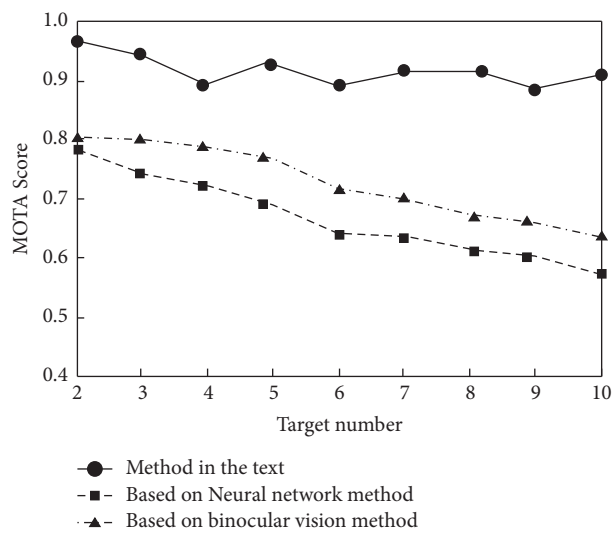

Figure 10: Comparison of MOTA scores for different methods in a daytime environment.

3.4. Tracking Performance Comparison. To enhance the visualisation of the experimental results, simultaneous experimental analyses were carried out in different experimental scenarios by applying the techniques mentioned in the text, a neural network-based approach, and a binocular vision-based approach, respectively. The targets to be detected and tracked were set to keep increasing, and the detection and tracking results of the different methods were recorded. The variation of MOTA scores for different methods in the night environment is shown in Figure 9.

According to Figure 9, the MOTA scores of the tracking results of the designed methods in the paper do not fluctuate much after the number of targets increases, with an average value of 0.87. The MOTA scores of the other two methods, however, keep decreasing as the number of targets increases. The neural network-based approach reduced the MOTA score from 0.76 to 0.52, with an average MOTA score of 0.66, while the binocular vision-based approach for multitarget detection and tracking in different environments achieved a maximum MOTA score of 0.78 and a minimum of 0.43, with an average MOTA score of 0.62. In summary, the MOTA scores of the intelligent tracking results of the proposed technique improved by 24.14% and 28.374% compared to the other two methods.

The change in MOTA scores for the different methods in the daytime environment was then analysed to form the comparative results of MOTA scores shown in Figure 10.

According to Figure 10, the mean MOTA score for the multitarget tracking results of the proposed technique in the daytime environment is 0.94, while the mean MOTA scores of the other two methods are 0.67 and 0.73, respectively. As a result, the proposed technique improves MOTA scores by 28.72% and 22.34% compared to neural network-based and binocular vision-based methods, respectively.

4. Conclusion

Intelligent driving is the development trend of the future automobile industry. The application of intelligent driving in urban scene depends on the development level of dynamic object tracking technology.

In this paper, the traditional computer vision technology based on deep learning is optimized. By adding attention mechanism, this paper constructs a new multiobject detection algorithm in computer vision to achieve more accurate and fast multiobject detection. Moreover, using the STC model, the results of the intelligent target tracking algorithm established in this paper are also more accurate.

The intelligent tracking method designed in this paper can maintain accurate detection and tracking of multiple targets in complex traffic environment. It performs better than the traditional intelligent tracking method in the environment of multitarget and changing illumination conditions. The intelligent tracking method constructed in this paper is applied to the field of intelligent driving, which is beneficial to enhance the stability of vehicle driving.

Data Availability

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

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Retraction

Retracted: Adaptive Classification Algorithm Design for Online Teaching Resources of Opera Singing

Mobile Information Systems

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] C. Xu, "Adaptive Classification Algorithm Design for Online Teaching Resources of Opera Singing," *Mobile Information Systems*, vol. 2022, Article ID 8609097, 9 pages, 2022.

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Research Article

Adaptive Classification Algorithm Design for Online Teaching Resources of Opera Singing

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In the context of the integration of each professional course's online education platform and teaching knowledge system, teaching resources are experiencing explosive growth, and classroom-based instruction is gradually being replaced by resource-based instruction. In the modern era, the optimization, integration, and efficient use of online teaching resources have become central concerns in education. In particular, the categorization and integration of resources have become the central focus of teaching work. The cognitive stratification theory classifies and orders the educational objectives in the cognitive domain in a scientific manner, which provides teachers with important ideas and foundations for implementing online and offline integrated teaching designs centered on the students' skill acquisition. Adaptive classification algorithm is introduced to subdivide the objectives of online singing teaching resources, and on this basis, the online resources are classified and integrated according to the characteristics of different teaching sessions, thereby achieving the efficient use of resources, which is an innovative path of singing resources classification and integration in the new stage of online resources teaching.

1. Introduction

Considering the current state of opera singing instruction in China, the number of students choosing this major is on the rise [1]. As each student's vocal foundation and learning aptitude varies, this has a significant impact on opera singing educators' normal methods of instruction. It is clear that traditional methods of teaching opera singing can no longer meet the requirements of the new era.

Since 2013, the development of online resource platforms such as massive open online courses (MOOC) has accelerated, and the launch of online education platforms such as National Quality Courses, Online Open Courses, and University Open Online Courses (UOOC) Consortium has integrated information technology with education teaching in order to enhance the quality of online courses and promote educational equity [2]. Watching course videos is one of the most important learning links for students. Different lecture formats, subject matter, and media applications determine various video presentation formats.

Since the online resource platform community encourages community members to freely create, publish, and share knowledge resources, and platform activities are unrestricted by time and space, it has gradually evolved into a massive dynamic knowledge resource repository that absorbs massive amounts of information and has become an essential location for global knowledge management, knowledge learning, knowledge sharing, and knowledge innovation [3]. However, the constantly updated and ever-expanding information resources will undoubtedly reduce the efficiency of users in locating the relevant resources they require, preventing students from discovering and utilizing the resources effectively and aggravating the problem of information overload.

Therefore, a reasonable description, annotation, organization, and management of community knowledge resources can increase the efficiency of user community information retrieval and browsing and promote the use and sharing of knowledge [4]. To this end, this paper uses the adaptive weighted KNN algorithm to reasonably classify the

resource data for the opera singing resources of the online platform, in order to conduct a comparative analysis for different types of classification systems, with the goal of providing relevant scientific researchers and online community practitioners with a comprehensive understanding of the current field of online community classification systems, thereby assisting researchers in recognizing the most effective classification systems. This paper is intended to provide researchers and online community practitioners with a comprehensive understanding of the current online community classification system. In addition, this paper can serve as a foundation for online community developers to construct a classification system that is conducive to the improvement and refinement of existing classification systems as well as the design and construction of new classification systems to facilitate the description and labeling of resources, information organization, and knowledge discovery in communities.

The main contributions of this paper are as follows.

(1) A k value adaptive weighted KNN algorithm is proposed in this paper, and the algorithm is applied to the classification of opera singing online resources with good results [5].

(2) Considering the distribution of sample data, this paper achieves the adaptive value of k according to the local density of the nearest neighbor points of the sample to be tested, which avoids the shortcoming of the traditional KNN method of fixed k value and makes the selection of the number of nearest neighbor points more reasonable.

(3) The case study shows that this method can make up for the shortcomings of the traditional KNN algorithm by adaptively taking the value of k and considering the sample distribution when weighting and has a higher accuracy rate compared with the modified three-ratio method [5], back-propagation neural network (BPNN) [6], support vector machine (SVM) [7], and the traditional KNN classifier.

The first chapter, which is the introduction, contains a description of the purpose, importance, and contribution of this work. The second chapter of the paper's related work provides an introduction and summary of the earlier work. The third chapter, Methods, provides a detailed explanation of the methodology used in this paper. The experimental findings and an analysis of this method's superiority are covered in the fourth chapter. The conclusion, which summarizes this paper's work and discusses its flaws and future directions, is the last chapter.

2. Related Work

2.1. Resources for Teaching Opera Singing. Online resources must be evaluated based on whether or not they contribute to the growth of students. Due to the individuality and diversity of each student, distance online resources must be utilized for effective teaching and learning with the ultimate goal of fostering individualized learning. Taking into account their individual differences, students should seek out learning resources that match their characteristics [8]. Teaching and learning resources should be categorized according to the following principles, based on the needs of students:

(1) Classification according to needs.

Different learning purposes generate different learning needs. Students have both short-term learning needs for examination purposes and needs for knowledge exploration out of personal interest, and also hope that teaching resources can help to improve their professional abilities in the long run.

(2) Designing an index of questions

The most effective state of opera singing learning is stage-based, libretto-based, or emotionally inclined learning. Are the questions set scientifically in the teaching resources? The set scenarios should be open and diffuse to facilitate students' imitation and learning.

(3) Higher level of education literacy in stage singing refers to the internal psychological quality and external form, voice, and some other professional qualities that can adapt to the requirements of film and television art creation, such as observation, imagination, focus, perception, judgment, and expression. The teaching staff's behavior, mannerisms, and speech will leave a visual impression on students through video images that can be viewed multiple times. It is essential to master specific camera skills, pay constant attention to improving their stage, shape a positive image of the photograph, discover their own potential, and present their best side to the learners.

2.2. Online Resource Platform Categorization

2.2.1. Classification Method of Resources. The classification method is generally based on disciplinary clustering, and the hierarchical division of knowledge categories is based on the nature and logical level of disciplines, so as to achieve the orderly organization of information. Its compilation, revision, and maintenance are all carried out by professional and technical personnel in the fields of library and intelligence. The taxonomy emphasizes systematicity and has a stable hierarchical classification scheme. The strict affiliation or parallelism between categories can guide users to independently expand or narrow the scope of search resources, thereby improving the search rate and accuracy [9].

The subject method, in contrast to the discipline-based classification method, is object-oriented and centered on the subject of the object. It is a method that uses the subject words that express the characteristics of the document's content as the search mark and organizes the document according to the word order of the mark [10]. In contrast to natural language, which lacks lexical control, the subject word list is a collection of strictly defined and organized normative subject words that facilitate the development of a rigorous and standard classification system.

2.2.2. User Taxonomy. The classification method is generally based on disciplinary clustering, and the hierarchical division of knowledge categories is based on the nature and logical level of disciplines, so as to achieve the orderly organization of information. Its compilation, revision, and maintenance are all carried out by professional and technical personnel in the fields of library and intelligence. The taxonomy emphasizes systematicity and has a stable hierarchical classification scheme. The strict affiliation or parallelism between categories can guide users to independently expand or narrow the scope of search resources, thereby improving the search rate and accuracy [9].

The subject method, in contrast to the discipline-based classification method, is object-oriented and centered on the subject of the object. It is a method that uses the subject words that express the characteristics of the document's content as the search mark and organizes the document according to the word order of the mark [10]. In contrast to natural language, which lacks lexical control, the subject word list is a collection of strictly defined and organized normative subject words that facilitate the development of a rigorous and standard classification system.

2.3. KNN Clustering

2.3.1. Traditional KNN Algorithm. The K nearest neighbor (KNN) algorithm [11] is a simple and classical machine learning classification method. The samples are classified by measuring the distance (usually using Euclidean distance) or similarity between the samples to be classified and the known class samples. The algorithm steps are described as follows:

(1) The distance between sample points to all sample points is calculated using the Euclidean distance [12], which is defined by the following formula:

$$d(x, y) = \sqrt{\sum_{i=1}^{n} (y_i - x_i)^2}, \tag{1}$$

where $d(x, y)$ is the distance between sample x and sample y; n is the feature dimension.

(2) The samples are sorted incrementally according to the calculated Euclidean distance size. If the distance is smaller, the higher the similarity is.

(3) Select the first k nearest neighbor sample points.

(4) Count the number of k nearest neighbor sample points belonging to each category.

(5) Using the voting method and the principle of minority rule, the category with the highest frequency among the k neighboring sample points is used as the prediction category of the sample point.

It can be seen that there is only one hyperparameter k in the KNN algorithm, and the determination of the k value plays a crucial role in the prediction results of the KNN algorithm. K value is too small, which will easily lead to overfitting of the KNN algorithm; k value is too large, the nearest neighbor error of the algorithm will be large, and underfitting will easily occur. In addition, when the data samples are unbalanced, the prediction results of the KNN method will be biased towards the sample number dominant class, and the prediction accuracy of the rare class is low.

3. Method

In order to adapt the k values in the KNN algorithm to the data distribution and to consider the importance of each nearest neighbor in the classification, this paper adaptively takes the k values according to the local data density and combines the Euclidean distance and distribution similarity to weight each nearest neighbor in order to make the final classification results more reasonable.

3.1. Outlier Detection. Since the classification of the KNN algorithm is based on the class of the nearest neighbors of the sample to be measured, if the nearest neighbors contain outlier data, it will adversely affect the results. Therefore, it is necessary to perform outlier detection on the sample data to eliminate obvious outlier samples and reduce the interference to the classification results. In this paper, we detect outlier samples by calculating the local anomaly factor of each sample point [13], and the basic principle is as follows.

Let the distance between point p and the kth nearest neighbor in data set D be $d_k(p)$, and establish the nearest neighbor ensemble $N_k(p)$ of point p based on this distance; that is, the distance between all data points in $N_k(p)$ and point $p \le d_k(p)$, and $N_k(p)$ is called the distance neighborhood of point p, denoted as

$$N_k(p) = \{q | d(p, q) \le d_k(p)\}. \tag{2}$$

In equation (2), $d(p, q)$ is the distance between data points p and q. If $d(p, q) > d_k(p)$, the reachable distance between point p and point q is defined as d (p, q); if d (p, q) $\le d_k(p)$, the reachable distance is defined as $d_k(p)$, i.e.,

$$d_{\text{reach}}(p, q) = \max\{d_k(p), d(p, q)\}. \tag{3}$$

The local reachable density is calculated based on the reachable distance of the data point and used as the relative density of the data point, and the local reachable density is calculated according to the following equation:

$$lrd_k(p) = \frac{|N_k(p)|}{\sum_{q \in N_k(p)} d_{\text{reach}}(p, q)}. \tag{4}$$

In Equation (4), $lrd_k(p)$ denotes the local reachable density of point p. The larger its value, the greater the possibility that point p is the same kind of point as its immediate neighbors; conversely, the greater the possibility that point p is an outlier.

$$LOF_k(p) = \frac{1}{|N_k(p)|} \sum_{q \in N_k(p)} \frac{lrd_k(q)}{lrd_k(p)}. \tag{5}$$

To further express the possibility of point p being out of cluster, define the local anomaly factor $LOF_k(p)$, which is

the average of the ratio of the local reachable density of the kth distance neighborhood $|N_k(p)|$ of point p to the local reachable density of point p.

If the value is closer to 1, it means that the density of point p is similar to its neighboring points; if the value is less than 1, it means that the density at point p is greater than the density of neighboring points; if the value is greater than 1, it means that the density at point p is less than the density of neighboring points; that is, the larger the value is, the greater the possibility that point p is an outlier.

3.2. Adaptive K Value Based on Local Density. To address the drawback that the k value in the traditional KNN method is fixed and cannot be adapted to the data distribution, this paper selects the k value based on the local density of the data to achieve the adaptive value. To facilitate classification, the k value is typically assumed to be an odd number, and its range is restricted to the interval [14] to prevent interference from the nearest neighbor and reduce computational complexity.

Let k represents the number of the sample's nearest neighbors, d represents the distance between the sample and the k th nearest neighbor sample, and define the sample local density as the number of nearest neighbor samples per unit area.

$$\rho = \frac{k}{\pi d^2}. \tag{6}$$

The value of k is taken in a limited interval, and the magnitude of the local density is recorded for different k values. If the density is larger, it means that the k value is more credible, and finally, the k value when the density is the largest is taken as the number of nearest neighbors k of the sample point to be tested.

3.3. Weighted KNN. The weighted KNN algorithm is a classification method based on mathematical statistics [9]. Let $X = (x_i, l_i), x_i \in R^d, i = 1, 2, ..., n$ be a training set consisting of n samples [15], each sample xi has a known class identity $l_i, l_i \in \{l_1, l_2, ..., l_r\}$. x_t is the sample to be tested, and its class l_t is to be tested. The basic idea of weighted KNN classification is that for a given test sample x_t, find its k nearest neighbors in the training set and determine the classification attribute l_t of the test sample x_t by voting on the classification attributes of the k nearest neighbors:

$$M(l_j) = \sum_{l_i \in L} P(l_i|x_t) R(l_i, l_j), \tag{7}$$

where $P(l_i|x_t)$ is the probability of classifying the test sample x_t as li, $R(l_i, l_j)$ is the error arising from classifying attribute li as l_j, and the weighted KNN sets all

$$R(l_i, l_j) = \begin{cases} 0, i = j \\ 1, i \neq j \end{cases}. \tag{8}$$

The specific steps of the weighted KNN implementation for classification are as follows:

(1) For the test sample x_t, calculate the distance $d(x_t, x_i)$ between x_t and each training sample x_i [16] using the Euclidean distance formula:

$$d(x_t, x_i) = \left(\sum_{j=1}^{d} \left\| x_{tj} - x_{ij} \right\|^2 \right)^{1/2}. \tag{9}$$

Find $k+1$ nearest neighbor samples $x_{t,1}, x_{t,2}, ..., x_{t,k+1}$, $k+1$ of x_t from the training set X according to the distance magnitude.

(2) From the $k+1$ nearest neighbor samples, select the sample with the largest distance from x_t as $x_{t,k+1}$, and the corresponding distance as $d(x_t, x_{t,k+1})$, and use $d(x_t, x_{t,k+1})$ to normalize the distances of the other k nearest neighbor samples from x_t [17]:

$$D(x_t, x_i) = \frac{d(x_t, x_i)}{d(x_t, x_{t,k+1})}, i = 1, 2, k. \tag{10}$$

(3) For the normalized distance $D(x_t, x_i)$, use the Gaussian kernel function to transform it into the same kind of probability $p(x_i|x_t)$ of x_t and x_i, i.e.,

$$p(x_i|x_t) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{D(x_t, x_i)}{2} \right). \tag{11}$$

(4) Based on the like-kind probability $p(x_i|x_t)$ of x_t with k nearest neighbor samples, find the posterior probability $p(l_i|x_t)$ of x_i being a category $l_i (i = 1, 2, ..., r)$, i.e.,

$$p(l_i|x_t) = \frac{\sum_{x_i \in X} \begin{cases} p(x_i|x_t), l_i = l_t \\ 0, \text{others} \end{cases}}{\sum_{x_i \in X} p(x_i|x_t)}. \tag{12}$$

The weighted KNN method does not yet calculate the exact categorical attribute value ofx_t but gives the most probable categorical attribute value, i.e,

$$KNN(x_t) = \underset{l_i \in L}{\operatorname{argmax}} (p(l_i|x_t) J), \tag{13}$$

where $KNN(x_t)$ denotes the classification result of the weighted KNN method corresponding to the tested sample x_t.

The weighted KNN assigns different weights to the nearest neighbor samples according to the similarity between each nearest neighbor sample and the test sample, so that the classification result of the test sample is closer to the training sample with higher similarity [18]. This further weakens the sensitivity of k value selection and strengthens the robustness of the classification results.

3.4. Resource Classification Steps. The k value adaptive weighted KNN method proposed in this paper is used in the classification of opera singing resources to establish a classification model, and the specific steps are as follows.

(1) Collect the resource sample data, and normalize the original data by the logarithmic transformation method according to the equation, and then, randomly divide it into training sample set and test sample set according to the ratio of 3 : 1

(2) Perform outlier detection on the normalized training sample data, and eliminate obvious outlier samples

(3) Adaptively taking the k value according to the local density of the samples

(4) To consider the distance between each nearest neighbor point and the sample to be tested, as well as the relationship between the sample to be tested and the distribution of nearest neighbor points, and to calculate the weights of the nearest neighbor points

(5) Counting the categories of each nearest neighbor point of the sample points to be tested, calculating the total weights of each category of nearest neighbor points, and classifying the sample to be tested with the principle of maximum weight [19]

4. Experimental Results and Analysis

4.1. Data Set. In this paper, we selected 452 opera singing course resources on the web online platform as sample data and analyzed them for the course evaluations as well as the number of resource video frames, and we divided the data into training set, test set, and validation set in the ratio of 300 : 100 : 52. Table 1 shows the number of resource frames and resource evaluations of our course resources.

4.2. Data Preprocessing. Since transformer data values are widely dispersed and even significantly different in magnitude, the raw data are typically preprocessed to eliminate excessive differences in data values, which impact the model's stability and convergence. Commonly used data preprocessing methods are outlier normalization (MMN) [20], standard deviation normalization (ZSN), and inverse tangent function transformation (ATAN), etc.

MMN and ZSN are linear preprocessing techniques that scale the original data to fit within a specified space. However, linear methods cannot reduce the order of magnitude differences between data and typically map each feature separately without considering the horizontal connection between features, resulting in the loss of valuable information from the original data. The data are distributed unevenly. The aforementioned analysis demonstrates that the aforementioned methods are unsuitable for transformer fault data with an uneven data distribution and a wide value distribution.

The log-transform method can reduce the order-of-magnitude differences of the original data and make the data distribution more compact, while its overall mapping of the data can preserve the data characteristics reasonably well [21]. In this paper, we use log-transform to preprocess the data using the following equation, and Table 2 compares preprocessed and unpreprocessed data after 100 repetitions of the same training.

Table 1: Dataset.

	Training set	Test set	Validation set
Number of resources	300	100	52
Number of frames	17731	5764	3051
Evaluation entries	1866	724	276

$$x' = \frac{\log_{10}(x)}{\log_{10}(x_{\max})}. \tag{14}$$

4.3. Outlier Rejection. The outlier detection is performed on the training samples by category, and the distribution of local outliers is shown in Figure 1.

As shown in Figure 1, we can see that the local outlier value of the sample points usually fluctuates around 10 but fluctuates more at some "outliers," so we take the threshold value of 15 to eliminate 10 "outliers" in the original data, i.e., outliers.

As shown in Figure 2, it can be seen that most of the excluded outliers are obviously outliers, and their elimination is beneficial to the final classification work.

4.4. Comparison of Different Classification Algorithms. In this paper, we compare the traditional KNN, SVM, and our weighted KNN adaptive classification algorithm using the same data for experiments and statistically analyze the experimental results. The accuracy and F1 values of the classifiers on the test set are calculated, and the calculated results are organized in Table 3. The ROC curves and AUC values for each model are shown in Figure3.

As demonstrated in Figure 4, the integrated model outperformed the three primary classifiers. The values of our accuracy and F1 indicators are greater than those of other classifiers, and the accuracy rate exceeds 90%, indicating that the model has improved classification performance and strong classification ability. The classification model implemented in this paper based on the weighted KNN algorithm is feasible and effective for the classification of opera singing resources, and it can be concluded.

As shown in Figure 3, the weighted KNN meta-classifier has an AUC of 0.94, which is also higher than the other meta-classifiers. In order of classification performance from highest to lowest, the other three algorithms are weighted KNN > KNN > SVM.

4.5. Ablation Study. We compared the effect of all the methods we used on the overall experimental results.

4.5.1. Treatment of Experimental Datasets. We compare and analyze the effect of the distribution ratio of training and test data sets on the final results, and we do a comparative ablation experiment with or without setting the validation set, as shown in Table 4.

Table 2: Comparison of the training process with and without data preprocessing.

Training sessions	Convergence accuracy	Standard deviation	Relative error
100	0.67	26000	(−0.5, 0.3)
100	1.8	43370	(−1.1, 1.4)

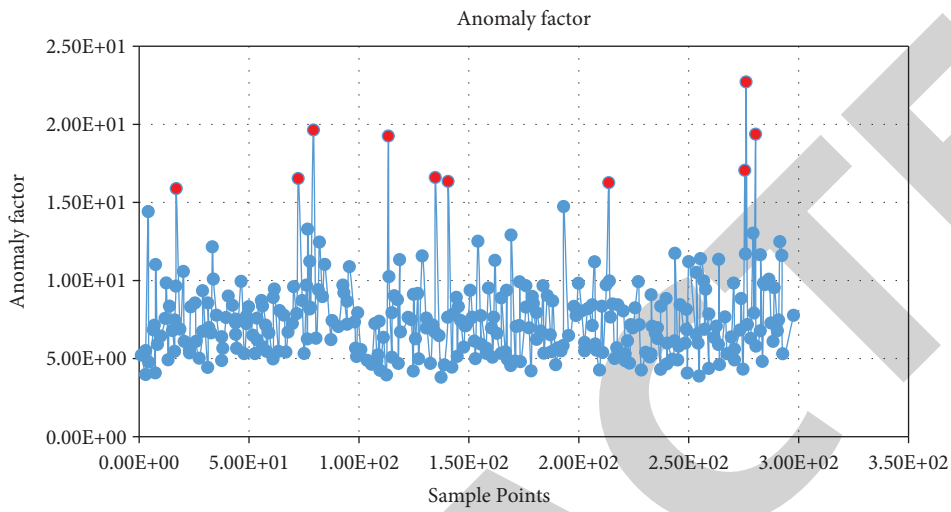

Figure 1: Factor distribution.

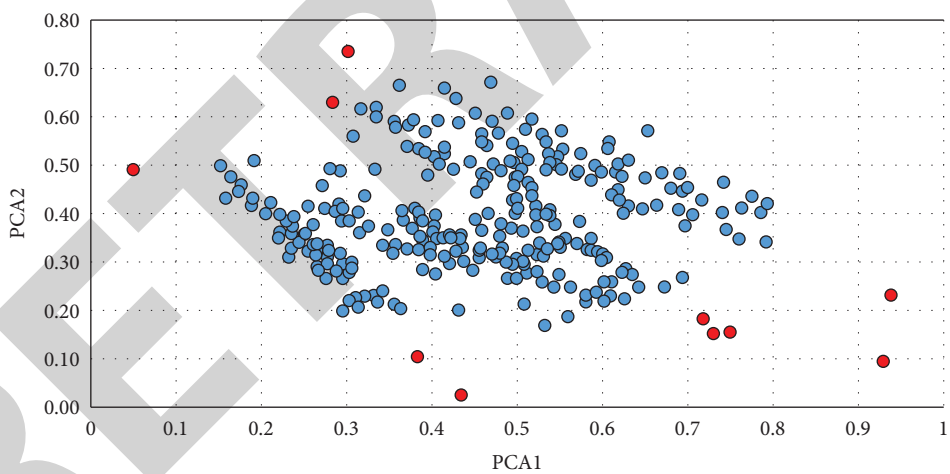

Figure 2: Outlier data distribution.

Table 3: Algorithm accuracy and F1 comparison.

Indicators	SVM	KNN	Weighted KNN
Accuracy	0.873	0.895	0.913
F1	0.851	0.889	0.909

4.5.2. Treatment of Experimental Datasets. We did ablation experiments on principal component analysis and outlier removal in the data preprocessing session, noting that the training and test datasets in this session used a 3 : 1 ratio, and we used the validation dataset, and the final results are shown in Table 5, which shows that the use of these two methods in the data preprocessing session is also helpful for the results.

Figure 3: Performance of different classifiers.

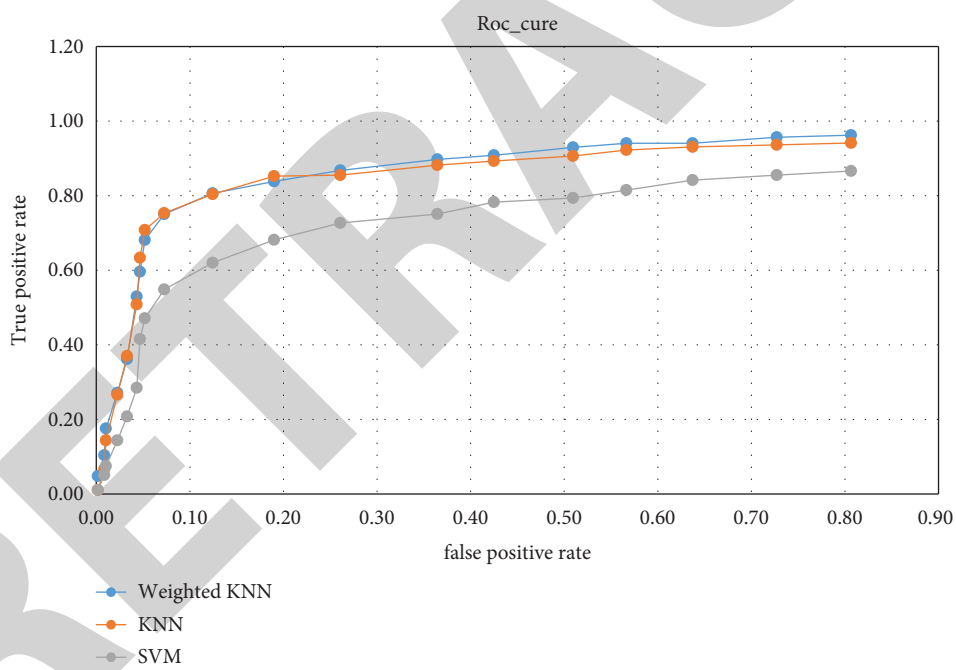

Figure 4: Performance of different classifiers.

Table 4: Proportion of dataset.

Proportion (train : test)	Accuracy	F1	Availability of validation set
3 : 1	**0.913**	**0.909**	**1**
4 : 1	0.907	0.896	1
5 : 1	0.912	0.909	1
3 : 1	0.882	0.870	0
4 : 1	0.895	0.813	0
5 : 1	0.910	0.845	0

Table 5: Proportion of dataset.

Session	Accuracy	F1
Both methods are used	**0.913**	**0.909**
Only use PCA	0.877	0.786
Use only outlier removal method	0.876	0.882

5. Conclusion

In this paper, we collect online opera singing teaching resources on the current online teaching platform, apply an adaptive weighted KNN classification algorithm, and introduce an adaptive classification algorithm to subdivide the online singing teaching resources objectives in order to realize the personalized utilization of teaching resources for material-based and individualized instruction.

Due to limited data collection and research time, this thesis contains some issues that will require additional work in the future.

(1) Due to the constraints, this paper only analyzes the algorithm's performance based on the online resources discovered, and the training results may not be as accurate due to the limited number of resources. The next step will be to increase the amount of data used to train the model in order to improve its classification accuracy.

(2) In this paper, an adaptive classification algorithm is introduced to subdivide the online singing teaching resources target, and the criteria of classification are only based on online assessment and evaluation, and if the evaluation criteria change, the model must be modified for training, so a fair and general evaluation criterion must be determined [22–27].

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.

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Hindawi
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Retraction

Retracted: Research on University Network Public Opinion Monitoring and Early Warning System Based on Big Data

Mobile Information Systems

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

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

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

In addition, our investigation has also shown that one or more of the following human-subject reporting requirements has not been met in this article: ethical approval by an Institutional Review Board (IRB) committee or equivalent, patient/participant consent to participate, and/or agreement to publish patient/participant details (where relevant).

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

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

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

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[1] R. Yang, "Research on University Network Public Opinion Monitoring and Early Warning System Based on Big Data," *Mobile Information Systems*, vol. 2022, Article ID 1884526, 6 pages, 2022.

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Research Article

Research on University Network Public Opinion Monitoring and Early Warning System Based on Big Data

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Undergraduate self-consciousness is still in the formative stage and is highly susceptible to external environment. Schools must adapt to the new forms and requirements, improve their ability to search, analyze, and prevent online public opinion through big data technologies; we should make early discovery, early action, and early resolution, so as not to give time and space for public opinion crisis fermentation and consolidate the dominant position of the mainstream ideology. This paper focuses on the university network public opinion monitoring and early warning system based on big data and analyzes the university public opinion from the perspective of the specificity, sensitivity, identification, early warning and prevention ability of the system to deal with public opinion, and effectively solves the network public opinion crisis. Combined with the current actual situation and specific needs, this paper explores the intervention measures and guidance strategies for the network public opinion of college emergencies, so as to lay a solid foundation for the healthy, stable, and sustainable development of colleges and universities.

1. Introduction

At present, the network has become the first channel for college students to show their ideological trends and respond to contradictory problems. The traditional public opinion pattern has changed, and social media represented by Weibo, Tiktok, Kwai, and Xiaohongshu have reconstructed the public opinion pattern. Lang said that the rapid development of new media has brought opportunities as well as hidden dangers and challenges to the network culture work in schools [1]. Most of the network public opinion crisis in colleges and universities is caused by campus emergencies, and it is easy to cause rumors and abuse on the Internet, causing students to float in the hearts of the people, extreme emotions, and disrupting the normal campus order. Once the handling is not effective or timely, it is very easy to evolve into a public crisis event. Zhu believes that the information resources of new media are uneven. Although there are many positive energy information, it also contains many negative energy information, even illegal and criminal information [2].

Wu believes that the reason for this trend is that the network has the characteristics of virtuality, rapid propagation, etc. At the same time, young people have keen insights, coupled with the driving of clustering psychology and empathy [3]. The thinking and discussion of social contradictions among school teachers and students is extremely easy to evolve into a hot spot of network public opinion. Zhao said that the Internet public opinion of schools is relatively free, so some college students with weak self-regulation will make mistakes and deviate from the reality, which will affect the ideology of other college students [4].

Wang, Shi, and others believe that online public opinion is not enemy sentiment. Schools should take the initiative to occupy the highland of public opinion and establish a scientific and operable governance mechanism with rationality, temperature, evaluation, and feedback [5]. When dealing with the Internet public opinion events, colleges and universities must correct their work attitude, comprehensively understand the truth of the event through multiple channels and methods, not shirk their responsibilities, dare to assume their responsibilities, inform the public of the truth at the

first time, and conduct sincere, open, and timely communication, so as not to further intensify the contradictions and win the public's understanding and trust. Chen et al. believe that schools should carry out risk assessment and value screening on the massive network public opinion information of schools to reduce the adverse impact of sudden network public opinion on students [6]. Zhou said that the Internet public opinion of schools should be managed and prevented. By establishing an early warning evaluation index set, we prevent emergencies from having a negative impact on schools and society [7].

Zhang, Bo, and others said that schools still use traditional search engine manual monitoring technology in the face of online public opinion events. However, this method seriously lacks professional big data analysis of public opinion and is unable to give early warning, periodic changes and stage countermeasures of public opinion, which is not commensurate with the avantgarde nature of the current rapid development of media integration, so it will inevitably lead to incomplete, unknown, untrue, and hidden dangers of online public opinion monitoring information in schools [8].

Using big data technology, schools can detect the reactions of different groups on various social media in real time, establish accurate publicity strategies, timely and effectively announce the context of events, and prevent the fission propagation of public opinion events. Zhong said that schools should conform to the times, improve their ability to search, analyze, and prevent online public opinion use big data, and consolidate the dominant position of the mainstream ideology in schools [9]. For example, it monitors and collects news reports, media comments, and netizens' comments distributed on media, Weibo, forums, blogs, post bars, WeChat, and other platforms. At the same time, it conducts analysis, research, and judgment of relevant data to find out the nodes that cause public opinion crisis, and then formulate targeted disposal strategies to maximize the effect of public opinion crisis disposal in colleges and universities. Jing and others said that depth study the occurrence, development, evolution, and decline mechanism of public opinion in schools, design monitoring indicators, carry out monitor and warn public opinion events, unblock information exchange channels with relevant departments outside the schools, and monitor and effectively guide the relevant Internet public opinion [10]. At ordinary times, the school needs to pay attention to the construction of teacher-student interaction channels, set up online and offline "student hotline" columns, and provide patient, full and detailed answers to all kinds of hot issues, focus issues and difficult issues raised by students about learning and life. Zhang, Liu, and others expressed the same view. They believe that to establish public opinion in schools, we should detect and pay attention to negative public opinion, timely warn and monitor, and strive to find and dispose of all kinds of bad information in the bud [11].

This paper focuses on the monitoring and early warning system of college network public opinion based on big data technology. Knowing how to effectively manage and guide college students' network public opinion events is of great significance for building a harmonious campus. It is hoped to provide reference value for the research of college network public opinion monitoring and early warning system.

2. Characteristics of the Internet Public Opinion Communication in Schools

2.1. Particularity and Collectivity. The main body of network public opinion in schools is mainly college students. As the mainstay of the future national development, their identity makes the network public opinion of schools have certain particularity, which is easier to attract the attention of the society. Therefore, when college network events occur, college students are the main participants in public opinion and their attitude is collective.

2.2. Interactivity and Uncontrollability. Wang said that college students are in an immature stage, and their cognition of things in their growth stage is often irrational [12]. Although college students have some insights, their values are not yet fully mature. Therefore, college students are very vulnerable to the inducement of the outside world or make extreme and unrealistic statements for their own psychological reasons. At the same time, driven by the psychology of clustering and empathy, college students' thoughts are easy to be influenced by network opinions, which leads to the difficulty of the schools to control public opinion.

2.3. Cyclical and Long-Term. The communication cycle of public opinion in schools can be roughly divided into five stages: germination, fission, spread, dilution, and activation. College students will pay long-term attention to events related to personal interests, such as study, accommodation, employment, and love. Therefore, when there are new developments in online public opinion related to such topics or similar events, college students' attention will increase and the popularity of online public opinion will rise again.

3. Problems Faced by Network Public Opinion Monitoring in Schools

3.1. Insufficient Attention and Capital Investment. The establishment of university network public opinion monitoring and early warning system based on big data requires a certain amount of capital investment. Deng said that due to the rapid development of the Internet in China, many schools did not have time to establish a sound network public opinion guidance mechanism, and some schools even did not have relevant response mechanisms [13].

The inefficient manual detection method is still adopted in the monitoring of network public opinion in schools. In reality, a large amount of network information will be generated every day; this method has been difficult to meet the needs of schools to monitor network public opinion.

3.2. The Management Mechanism of Public Opinion in Schools Is Not Perfect and the Reaction Speed Is Slow. After the

occurrence of network public opinion in schools, we should deal with and control the development of the situation at the first time, so as to minimize the negative impact of public opinion. The public opinion management mechanism of some schools is not perfect and the speed of information transmission is single. Therefore, schools have only just realized the occurrence of public opinion and reacted after the public opinion fermentation in schools has produced a certain negative impact. However, the golden time for dealing with public opinion has passed, and the negative effects have been produced and gradually expanded. The response action taken by schools cannot achieve a good treatment effect and may even cause a new round of public opinion crisis because of the slow response.

3.3. Improper Handling Cannot Effectively Guide the Development of Public Opinion. Many schools take a cold approach when dealing with the network public opinion of schools, trying to dilute public opinion by avoiding and blocking. However, this way of handling cannot really solve the problem. At the same time, it may arouse the rebellious psychology of college students and then lead to secondary public opinion, leading to the development of public opinion completely out of control. Those who pay attention to public opinion attach importance to the attitude of schools to deal with problems. If the schools can face up to the problem and provide feasible and effective solutions, the public opinion will naturally subside slowly. If the schools chooses to avoid the problem or shirk its responsibility, it will only intensify the contradiction and cause secondary public opinion.

4. Application Value of Big Data in the System

Sudden public opinion events will aggravate the contradiction in college campus cyberspace, and even cause social public opinion if serious. With the development of new media as the communication carrier, it is more convenient to make comments, and the personalized communication mode is highlighted in cyberspace. Some comments and opinions are easier to find among college students with the same ideas. The public opinion information obtained through the traditional network public opinion monitoring and early warning system is incomplete, unknown, untrue, and there are hidden dangers. At the same time, the monitoring is becoming more and more difficult. The dynamic trend of network public opinion and the trend of public opinion need key technologies. Big data mining technology can collect and mine public opinion information and analyze it at the same time, so as to predict sudden public opinion on the network.

Big data breaks through the unilateral and single form of traditional college network public opinion. The key to big data application is related public opinion, which pays more attention to the correlation between data information. The main body of college network public opinion communication has its particularity. Therefore, in the process of communication, college network public opinion will show an irrational development trend, and if not properly guided, it will evolve into a network public opinion crisis. The school can master the dominant power of public opinion. The limitations of traditional system monitoring make it difficult for the university authorities to comprehensively and objectively grasp the panorama of public opinion, while big data technology can quickly analyze massive information data and make corresponding judgments. Relying on big data technology, the timeliness and accuracy of the school's handling of public opinion have been greatly improved, and its ability to cope with public opinion crisis has been enhanced.

College network public opinion usually consists of a small problem and a small event, which becomes a network public opinion event through the continuous fermentation of the network. If public opinion is not controlled in time and allowed to develop, it will inevitably have a negative impact on the safety and stability of colleges and universities. With the blessing of big data, the university can better handle online public opinion and effectively improve the management level of public opinion. In the process of monitoring, once sensitive words are found, they will touch the early warning system. The school can timely invest in the prediction link, control the public opinion risk from the source, monitor the campus network platform, and nip the public opinion in the cradle.

5. Simulation Verification

5.1. Comparison of Specificity and Sensitivity of the System. The network public opinion collection mechanism of big data improves the efficiency of obtaining data information, whether it is from the school website and school forum, or from outside the school, including WeChat, Weibo, post bar, and various multimedia channels, to filter and integrate public opinion data. The final outcome of big data analysis is directly impact by the quality of data collection. The gathering of network public opinion ensures the efficiency of early warning processing. With the use of gathered public opinion data, big data analysis and deep mining can be used to extract the pertinent information about public opinion and give decision support for later crisis early warning and emergency processing. The reactions of different systems are analyzed and Table 1 is obtained.

In Table 1, the research system can grasp the guidance, dynamics, and development trend of network public opinion at any time and do a good job in daily monitoring and analysis. The specificity and sensitivity are higher than those of the traditional public opinion monitoring system.

According to the statistical information in Table 1, Figure 1 is obtained.

As shown in Figure 1, the visualization effect of the specificity and sensitivity of the two different systems in dealing with public opinion, which can clearly see the contrast gap between the two groups of data. This research

Table 1: Specificity and sensitivity analysis of different systems (%).

Group	Specificity	Sensitivity
Traditional university system	88.29	89.34
This research system	64.36	65.78

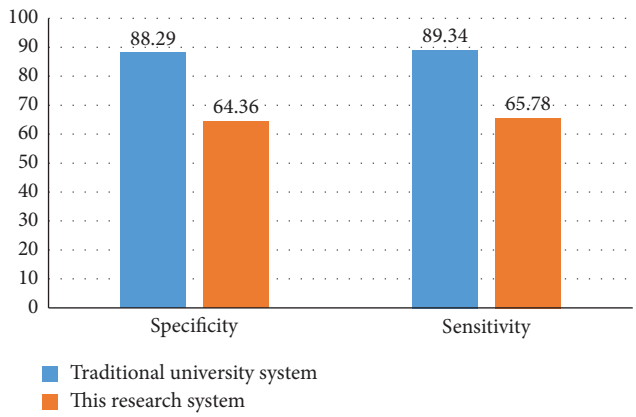

Figure 1: Visualization of specificity and sensitivity of different systems (%).

system can prevent the crisis of college network public opinion from expanding.

5.2. Comparison of Identification, Early Warning, Prevention, and Control Capabilities under Different Systems. As a basic tool in daily life, the Internet has a certain relevance in the fermentation degree of public opinion. College students, as the main body of public opinion, have obvious cluster benefits on hot issues, and it is easy to quickly form network clusters. Big data monitoring and early warning systems are used to quickly respond to information about public opinion. They are used to monitor negative public opinion. The application of big data in public opinion events in cyberspace will judge, analyze public opinion fragments, deeply mine hidden information, and predict public opinion content. Now, the identification, early warning, and prevention capabilities of different systems are compared. Table 2 is obtained.

Table 2 shows the comparison results of the identification, early warning, prevention, and control capabilities of the two different systems. The research system can conduct comprehensive monitoring and analysis in all aspects to ensure the rapid and effective handling of public opinion events.

According to the statistical information in Table 2, Figure 2 is obtained.

Figure 2 shows the visualization effect of two different systems in public opinion recognition, early warning, prevention, and control ability. In terms of identification, early warning, and prevention, big data analysis technology is stronger than traditional monitoring and early warning systems.

5.3. Comparison of Public Opinion Evaluation in Different Systems. This research adopts the big data public opinion monitoring and early warning system, which has complete functions for public opinion monitoring inside and outside the school. It has a certain effect on public opinion monitoring in colleges and universities. College students have a high dependence and compliance on cyberspace. The big data analysis system can stabilize students' mentality to a certain extent and effectively avoid the large-scale outbreak of public opinion. There are serious hidden dangers in the monitoring of public opinion in colleges and universities in the environment of freedom of speech and numerous communication carriers. Table 3 shows the results of our comparison of the nature of public opinion in different systems:

Table 3 shows the comparison results of public opinion evaluation of different systems. Big data analysis technology can filter the data content, extract information, remove the miscellaneous content of the collected diversified public opinion data, and ensure the objectivity to the greatest extent.

According to the statistical information in Table 3, Figure 3 is obtained:

As shown in Figure 3, the visualization effect of evaluation comparison of different systems is shown. In terms of the diversity, timeliness and observability of public opinion in cyberspace, the traditional system evaluation is lower than the evaluation results of the research system, which can indirectly explain that the big data analysis technology has certain observability on public opinion control.

5.4. Influence Analysis under Different Network Public Opinion Monitoring and Early Warning Systems. With the development of the Internet era, its network interaction has become a matter in the daily life of colleges and universities, and it is also the main source for teachers and students to obtain information. College students, as a special audience group, have their active thinking and reaction. The high-frequency interaction in cyberspace and the information dissemination of the public opinion field will have an impact on the reputation of colleges and universities, which will seriously spread to the whole society. The system used in this study can guide students in public opinion events, indirectly improve students' comprehensive quality, timely understand students' ideological trends, and maintain campus stability. Now, we analyze the public opinion influence of different systems and obtain Table 4:

Table 4 shows the comparison results of the public opinion impact of the two different systems. In the analysis and processing of public opinion, the system can grasp the trend of public opinion in colleges and universities. Effectively control negative comments and create a harmonious campus environment.

According to the analysis results in Table 4, the following Figure 4 is obtained:

Figure 4 shows the visualization effect of public opinion influence of different systems. There is a statistical significance of $t < 10.000$, $p < 0.05$ when comparing the data. From

Table 2: Comparison of identification, early warning, prevention, and control capabilities of different systems (%).

Group	Public opinion judgment	Prediction of public opinion content	Risk prevention and control
This research system	87.45	90.71	84.78
Traditional university system	60.35	63.68	56.45

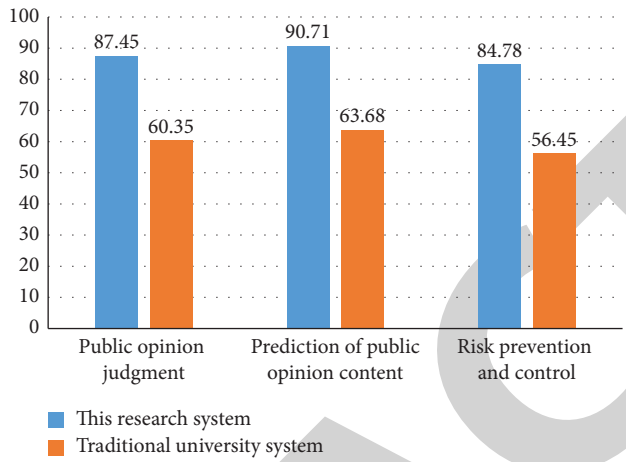

Figure 2: Visualization of identification, early warning, prevention, and control capabilities of different systems (%).

Table 3: Comparison of public opinion evaluation of different systems (%).

Group	Diversity	Timeliness	Objectivity
This research system	89.93	90.52	87.65
Traditional university system	68.54	65.32	63.22

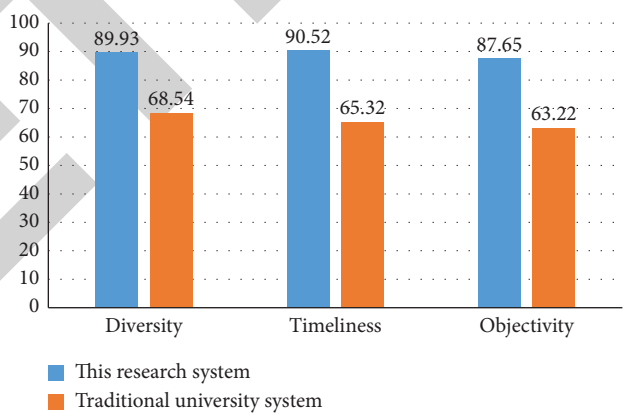

Figure 3: Visualization of public opinion evaluation in different systems (%).

Table 4: Analysis of public opinion influence of different systems (%).

Group	Campus network environment	Comprehensive quality of college teachers and students	College reputation
This research system	86.55	85.42	91.65
Traditional university system	60.51	62.35	65.22

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Retraction

Retracted: Analysis of University Management Model of National Higher Education Institutions Based on Machine Learning Algorithm

Mobile Information Systems

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] D. Zhang, "Analysis of University Management Model of National Higher Education Institutions Based on Machine Learning Algorithm," *Mobile Information Systems*, vol. 2022, Article ID 4553185, 7 pages, 2022.

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Research Article

Analysis of University Management Model of National Higher Education Institutions Based on Machine Learning Algorithm

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The development of state-owned colleges and universities has a long history and profound foundation, which has more political tasks in the field of higher education in China; national development cannot be separated from the next generation of education. The purpose of this paper is to analyze the effectiveness and advantages of using machine learning algorithm in the efficient management model of national higher education institutions; by comparing the effect of university management mode and teaching facility environment under different environments; compare the teaching management quality and coupling analysis under different algorithms; the results are statistically significant; through the research, it is found that the algorithm of machine learning has a positive impact on the data processing and auxiliary management mode based on the degree of anthropomorphic simulation, it can effectively improve the level and quality of education management in Colleges and universities and enhance students' learning motivation and ideological value; conform to the development concept of social sustainable development; it has research value and positive significance for the future management of educational colleges and universities.

1. Introduction

Education has always been one of the most basic problems in national construction. Only the talent cultivation achievements of the next generation can strengthen China's comprehensive strength. The success of education is also closely related to education management; Since its establishment and launch, China's national education has had certain political characteristics, and its management also belongs to the way of Party and government management. The management of colleges and universities also reflects the comprehensive teaching level of colleges and universities to a certain extent. In today's environment of the development of the Internet, how to further improve the management method and effect is a major problem; Hongying now, the requirements of universities for data analysis have surged. In the period of the prosperity of the concept of machine learning, using machine learning algorithm can better assist the operation of university management and improve teaching quality [1]. Liu in Colleges and universities, the research on scientific research literature is a professional field, in which the processing and operation of big data can be statistically analyzed by machine learning, which can effectively improve the operation speed and achieve certain results [2]. The higher the scientific research achievements of the school, the better the management mode. Peijun the purpose of education in the new era is the process of educating people with wisdom. In the process of educational reform and management, using modern scientific and technological advantages to create a management mode that conforms to the characteristics of the times is the modernization goal [3]. Ni with the progress and development of social economy, science, and technology, China's education is also progressing. Machine learning, as a type of big data technology, has also played an important impact of the Internet has led to the application of many advanced technologies in the field of education. As an artificial intelligence computing method, the machine learning algorithm can also play a promoting role in university management [4]. Chen in the era of big data, higher education needs to be more refined and diversified. Data mining and statistics need the support of new technologies, which is

conducive to increasing management efficiency [5]. Kong the national digital economy continues to develop and change. In line with the times, national education management also needs to achieve a synchronous development trend. In the machine learning environment, greater achievements in education management can be achieved in the new platform [6]. Xia and Jiang machine learning course can better achieve student satisfaction and teaching performance from teaching design to practical simulation and data result analysis, which plays a positive role in education management [7]. Wang et al. in the construction of political and ideological integration of college teaching mode, new teaching contents and methods that meet the cultivation purpose of modern people are conducive to improving personal comprehensive ideological and political construction and facilitating college management and progress [8]. It can be seen from the literature that all aspects of the development of the new era need to take advantage of the progress of new technology. Only by integrating new educational concepts and new technical concepts can we better carry out educational reform and educational management. In order to improve the education level of the next generation and explore the way forward, a machine learning algorithm is an essential technical way; It also provides certain research value for the development of education in the new era. Through analysis and research, this paper concludes that the university management mode under the application of a machine learning algorithm is better than the traditional algorithm. They have better educational ideas and political work for the party and government, and they are more time-saving and labor-saving for the work operation of various management institutions.

2. Introduction to Machine Learning Algorithm

2.1. Machine Learning Algorithm. The machine learning algorithm is a multidisciplinary interdisciplinary subject in nature. It is the core of artificial intelligence. It mainly studies how to simulate human learning behavior and methods to obtain new knowledge and technology, mainly using inductive and comprehensive computing methods; machine learning algorithm refers to the effective premise that the conformance class includes training data and test data, and the data have the same statistical regularity. The stronger the statistical regularity, the stronger the effectiveness of the algorithm. Machine learning algorithms are divided into three supervised learning algorithms, unsupervised learning algorithm, and reinforcement learning algorithm. In the process of supervised learning, a supervised learning algorithm can build a pattern from training data or infer new instances according to the pattern, and the algorithm should input or output according to instructions. The second is the unsupervised learning method, which means that there is no specific output target, and the algorithm converts the data into different groups. In addition, the reinforcement learning algorithm, which has strong applicability, is basically trained according to the decision-making. The algorithm also trains itself according to the success of the output of the result and summarizes the good prediction after the algorithm is optimized by multiple training methods.

2.2. Application of Machine Learning Algorithm in Higher Education. With the continuous development of science and technology, higher education has gradually become intelligent with the help of machine learning. In many aspects of education, the recognition and reading mode of the machine learning algorithm can predict and analyze its input data-driven and decision-making algorithm. The more information you input, the more intelligent the algorithm will become. Zhong uses the decision tree algorithm commonly used in machine learning to learn knowledge from the existing teaching management platform data, extracts useful predictions from the information obtained from the data, and uses this information to affect the teaching quality, so as to optimize the daily teaching workload of teachers and improve the teaching management level [9]. Wan realized education prediction in the algorithm era. It should show the application value of algorithm prediction from both macro and microaspects, from traditional methods to machine learning, and from a single path to diversification. With the continuous application of machine learning algorithms, education prediction research will help the whole education achieve breakthroughs [10]. Zhang et al. machine learning algorithms are applied in data mining, pattern recognition, and many other fields. In the context of machine learning algorithms, the application value of new machine learning algorithms such as support vector machines and convolutional neural networks has attracted extensive attention [11]. Xu et al. machine learning is one of the important directions in artificial intelligence and data analysis. Machine learning divides machine learning algorithms into unsupervised learning, reinforcement learning, and supervised learning according to training samples and training experience. According to the representative algorithm of machine learning and its application, it shows the development direction of the machine learning algorithm [12]. The role of machine learning in education is gradually emerging. The application of machine learning algorithms, education management, and teaching efficiency have been improved. Educational institutions develop the teaching quality of higher education by tapping the potential of machine learning algorithms. They also use computing methods in educational management to simplify the management mode, improve the efficiency and quality of management, and promote the comprehensive development of colleges and universities.

3. Management Mode of National Higher Education Institutions

With the establishment of the socialist market economic system, the autonomy of colleges and universities has been further expanded. The management of higher education selects centralization and decentralization, unity and diversity, a comprehensive planning system, and operates in strict accordance with the mode of China's socialist

development on the management system of higher education. In terms of the inadequacy of the management system of traditional higher education, the operation of the new higher education management system is only the initial stage, and the establishment of a stable system still needs the support of the government, society, colleges, and universities. In the management of colleges and universities, the operation mode of management is too rigid. The unified education policy of the current education system leads to the immobilization and low efficiency of the current education system and the influence of bureaucratic negative factors. Secondly, the theme of running a school is too single, and the rules of running a school are not flexible. Therefore, the mode of talent training is relatively single, and the unreasonable education structure and the waste of educational resources have seriously affected the development of efficient education. In terms of college enrollment, employment management is not flexible enough to be updated in time according to the professional needs of market talents. In the development of national higher education institutions, the right of administration has always occupied an important position in the management mode. In this case, the management of colleges and universities is affected by administrative management, which is not conducive to the improvement of teaching quality, and teaching management is also deeply affected, In the actual teaching, the development of teachers is limited by the management system. Therefore, teachers' teaching innovation consciousness is gradually lost, and students' subjective consciousness and creativity cannot be often displayed. Therefore, the management work has been affected. Through the education method, we know that the development of higher education should be democratic, the teaching of students should be put in the first place of management, people-oriented, its value should be excavated, and the management level should be improved as much as possible to achieve the desired effect. During the management period, teachers should give full play to their own advantages, consider more for students, not blindly instill knowledge, more is communication, and improve their teaching ability, Ensure that students can freely show their charm while improving their abilities, so that teaching can be carried out effectively. Teachers should continue to innovate while ensuring efficient education management, better teaching students, so as to improve the level of efficient management.

4. Statistical Methods

4.1. Machine Learning Algorithm. Use machine learning algorithm to deeply mine the institutional management of national universities, calculate its effect in university management, and observe its effectiveness and stability in efficient management.

4.2. Bivariate t-Test. There are t value and p value in the bivariate t-test. T value is the value value of the output result. When $t > 10.000$, it is considered that there is statistical consistency between the two groups of data, and the greater the T value, the greater the consistency. When $T < 10.000$, it is considered that there is a statistical difference between the data; The p value is the log value of the output result. When $p < 0.05$, the result data is considered to be credible. When $p < 0.01$, the result data is considered to have significant statistical significance. The smaller the p value, the higher the degree of confidence.

5. Comprehensive Analysis of University Management of National Higher Education Structure

5.1. Analysis of University Management Mode under Different Development Environments. The development of national colleges and universities is political and social. In the management mode of higher education, it is more prominent to cultivate talents useful to society and technical talents in line with the needs of social development for the motherland; have different educational ideas and management methods under different social development backgrounds; the comparison of educational equipment and facilities on the campus of national higher education in two environments is analyzed, and Table 1 is obtained.

As shown in Table 1, from the comparison between the traditional education environment and the machine learning environment, it can be seen that the campus under the machine learning environment has facilities and equipment and the overall environment; the development of the campus network and the scale of teachers' team are better than those in the traditional environment; a good learning environment and advanced educational resources, equipment and facilities can greatly improve students' learning initiative and contribute to educational management; visualize the data in the table to get Figure 1.

As shown in Figure 1, it can be seen from the figure that the development effect under the machine learning environment is more ideal, and the education environment and teacher team under the traditional environment will be more conducive to the education of colleges and universities; environment changes people, in the development of higher education; a good learning environment and excellent teacher team can more comprehensively and systematically educate and manage students; it is conducive to cultivating students' personal quality and collectivism spirit; it can help create a comfortable and relaxed learning atmosphere.

5.2. Comprehensive Effect of Management Mode of Higher Education Institutions in Different Environments. In the educational management of modern colleges and universities, the requirements for educational institutions need to follow the principle of all-round development, in line with the national political environment and sustainable road; a good educational environment and modern science and technology are conducive to increasing students' learning motivation and ideological understanding and are more convenient for management. Especially with the rapid development of the Internet, the comprehensive level and personal quality development of teachers and students can

Table 1: Comparative analysis of educational facilities in national universities (%).

Group	Campus environment (%)	Campus facilities (%)	Campus network (%)	Teacher resources (%)
Traditional environment	46.21	51.24	52.11	56.68
Machine learning environment	63.21	71.05	76.28	73.59

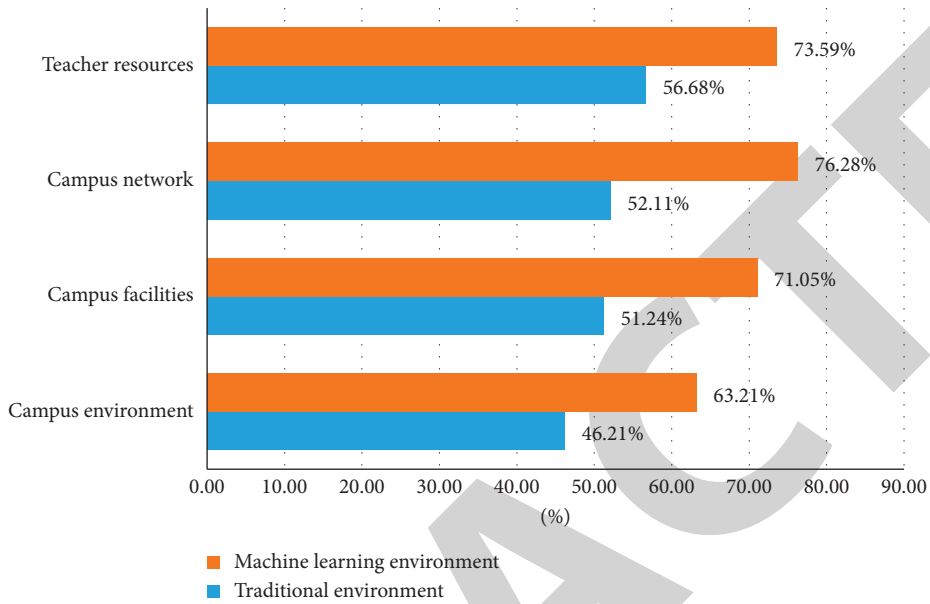

Figure 1: Comparative analysis of educational facilities in national universities (%).

be improved by using machine learning algorithm for education and auxiliary service management in university management; by analyzing and comparing the management effects of colleges and universities in different environments, the following Table 2 is obtained.

As shown in Table 2, it can be seen from the data in the table that the educational development of students and teachers under the traditional management mode is far less than that under the machine learning environment; In the development environment of the digital economy and the social environment of sustainable development, national colleges and universities, as the management organization of the integration of Party and government, need to abide by the political policy, and the use of machine learning algorithm can increase the management effect of college management. The following figure is obtained by visual processing of the data in the table.

As shown in Figure 2, college management, as a core element, is primarily responsible for students' education. A good management method is conducive to students' learning progress and positive thinking. Machine learning not only adds a lot of intelligent convenience and analysis and statistics methods to institutional management but also helps students and teachers to open up new scientific and technological horizons; increase the means of communication between teachers and students; provide more educational directions for educational development.

5.3. Analysis of Management Model of National Higher Education Institutions under Different Algorithms. According to the differences between scientific research division and discipline planning, national colleges and universities in China are set up and managed according to entity institutions and nonentity institutions, and entity institutions will have certain management personnel, scientific research funds, venues, and other support; for the management of colleges and universities, the purpose is to assist educational achievements, cultivate talents needed by the country and new scientific research achievements; this paper evaluates the university management models under different algorithms and obtains the following table.

As shown in Table 3, through the party and government management in the management of colleges and universities; Scientific research achievements; service guarantee and organization establishment are analyzed, respectively; it is found that the performance is higher under the machine learning algorithm. The following figure is obtained from the visual processing of the data in the table.

As shown in Figure 3, the management mode of colleges and universities is assisted by advanced technical means, which greatly avoids the impact of staff waste and insufficient resources in terms of teacher resources; in terms of some data statistics and analysis of simulated data, scientific research can better assist administrators in management, analysis, and control. It has a great positive impact on the development of colleges and universities as a whole; among

Table 2: Effect analysis of university management mode under different environments (%).

Group	Innovation of teaching methods (%)	Students' own innovation (%)	Students' ideological development (%)	Improvement of teaching level (%)
Traditional environment	44.25	40.23	51.23	41.26
Machine learning environment	58.22	62.21	70.14	68.45

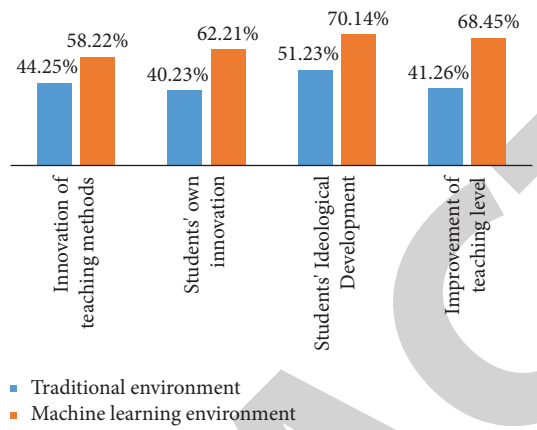

Figure 2: Effect analysis of university management mode under different environments (%).

Table 3: Evaluation of management model of national higher education institutions under different algorithms (%).

Group	Party and government management	Teaching and scientific research	Service guarantee	Establishment of institutions
Traditional algorithm	33.51%	41.03%	50.68%	48.26%
Machine learning algorithm	56.20%	56.26%	60.26%	68.66%
t	7.562	8.035	8.115	8.865
P	0.019	0.025	0.036	0.027

them, the analysis results, $t < 10$; $p < 0.05$, the data was statistically significant.

5.4. Management Coupling Degree of Higher Education Institutions under Different Algorithms. In the final analysis, the management of colleges and universities is still a people-oriented management mode. In national universities and scientific research colleges, the structure and establishment of management organizations are hierarchical and structural. The division and management of each level need data recording and management. The computing mode of machine learning is to research an effective auxiliary management mode through anthropomorphic simulation characteristics and data analysis ability; it has good performance results in terms of functionality and stability; through the analysis of the coupling degree of university management under different algorithms, the following table is obtained.

As shown in Table 4, it can be seen from the table that the degree of the coupling under the machine learning algorithm is higher than that under the traditional algorithm, whether before or after coupling; $t < 10$; $p < 0.05$; the data are statistically significant; the following figure is obtained by visual processing of the data in the table:

As shown in Figure 4, the development and management of modern colleges and universities with the progress of science and technology, new data processing and analysis methods have a more anthropomorphic mode. In the society of Internet development, it has become a phenomenon to use advanced development technology in both education and management, as well as in more fields; this has also promoted the emergence of new models. In terms of university management, the application of this algorithm has also led to progress in the field of education; It has a certain positive impact on the cultivation of talents, the establishment of students' values, and the development of communication between teachers and students.

6. Summary

The reform, development, and management mode of education need to keep pace with the times, and the management needs of state-run schools should be in line with the national political development; in the Internet environment, the application of machine learning algorithm is in line with

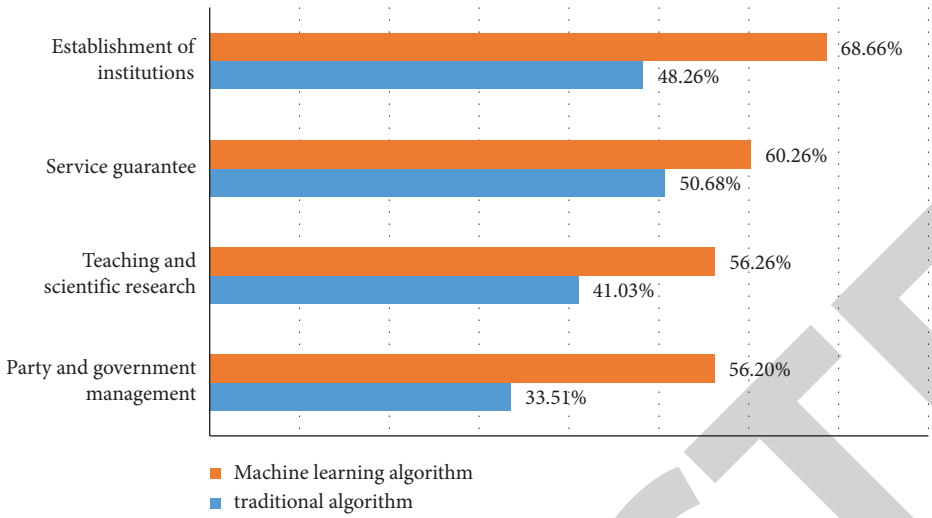

Figure 3: Evaluation of management model of national higher education institutions under different algorithms (%).

Table 4: University management coupling degree under two algorithms.

Group	Efficient management of national higher education institutions	
	Before coupling	After coupling
Traditional algorithm	52.32%	59.26%
Machine learning algorithm	63.15%	78.25%
t	8.652	8.865
P	0.026	0.015

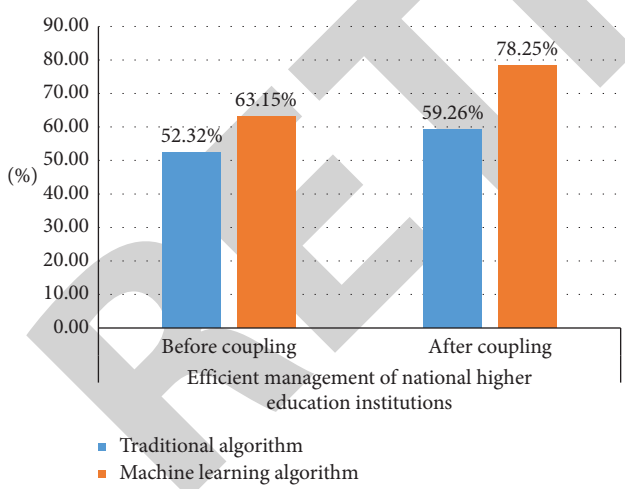

Figure 4: University management coupling degree under two algorithms.

the progress direction of modern education management; how to adapt to new technologies in the new environment and use advanced science and technology to improve life and social development. In terms of education management, machine learning algorithms have changed the efficiency of management and effectively improved the utilization of human resources, the change and development in the field of education is in line with the strategic objectives of modernization and the political direction of sustainable development; give guidance to improve students' knowledge reserve and life direction; be able to touch a broader field of knowledge, go to the world, go international, and establish a higher ideal of life; it also provides a greater direction and development path for China's educational management institutions and provides beneficial data support and research value for the development and progress of the future management mode of colleges and universities. By changing the algorithm and technical means of university management, we can improve the informatization and humanized management mode of university management and enhance students' awareness of autonomy and collective awareness; strictly managing the democratic construction of teachers and students plays a positive role in improving management efficiency.

Data Availability

The data underlying the results presented in the study are available within the manuscript.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

A Cross-Border e-Commerce Cold Chain Supply Inventory Planning Method Based on Risk Measurement Model

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Inventory planning results are less reliable when the statistical problem of supply chain risk factors is not considered. In conjunction with the risk measurement model, a cross-border e-commerce cold chain supply inventory planning method is proposed to effectively address the aforementioned issues. This paper aims to define the fundamental elements of the supply chain network, determine the supply chain's imbalance range, and develop a risk measurement model and also to calculate the ordering cost and storage cost, the storage cost, the cross-border e-commerce imbalance index based on the risk measurement model, the node imbalance, the dynamic programming algorithm for the imbalance node, and the identification method for the cross-border e-commerce supply chain imbalance node. Taking inventory strategy into account, the optimization model of distribution node location and the node importance evaluation system are developed. The planning of cold chain supply inventory for cross-border e-commerce is studied based on an optimized management inventory. The experimental results indicate that the throughput of the research method is between 1000 and 2500 Mbps, that the overall fluctuation range and delay are small, and that the inventory turnover rate has been significantly increased, thereby satisfying the requirements of engineering materials inventory management.

1. Introduction

Due to the gradual improvement of people's living standards and the gradual penetration of electronic networks into everyday life, cross-border e-commerce has begun to rapidly dominate the retail industry. The expansion of international e-commerce has fueled the growth of the logistics industry. Therefore, the stable supply of cold chain goods in cross-border e-commerce has become a hot topic [1, 2]. The imbalance of the supply chain can be caused by large-scale ordering and distribution, imbalanced order quantity distribution, and large-scale price fluctuations. When such an incident occurs, the e-commerce network as a whole will fail. It is of utmost importance to study the supply inventory planning of cross-border e-commerce cold chain in order to ensure that the commodities can flow quickly and reliably along the entire supply chain and can respond quickly when the supply chain is unbalanced [3].

In this regard, numerous relevant studies have been published. On the basis of horizontal inventory share, reference [4] proposes a sustainable food supply network model for cross-border e-commerce of the Internet of Things. We investigated a business model based on a horizontal inventory sharing e-grocery network where online groceries are interconnected as a whole in an IoT environment. This paper aims to design a sustainable food supply chain network for cross-border e-commerce food companies by employing the horizontal inventory sharing strategy and accounting for the existence of strategic alliances between the organizations, reducing food waste and backlogs to create a network that is more sustainable. Reference [5] proposes an inventory sharing strategy design for a sustainable omnichannel cross-border e-commerce network. By pursuing an effective integration strategy for online and offline retailers, the entire supply network can reduce costs, lessen the environmental impact of shipments from the main warehouse, and improve its responsiveness. To reduce the negative impact of demand uncertainty and increase the network's profitability, the inventory share policy based on the strategic alliance concept is being studied. Through the

inventory sharing policy, businesses share their current inventory with other businesses, thereby reducing transportation expenses and carbon dioxide emissions caused by the network's traffic density. The simulation modeling technique is utilized for modeling, and the strategy results based on the total network cost, the total number of shipments completed from the main warehouse, and the total sales loss cost are compared at the optimal level. The optimal strategy design is then proposed.

Although the preceding research has made some progress, risk assessment has received less attention. Therefore, it is proposed to conduct research on cross-border e-commerce cold chain inventory planning based on a risk measurement model. Risk evaluation is the foundation of risk management. Nonetheless, due to the inherent complexity of risk, research on risk measurement has always posed a challenge for the academic community. This paper examines the theoretical foundation for the measurement of cold chain supply inventory risk in cross-border e-commerce. The technical basis and applicability are examined, which provides a certain hint for the relevant research work on risk management, and the simulation experiment is used to draw an effectiveness conclusion.

2. Identification Method of Unbalanced Nodes in Cross-Border e-Commerce Supply Chain Based on the Risk Measurement Model

2.1. Establishment of the Risk Measurement Model. Before considering the overall model of a supply chain at a certain stage, it is necessary to first calculate the flow of information, logistics, and capital. There is a flow guide between raw materials and intermediate products, which can flow all raw materials from the place of production to the manufacturer. In the same way, there is a circulation guide between intermediate products and suppliers, which will flow all products from manufacturers to merchants. In the final stage from the merchant to the buyer, it is necessary to pass the products to the individual through the circulation of goods. Risk measurement is the evaluation and estimation of the impact and consequences of risks [6]. Risk measurement includes the evaluation and estimation of the probability or probability of project risks, which is called the risk measurement model. In this complex network, many scale-free data networks exist due to nodes. Due to self-organization and unrelated attraction strategies, many supply chain network nodes are unevenly distributed. Therefore, it is necessary to lead and connect core enterprises in the form of feature scale among the significant characteristics of network nodes.

In the supply chain network, there are several basic elements, the most important of which are nodes and edges. Nodes exist in the form of business entities in the main network of the supply chain, including raw material suppliers, commodity processors, sellers, and buyers. The above is the simplest single chain supply chain. If you increase the supply and demand side, you can also add business entities at any time. Although these business entities have the right to operate independently, there are certain limitations in the economic exchanges between each entity, showing an independent and limited structure. And the edge structure is mainly manifested as a kind of material flow, capital flow, information flow, and other circulation modes between the main bodies of the supply chain network. These edge structures can ensure that the different network nodes have business transactions, and make different structured networks have strong mobility. In addition to nodes and edges, there are other elements such as weight and direction, which can define and propagate the supply chain network. When an emergency occurs, it will directly lead to an imbalance between supply and demand in the market. At this time, the risk measurement model needs to be rebuilt. By setting the raw material supplier as A_a, the commodity manufacturer as B_b, the merchant and the buyer as C_c and D_d, respectively, and defining their logistics results, we can obtain the imbalance range of the supply chain:

$$\begin{cases} M_{AB} = \dfrac{N_i - N_1}{Z_X} \times A_a \\ M_{BC} = \dfrac{N_i - N_2}{Z_X} \times B_b \\ M_{CD} == \dfrac{N_i - N_3}{Z_X} \times C_c \\ M_{DA} == \dfrac{N_i - N_4}{Z_X} \times D_d \end{cases}. \tag{1}$$

In formula (1), M_{AB} represents the logistics imbalance amplitude from stage A to stage B, M_{BC} represents the logistics imbalance amplitude from stage B to stage C, M_{CD} represents the logistics imbalance amplitude from stage C to stage D, and M_{DA} represents the logistics imbalance amplitude from stage D to stage A, N_i represents the supply loss when there is no emergency, Z_X represents the label cost, N_1, N_2, N_3 and N_4 represent the supply and demand costs of products in the four supply chain structures when an emergency occurs. Through this formula, the risk measurement model can be obtained.

2.2. Risk Measurement Model Defines Cross-Border e-Commerce Imbalance Indicators. Through the edge structure of all network nodes, goods can flow from the factory to each distribution center in order to maintain warehouse inventory. To ensure that node indicators can be queried quickly, it is generally configured so that each seller can only transfer goods from a single warehouse. Thus, the location of the distribution center must be carefully considered during the initial stages of establishment. The primary objective of selecting and establishing a distribution center is to save money on logistics operations. Therefore, when measuring the indicators of cross-border e-commerce supply imbalance [7, 8], it is necessary to first calculate the inventory center's construction, inventory, and transfer costs [9, 10]. The initial construction cost of the inventory center is the highest among

them, but it is a one-time expense that will not be repeated. The remaining two inventory costs and transshipment costs are continuous costs that necessitate the ongoing expenditures to maintain the inventory center's operation. Typically, inventory costs include both ordering and storage expenses. The ordering cost calculation formula is as follows:

$$E_{DH} = \frac{J_{12}}{T_{12}} + \sum_i \frac{k_O}{T_i}. \tag{2}$$

In formula (2), J_{12} and k_O, respectively, represent the overall ordering cost and the ordering cost of the O time, T_{12} represents the time of ordering in advance, and T_i represents the interval of inventory inspection. The ordering cost is generally proportional to the number of orders. In the distribution center, the lead time of inventory management is inversely proportional to the service level, so the overall replenishment times will not exceed the maximum inventory [11]. According to the operation mode of the distribution center, it is necessary to calculate the relationship between the goods in the inventory center and the goods of retailers in order to grasp the distribution level of the cross-border e-commerce supply chain in a timely manner. The calculation formula of storage cost is

$$J_{\alpha\beta} = J_\alpha + J_\beta. \tag{3}$$

In formula (3), J_α represents the maintenance cost that the inventory center can safely store goods, and J_β represents the storage cost when goods are transferred on the road. The transportation cost is quite different from the inventory cost. For example, when a large truck transports a box of fruit from city A to city B, the vehicle running loss on the road and the daily cost of the driver are all transportation costs. The cost of keeping the fruit in the truck without spoiling it is classified as storage cost. The calculation formula of transportation cost is

$$J_{\chi\varphi} = \sum_i \sum_j E_{ij} R_{ij}. \tag{4}$$

In formula (4), E_{ij} represents the transportation volume of goods j transported by the distribution center i, and R_{ij} represents the transportation cost per unit mass of goods j transported by the distribution center i during transportation. According to the above formula, the best inventory address of certain goods can be obtained through various costs. By integrating all goods and using buffer zone analysis, the best location can be obtained. Combined with the risk measurement model, the imbalance index of cross-border e-commerce supply chain nodes can be measured.

$$B(x, y) = \sum_j \left[E_{DH} + \sum_i \left(J_{\alpha\beta} \times b_{ij} \times V_e \right) \right] + J_{\chi\varphi}. \tag{5}$$

In formula (5), $B(x, y)$ represents the value of the objective function to measure the imbalance of cross-border e-commerce supply, b_{ij} represents the function value of retailers in the distribution center to minimize the objective function, and V_e represents the individual adaptability of the distribution center in the original location. When it is greater than 0, $B(x, y)$ indicates that the supply of the cross-border e-commerce supply chain node is unbalanced, and it is difficult for the node to effectively provide logistics services. When $B(x, y)$ is less than or equal to 0, it indicates that the supply of the node is good. Through this formula, it can be effectively determined whether there is a supply chain imbalance in the cross-border e-commerce transport entity nodes in the risk measurement model.

2.3. Dynamic Programming Algorithm for Designing Unbalanced Nodes. In combination with the risk measurement model and cross-border e-commerce imbalance indicators in the above, a corresponding dynamic planning algorithm is designed to quickly query the imbalance nodes in the cross-border e-commerce supply chain. The flow of the dynamic planning algorithm is shown in Figure 1.

As shown in Figure 1, after obtaining the supply chain imbalance index, the dynamic planning algorithm needs to send a query command to ensure the integrity of all supply nodes. All inventory decisions are traversed one by one to obtain the effective value of supply chain nodes. Search for tags and determine whether the tags respond to the unbalanced node. If there is no response, it is necessary to traverse other nodes again. If there is a response, it is further determined whether the tags collide. When the labels do collide, it indicates that there is an imbalance in the supply chain of cross-border e-commerce, and this node is the imbalance node. If there is no collision, check whether there is a continuous collision. And according to the continuity or not, the quadtree query is carried out to determine the classification of inventory location, and the connection mechanism of all supply chains needs to be updated. Use the constrained evaluation function to determine whether all the tags are recognized. The evaluation function $H(x, y)$ is

$$G(m, n) = \begin{cases} g(m, n), f \geq 0 \\ g(m, n) + k(m, n), f < 0 \end{cases}. \tag{6}$$

In formula (6), $g(m, n)$ represents the function value of the evaluation index for judging the supply chain imbalance; $k(m, n)$ represents the penalty function of code repair; f represents the satisfaction condition of the individual constraint. When f is greater than or equal to 0, it indicates that the individual meets the constraint conditions; when f is less than 0, it indicates that the individual does not meet the constraint conditions. If the results of the tags in the evaluation function are all identified, all the unbalanced nodes are successfully planned. However, when the results in the evaluation function are not all identified, it is necessary to resend the query command and replan. Through the above algorithm, the planning results of cross-border e-commerce supply chain imbalance nodes can be obtained.

3. Research on Cross-Border e-Commerce Cold Chain Supply Inventory Planning

3.1. An Optimization Model of Distribution Node Location considering Inventory Strategy. At this time, considering the inventory strategy and designing the location optimization

model of distribution nodes, it is necessary to describe the model, set all network vertices, and connect them. At this time, the connection between the vertices becomes the vertex path, select some demand nodes, and design the subset distribution cost at the nodes to ensure that the distribution can start from the parent distribution center and return to the distribution center through the circulation of child nodes. At this time, it is assumed that the distribution path set of a parent distribution center k is $P_k = \{p_1, p_2, p_3, ..., p_K\}$, the model is assumed, and the demand points are set as discrete points. At this time, the demand of the demand nodes in the cycle is constant. Grid planning is carried out for the international logistics transportation route of cross-border e-commerce, and a uniform rectangular grid is obtained, as shown in Figure 2.

When a demand point is selected as a sublevel distribution node, it provides services by itself. If it is not selected as a sublevel node, there is only one adjacent sublevel distribution node to serve it. Finally, the circular distribution adopts a uniform model, that is, the vehicle load limit in the distribution path is consistent, and the capacity of each sublevel distribution node is consistent. At this time, the distribution cost formula from node i to node j is shown in

$$L_{ij} = Z \times O_{vb}. \tag{7}$$

In formula (7), Z represents the node distance and O_{vb} represents the distribution cost. At this time, the cycle distribution cost can be designed according to the distribution route, and the calculation formula of distribution times is shown in

$$M_E = L_{ij} \times J_K \times R_T \times F_D \tag{8}$$

In formula (8), J_K represents the number of circular distribution, R_T represents the service cost of the node, and F_D represents the distribution demand. At this time, the distribution cost is in a fixed state. Therefore, in order to keep the node cost always in the optimal state, it is necessary to calculate the service cost of the node at this time, and build a distribution node location optimization model as shown in

$$R_{WE} = M_E \times U_{\alpha\beta} \times B_{ZX} \times G_{HJ}. \tag{9}$$

In formula (9), $U_{\alpha\beta}$ represents the average service times of coverage demand, B_{ZX} represents the service times of node i, and G_{HJ} represents the fixed cost of sequential distribution. At this time, the fixed operating costs can be listed using the distribution times and service costs calculated above, and then according to the inventory strategy.

3.2. Construction of the Node Importance Evaluation System. In the process of cross-border e-commerce cold chain supply inventory planning, the cross-border e-commerce cold chain enterprises are taken as the core of the whole supply chain, and the internal personnel of the core enterprises are controlled and guided. Among them, the cross-border e-commerce enterprises focus on the control of information flow, logistics, and capital flow [12, 13]. The cross-border

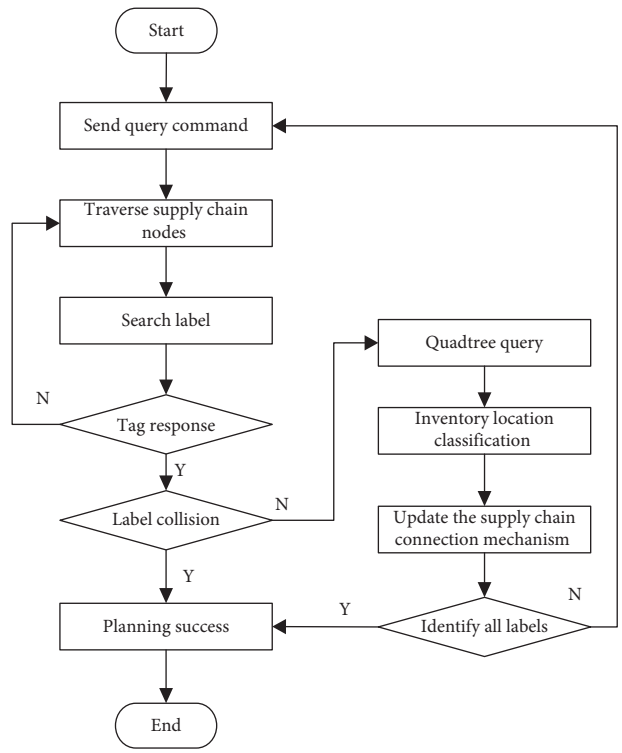

Figure 1: Flowchart of dynamic programming algorithm.

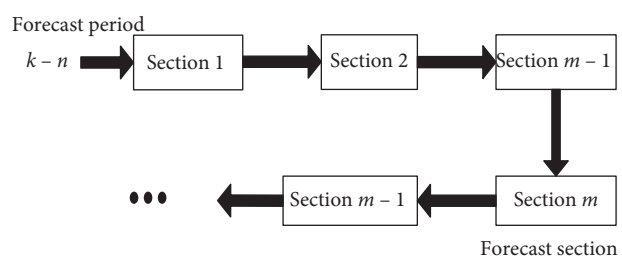

Figure 2: Cross-border e-commerce cold chain supply and transportation path grid planning.

e-commerce supply chain structure chart shown in Figure 3 is established by combining the most advanced technologies and equipment at the present stage.

Figure 3 demonstrates that the supply chain of cross-border e-commerce companies is a mesh structure, allowing for the elimination of inefficient operation processes and losses. Suppliers can view the detailed inventory information of e-commerce businesses in real time and make purchase and sales calculations without needing to obtain specific demand information in conjunction with the orders of businesses. In addition, businesses can comprehend consumer demand information in a timely manner and formulate corresponding purchase plans. Not only can the formulation of purchase plans effectively prevent losses caused by calculation errors, but it can also improve the overall operational efficiency of the method.

Cooperation is indispensable to the development of all businesses. All businesses are involved in the supply chain. When a supply chain risk occurs, all businesses will incur

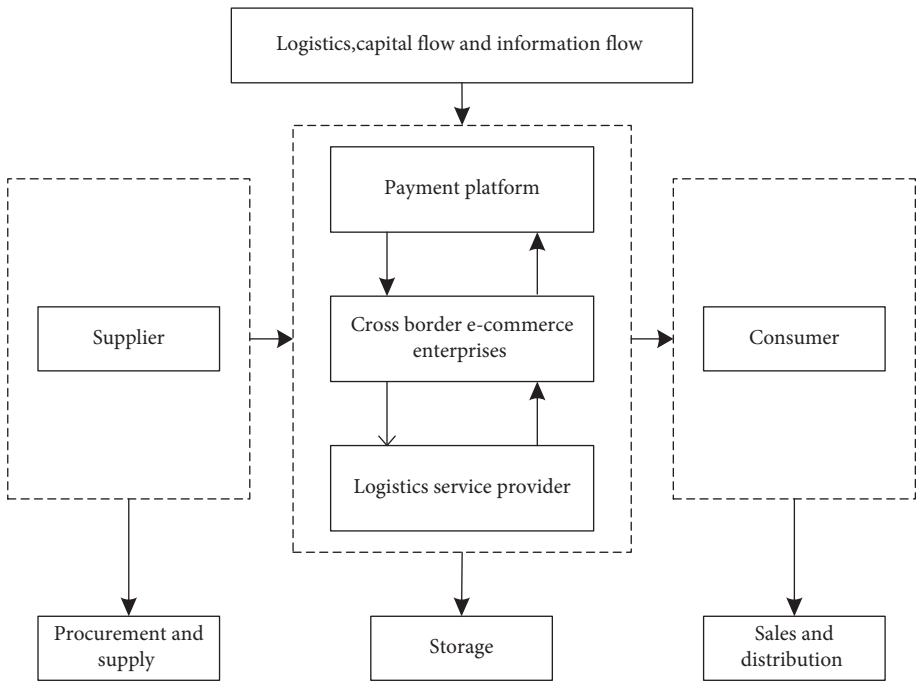

Figure 3: Supply chain structure of cross-border e-commerce enterprises.

losses. Consequently, the majority of businesses pay greater attention to enterprise supply chain management and strive to implement the most recent supply chain risk management strategy. Predicting supply chain risk is a vital component of supply chain management. Good risk prediction can effectively improve supply chain management efficiency [14, 15].

External environmental factors that contribute to the risk of the supply chain are the primary focus of the external risk of the supply chain. These external factors primarily consist of the natural and social environments. At the same time, these risk factors are unavoidable and cannot be controlled by the enterprise, but it can take preventative measures to reduce the losses effectively. Analyze the impact of a single enterprise on the network from the perspective of complex network and node importance, and tally the supply chain risk factors exhaustively from the perspective of supply chain risk.

In the framework of a model node importance evaluation system, the model's solution must be encoded to facilitate local search and the generation of domain solutions. This model utilizes three-segment natural number coding. They consist of the site code, the coverage point code, and the coverage relationship code. Assuming there are N demand points and P regular circular distribution paths, the location point code specifies the distribution node locations and the order of circular distribution. The code contains a total of $N + P + 1$ digits. 0 represents the distribution center's parent and separates the various distribution paths. The remaining natural numbers indicate the number of demand points chosen as child distribution nodes. The coding sequence is the circular distribution sequence. The current coding diagram is depicted in Figure 4.

As can be seen from Figure 4, the coverage point code and the coverage relationship code jointly represent the corresponding relationship between the coverage point and the location point. Coverage point coding and coverage relation coding are both n-k bit coding. The coverage point code represents the number of the covered demand node, and the coverage relationship code of the corresponding digits represents the child distribution node covering the demand point. The demand point 10 is selected as the No. 2 node of the child distribution node to cover the service, and the range of the shared logistics distribution center can be divided according to the specific coding status.

3.3. Optimizing Inventory Management. In order to realize the optimization of engineering materials and materials inventory, we need to adopt the economic ordering mode and realize the safety inventory through inventory control. Therefore, this paper estimates the optimal interval of various materials and materials inventory and then determines the order batch. The specific formula for calculating the annual storage cost per unit storage is

$$R_1 = \frac{1}{r_i} \times \frac{v_i}{\sum v_i} \times H_0. \tag{10}$$

In formula (10), r_i represents the annual demand of inventory, v_i represents the annual inventory value, H_0 represents the annual storage cost, in which the individual storage cost accounts for a small proportion of the total expenditure. Therefore, considering the comprehensive storage cost, the cost is defined to be proportional to the inventory, and the risk coefficient is introduced in combination with the historical experience data.

Optimizing inventory management necessitates a streamlined information channel, a rapid response to market changes, a transformation of the inventory management

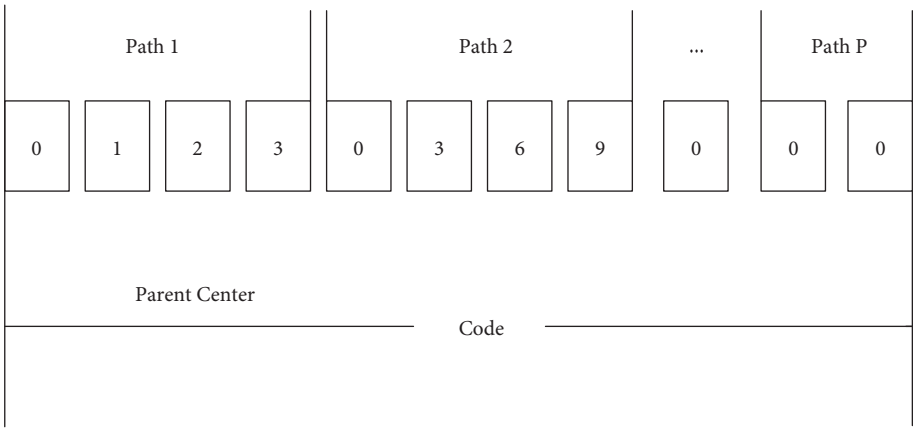

Figure 4: Coding diagram.

mode of thought, and the use of a multidimensional mode of thought to circumvent obstacles to departmental cooperation. Consequently, it is crucial to optimize the inventory of engineering materials and enhance the inventory management procedure. Reorganize the material procurement decision-making process so that it forms an internal organic whole, and give priority to the application of the project material auxiliary management system to facilitate the reorganization. The central challenge of optimizing inventory management is the precise forecasting of material demand. According to market forecasts, the handover time with suppliers can be minimized to the greatest extent possible in order to reduce the inventory costs. The greater the accuracy of the inventory forecast, the shorter the forecast period. If there is a significant difference between the actual demand for project materials and the planned quantity, there will be an inventory backlog or shortage. Consequently, from the four dimensions of external resource management, order-driven procurement, external collaboration, and internal collaboration of the project, optimize the management of inventory, set the forecast period of material inventory reasonably, and maintain and update inventory data in a timely manner. Establish an internal information system among the various project departments, query the inventory of materials and materials based on the shared demand and inventory information, and make adjustments to the actual project production plan and delivery activities based on the queried information, so as to achieve the optimization objective of minimizing the inventory based on the premise of meeting demand and supply. Master the project node information, examine the quality of materials and materials, manage the suppliers of materials and materials at various levels, terminate the cooperative relationship with the suppliers of unqualified materials and materials, avoid unnecessary costs, and optimize the inventory.

4. Simulation Experiment Analysis

In order to verify the effect and feasibility of cross-border e-commerce cold chain supply inventory planning based on the risk measurement model, a simulation experiment is designed to obtain the whole supply chain through cross-border e-commerce. The blockchain network needs to be obtained from the configured server. The specific server hardware and software configuration table is shown in Table 1.

In combination with the server configuration in Table 1, the unbalanced nodes in the cross-border e-commerce supply chain are identified. For different types of nodes, the identified parameters are slightly different. In the virtual server, multiple image systems can be formed through the function of dynamic logical partition, and the application requirements of the system can be obtained from all component resources. Cluster management is carried out by dynamically allocating the capacity as needed. If the configuration in the system is mostly reliable and secure, it can directly connect to the relational database, call, and create middleware applications.

In the experiment, the unbalanced nodes are tested and identified through the throughput. When the throughput has a large prominent range, the supply chain imbalance at the node can be judged. The calculation formula of throughput is

$$Y_t = \frac{T_t}{\Delta t} \times 100\%. \tag{11}$$

In formula (11), Y_t represents the throughput of a cross-border e-commerce supply chain node, T_t represents the number of commodities circulated in a period of time, and Δt represents the elapsed time of the experiment. Through this formula, the throughput of multiple nodes is calculated, as shown in Figure 5.

As shown in Figure 5, the throughput of most nodes in nodes 1–25 is between 1000 and 2500 Mbps. Although there is a certain fluctuation in the movement of each node, the overall fluctuation range is small. It can be seen that the supply environment in these nodes is stable and there is no imbalance. Only at node 16, the throughput has been greatly increased, from 1100 Mbps to 2500 Mbps. It can be seen that there is a supply chain imbalance at this node.

The supply chain channel from the origin of raw materials supplied by the cross-border e-commerce cold chain to the product production plant is taken as stage 1, the

Table 1: Server hardware and software configuration.

Serial number	Name	Parameter configuration
1	Server CPU	Intel (R) Core (TM)i3-8100 CPU @ 3.60 GHz 3.60 GHz
2	Operating system	Windows 1064 bit home edition
3	Memory capacity	24 GB
4	Develop and write programs	Java JDK 2.0 installation package
5	Development tool software	Net beans IDE 7.8
6	Solid state drive	40 GB
7	Bandwidth	1 G bit/s

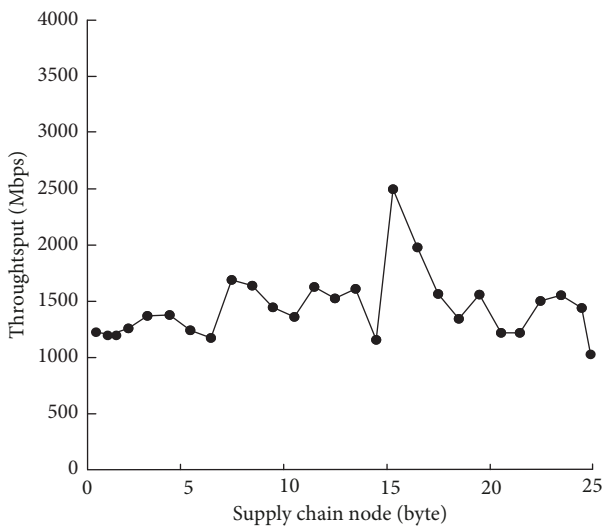

Figure 5: Throughput results of different supply chain nodes.

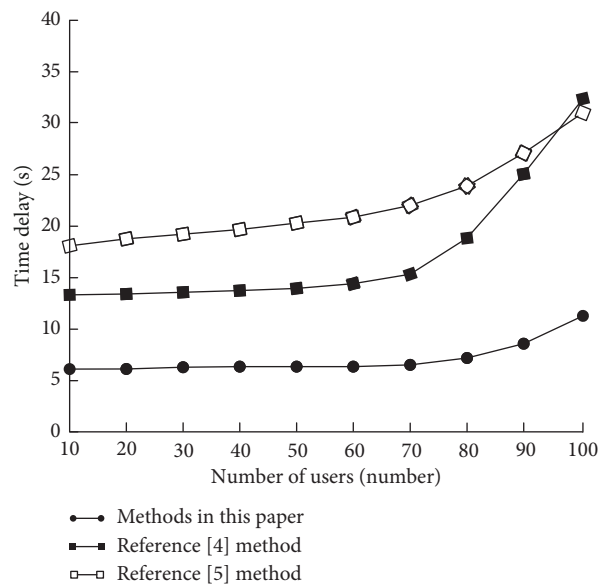

Figure 6: Test results of node planning time.

supply chain channel between the cross-border e-commerce cold chain product production plant and the seller is taken as stage 2, and the channel from the seller to the buyer is taken as stage 3. The operation delay of the cross-border e-commerce supply chain in the three stages in Figure 3 can directly indicate the efficiency of the algorithm. Therefore, the greater the operation delay, the worse the efficiency of the algorithm. And the delay will change according to the number of users. The calculation formula is

$$T_a = T_b - T_c. \tag{12}$$

In formula (12), T_a represents the response time of inventory planning under different throughput; T_b and T_c, respectively, represent the arrival time and departure time of the goods. The comparison experiment is conducted by using the method of reference [4], the method of reference [5], and the method of this paper. The test results of different supply chain segment planning times under the three methods are shown in Figure 6.

As shown in Figure 6, as the number of users increases, the delay of each planning method increases to a certain extent. In phase 1, when the number of users reaches 70, the delay starts to change. When the number of users reaches 100, the delay is 11S, which is 5S longer than the 6S delay when the number of users is 10. The delay of the method in reference [4] increases from 13s to 33S, and the delay of the method in reference [5] increases from 18s to 31s. In this stage, the time delay of this method is much less than the other two methods.

Then, the optimization results of cross-border e-commerce cold chain supply inventory turnover based on the risk measurement model from May 2021 to December 2021 are displayed, as shown in Figure 7.

Figure 7 clearly shows the trend of the optimized inventory turnover rate. With the continuous reduction of the inventory cost, the inventory turnover rate has been significantly improved. In May 2021, the inventory turnover rate was only 13% when this method was not applied for optimization. After this method was optimized, the inventory turnover rate reached 62% in December 2021, which proves that the operation level of the entire cross-border e-commerce cold chain supply chain for inventory materials has been significantly improved.

Compare the delivery rates of suppliers in four categories before and after the application of this method: frozen processing, frozen storage, refrigerated transportation and distribution, and frozen sales, as shown in Table 2.

It can be seen from Table 2 that before the application of this method, the delivery rate of frozen processing, frozen storage, refrigerated transportation and distribution, and frozen sales could not respond to the project demand in time, and it was difficult to guarantee the construction progress of the project. After the application of this method, the delivery rate of frozen processing, frozen storage, refrigerated transportation and distribution, and frozen sales

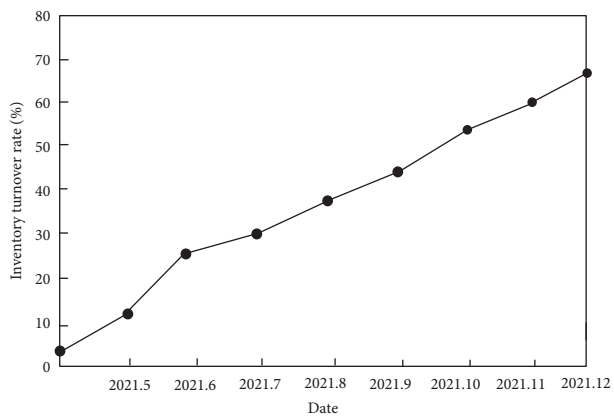

Figure 7: Inventory turnover rate.

Table 2: Comparison of delivery rate before and after optimization.

Category	Before and after application	Engineering procurement requirements (%)	Actual delivery by the supplier (%)
Freeze processing	Before application	93	80
	After application	93	93
Freeze storage	Before application	87	73
	After application	87	87
Refrigerated transportation and distribution	Before application	84	69
	After application	84	84
Frozen sales	Before application	90	89
	After application	90	90

were consistent with the project procurement requirements and gradually realized the synchronization with the project demand. Through the application of the above aspects, it can be seen that this method has a good inventory planning effect and can meet the requirements of engineering materials inventory management.

In conclusion, the research on cross-border e-commerce cold chain supply inventory planning based on the risk measurement model has good performance.

5. Conclusion and Prospect

5.1. Conclusion. Through the above research, the following conclusions are obtained:

(1) The throughput of the cross-border e-commerce cold chain supply inventory planning method based on the risk measurement model is between 1000 and 2500 Mbps, and the overall fluctuation is small. It can be seen that the supply environment in these nodes is relatively stable and there is no imbalance.

(2) With the increase in the number of users, the time delay of each planning method increases to a certain extent. The time delay of this method for identifying unbalanced nodes is much smaller than that of the other two methods.

(3) With the continuous reduction of inventory cost, the inventory turnover rate has been significantly improved, and the supply chain operation level of the whole cross-border e-commerce cold chain to supply inventory materials has been significantly improved.

(4) After the application of this method, the delivery rate of frozen processing, frozen storage, refrigerated transportation and distribution, and frozen sales are consistent with the requirements of engineering procurement, which has a good inventory planning effect and can meet the requirements of engineering material inventory management.

5.2. Prospect. Although this paper analyzes the cross-border e-commerce cold chain supply inventory planning, the actual cross-border e-commerce business is becoming more and more complex, which will be further discussed in the follow-up work.

(1) The cross-border e-commerce enterprises vary greatly, and the product types are also various. In reality, the calculation of models is different due to different products, which needs further research in the future

(2) The objective of inventory management is to reduce the inventory cost on the premise of meeting the market demand. On the basis of this objective, the logistics cost of each link of the cross-border e-commerce cold chain supply chain is analyzed, and the inventory cost calculation model is established.

When the demand and lead time are random, the safety inventory, purchase point, and purchase volume are calculated, so as to reduce the cross-border e-commerce cost and promote the cross-border e-commerce business development of enterprises.

(3) Cross-border e-commerce has diversity and complexity. The sales of products are affected by many factors, such as seasonal factors, product promotion factors, and price factors; all affect the sales and inventory of products. The next step is to further explore the characteristics of cross-border e-commerce cold chain supply inventory cost, so as to make a better inventory planning plan.

Data Availability

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

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Innovative Research on Intelligent Classroom Teaching Mode in the "5G" Era

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The integration of "5 G + education" has become a consensus and trend. The maturity and application of technologies represented by artificial intelligence, virtual reality, and big data in the 5 G era have provided a new and greater impetus for education and teaching reform. Education must adhere to the concept of people-oriented, high-quality talent training is the foundation and core of higher education, and colleges and universities need to quickly adapt to the development trend of education in the new era. Therefore, it is of significance to investigate some innovative strategies to address the existing problems in the intelligent classroom teaching mode in the "5 G" Era. This paper discusses the characteristics of high speed and low latency in the 5 G era, discusses the development of the intelligent classroom teaching promoted by 5 G technology, and creatively puts forward different teaching strategies in combination with the problems existing in an intelligent classroom in colleges and universities. Students interact with the constructed virtual or virtual real scenes in real time. With the help of artificial intelligence technology, can establish artificial intelligence teaching assistants and learning partners, support one-to-one skills training, will also provide teachers with an intelligent learning environment, integrate teaching resources, optimize the teaching path, improve teaching interaction, provide a reference for future teaching activities, explore the application of innovative teaching mode based on 5 G communication. Big data will record the learning behavior in the process and use it for the diagnosis and evaluation of dynamic learning results, providing a basis for educators to practice "people-oriented" and help students grow up.

1. Introduction

In 2018, the "Education Informatization 2.0 Action Plan" issued by the Ministry of Education emphasized the comprehensive promotion of educational modernization through informatization, and emphasized the integration of cloud computing, big data, and the Internet, and new technologies such as artificial intelligence. With the transition to smart education, the teaching methods based on classroom teaching are also slowly changing. More importantly, in the teaching environment, at the same time, with the help of virtual reality means and technology, through personalized immersive learning, students' interest in learning is improved, and the development of smart education is promoted [1]. My country's three major operators have also responded positively to this action plan and have proposed their own smart education plans. China Mobile released "5 G + Smart Education," covering "5 G" dual-teacher interactive teaching, "5 G" holographic projection teaching and "5 G" VR/AR immersive teaching, etc. and is committed to creating an immersive smart classroom teaching model; China Unicom It released "5 G + Smart Education" and established a Smart Education Demonstration Laboratory dedicated to smart education technology and product research and development; China Telecom focused on "5G" education cooperation with Education Group. In early July 2021, the Ministry of Education proposed in the "Guiding Opinions on Promoting the Construction of New Educational Infrastructure and Building a High-quality Education Support System" that the new educational infrastructure is guided by the new development concept, led by informatization, and oriented towards the education high school. Quality development requires a new infrastructure system focusing on information networks, platform systems, digital resources, smart campuses, innovative applications, trusted security, etc., [2]. Reforming the

existing classroom teaching requires not only "reversing" the information technology environment under the existing classroom teaching structure, but it is also necessary to think deeply about how to realize the transformation from knowledge-based to literacy-based, so as to reconstruct relationships, resources, abilities, processes, and assessments and reshape the classroom ecosystem. My country should take the classroom teaching in colleges and universities as the breakthrough point of reform, integrate traditional teaching with information-based classroom teaching, build a teaching community of teachers and students, and create a smart classroom. The smart classroom has become the product of the interaction between educational thinking and educational emotion. It is the process and result of the symbiosis of intelligent interaction between teachers and students.

In the current smart classroom teaching, there are problems such as education of students' innovative ability, ability training education, and personalized training. The effect of classroom teaching is closely related to the teaching environment, and different teaching environments often produce different teaching effects. At present, 5 G mobile communication and the Internet of Things have not been fully popularized in schools, and the equipment for data collection and processing technology is not advanced enough. In the construction of smart classrooms, the construction of the school network environment is still in the preliminary stage, and the school is not equipped with basic professional classrooms. As a result, teachers cannot push learning materials to be learned before class, and students are difficult to download materials; there is a lack of timely feedback mechanism in class, teachers It is difficult to adjust the teaching plan; after class, students cannot conduct independent tutoring, and it is difficult for teachers to provide personalized guidance.

Therefore, we aim to investigate innovative strategies about intelligent classroom teaching mode in the "5 G" Era. The characteristics of high speed and low latency in the 5 G era have been introduced. And, different teaching strategies have been promoted to solve the problems existing in an intelligent classroom in universities. To sum up, higher vocational colleges should follow the development of the times, make full use of the convenience brought by 5 G to information-based teaching, and create a new type of information-based teaching. Model, realize the remote sharing of course resources and teachers, break the barriers of education in time and region, improve the teaching level and talent quality, and truly deliver a large number of high-quality applied talents to all walks of life.

2. Characteristics and Integration of "5 G" Technology

The technology refers to the fifth-generation mobile communication technology, which is the latest generation of cellular mobile communication technology. It has the characteristics of ultrareliable and ultra-low-latency communication, ensuring that the network maintains stability and will not be congested and interfered with during operation [3]. On the basis of face-to-face physical one-dimensional classrooms, 5 G technology is used, online classrooms are added, and a dual-channel hybrid teaching environment is formed. Combined with the advantages of emerging network hardware resources and software resources, it adds new impetus to classroom teaching, thus forming a new driving force for classroom teaching. Smart classroom, followed by 5 G's ubiquitous network, low latency, Internet of everything, and other features provide technical support for educational and teaching applications such as blended teaching, distance education, and online interaction, which can realize visualization, scale, and real-time online teaching. Breaking the limitations of traditional teaching time, place and resources help to optimize teaching resources, realize resource sharing, and improve teaching quality. From a macro level, the emergence of smart classrooms in the 5 G era further breaks the time and space constraints, and students can study anytime, anywhere. From a micro level, education informatization makes the course content, teaching methods, assessment methods, and teaching evaluations in classroom teaching more objective and data-based.

Under the guidance of the teaching concept of "learning first, then teaching, and learning to teach," the smart classroom has comprehensively built a teaching model of "pre-class microlecture guidance, classroom interactive inquiry, and after-class personality counseling," breaking the traditional single-class teaching mode. The teaching method can better realize the two-way interaction between teachers and students. Bian and Xu [4] further pointed out that the learning mode based on the smart classroom mainly refers to the use of intelligent, personalized, and diversified learning services for learners in the system environment, and the use of mobile terminal equipment to achieve specific teaching goals. Deep, efficient, autonomous, and open classroom learning mode. The premise that AR and VR can give full play to their advantages is that data can be processed and transmitted quickly and effectively. 5 G technology can meet the above requirements to the greatest extent. It can be said that the advent of the 5 G era has provided strong support for the two to reach commercial standards, and their use in tourism, education, and other fields can usually achieve twice the result with half the effort. 5 G technology is building a new high-speed information highway. With the continuous optimization of 5 G technology, the deep integration of education + 5 G provides a broader development vision and new development space for education informatization. The promotion and popularization of "5 G" technology highlight the inevitable trend of adjusting the teaching mode of colleges and universities. Colleges and universities can explore a blended teaching model that points to practical projects to improve students' comprehensive literacy. In contrast to the traditional teaching model, students are limited to a limited teaching space, and there are not many opportunities for interaction and discussion between teachers and students. The emergence of 5 G technology has effectively solved this problem, not only the time and space boundaries are broken but also teachers and students. The interaction and communication are also

more convenient. The blended teaching model is a change to the traditional classroom teaching model. The fundamental purpose of the blended teaching model is to use a more flexible way to help students acquire knowledge and achieve better learning effects. It is centered on students' offline self-learning and summary.

3. Smart Classroom in the "5 G" Application Scenario

Realize the operation, rendering, display, and control of VR/AR applications with cloud computing technology, and then transmit the processed audio and video information flow to the smart classroom terminal through the 5 G network [5] and develop a text, image, and animation integrated system. Teaching content, and three-dimensional plane knowledge to improve the interaction and participation of the classroom, realize active interactive learning and display real scenes. This display method will reduce the delay of information dissemination, and the teaching records will also be shared. And, storage for a long time, the performance of VR/AR technology that requires extremely high network speed and capacity will be greatly improved. Integrating digital technologies such as VR and 3D into the teaching process, students' classroom experience jumps from 2D to 3D and is no longer the flat content presented by books or blackboards, such as three-dimensional graphics in mathematics, electromagnetic fields in physics, and the earth in geography Sports, etc., will no longer require teachers to explain, and students will rack their brains to imagine. VR/AR can display these scenes visually and visually, and students can easily recognize and understand them as shown in Figures 1 and 2.

Figure 1: Students learn through VR (1).

Figure 2: Students learn through VR (2).

Holographic technology actually uses the principle of interference of light to record all the information of the object in the form of interference fringes, and under certain conditions, forms a three-dimensional image that is highly similar to the object itself. Aiming at the problem of uneven distribution of educational resources in China, 5 G holographic projection teaching uses virtual reality and augmented reality technology to collect classroom teaching image information through holographic projection to present remote students' listening conditions and real-time interaction; the use of holographic technology can be more vivid To present things in other spaces in the classroom, in addition to introducing other expert teachers to explain knowledge to students as in this lesson, holographic technology can also be used to introduce a specific thing into the classroom for all-round display, such as An artifact, animal, or instrument. With the development of optical devices, holographic technology can also be used to superimpose another scene into the classroom space in the future, allowing students to experience the feeling of being in any place in the classroom. In addition, the holographic platform is deployed in the classroom, and through 3D technology, the real images and courseware content of some famous school experts and teachers can be presented to the remote students. Compared with the connection forms such as telephone and video, holographic technology can retain more The information that is visible to the naked eye connects and integrates the two separate spaces, so that the interaction between students and teachers and resources in different places can get rid of the limitation of separation of time and space, and realize the distance teaching of natural interaction [6]. Teachers can also reproduce the content of nature, science, history, biology, physics, chemistry, and other disciplines through holographic technology, making teaching and learning more vivid and improving teaching quality.

The key technology of speech recognition is to convert speech data into corresponding text or instructions by intelligent means. Speech recognition technology currently has a wide range of applications. For example, in the application of smart education, all the audio data of the teaching classroom are collected, and after the analysis of the pronunciation and semantics, it can assist the analysis of the teaching situation and the students' learning situation, and scientifically test the teaching level of the teachers and the learning situation of the students. It can also understand the individual characteristics of students through feedback data, and practice the people-oriented teaching concept. The main process of speech recognition is shown in Figure 3.

With the support of 5 G technology, the interaction between various multimodal resources will become more convenient, which provides an opportunity for the innovation of teaching and learning models and the integration

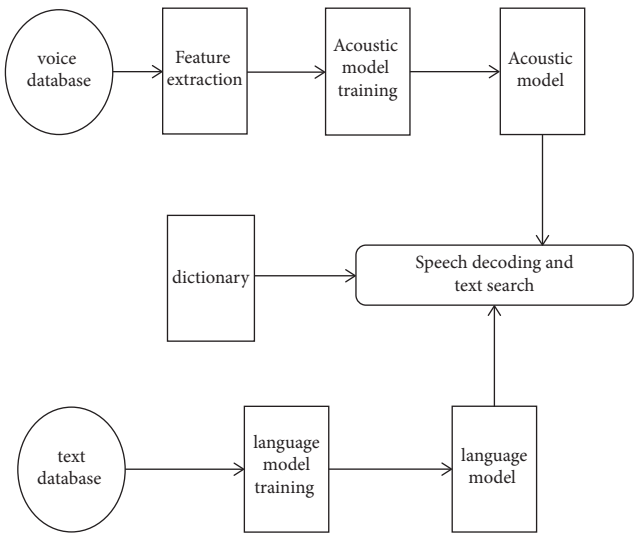

Figure 3: Speech recognition analysis flow chart.

and reorganization of many educational elements. Teachers, students, learning resources, and the learning environment are the four basic elements of educational scenarios supported by 5 G, and they interact and influence each other [7]. Multimodal smart classrooms need to give full play to the advantages of each element and use multimodal information technology in the 5 G environment to make the interaction between students and teachers, learning resources, and learning environments more diverse and personalized and explore various modalities. The potential of each element complements each other [8]. Online teaching, offline teaching, blended teaching, virtual simulation teaching, and other teaching forms in a smart environment help to integrate diversified online and offline learning resources, optimize teaching paths, improve teaching effects, and improve teaching evaluation.

Based on the above-given design ideas, we combined practice to build a multimodal smart classroom model in the 5 G environment, as shown in Figure 4. After the introduction of the smart teaching system, a network system environment covering smart learning terminals, smart learning management platforms, smart learning software, and resources has been formed based on the support of 5 G technology, forming a flexible, open, shared, convenient, and traceable smart learning space [9–11], and at the same time realize the seamless interconnection and collaborative work between a variety of software and hardware devices, providing learners with a truly immersive real-time learning experience [12–14]. In addition, the multimodal learning environment under the 5 G network should make full use of the technical characteristics of 5 G's high bandwidth, low latency, and large connection, by connecting to various forms of intelligent terminals and educational equipment (such as VR/AR/MR equipment, and holography). Projection, smart whiteboard, mobile terminal, smart learning pen, etc., to achieve seamless interconnection and collaborative work between various software and hardware devices, providing learners with a truly immersive real-time learning experience.

4. Discussion

With the guidance and expansion of teachers as the auxiliary, a new teaching method combines the two. The blended teaching model is conducive to expanding the dimension of teaching, promoting the interaction between teachers and students, and stimulating students' learning initiative. Teachers should not only pay attention to students' knowledge acquisition but also pay attention to students' ability development, and pay attention to the interaction between students' existing concepts and new concepts. Therefore, smart classrooms should design news broadcasts, new class explanations, assignments, and summaries. The way students explore awareness, optimize their learning experience, and the innovation of teaching models in colleges and universities should involve the exploration of employment orientation and employment preparation; that is, they need to be based on employment, give full play to the advantages of 5 G and cultivate talents needed by society.

"5 G" has just entered the first year of commercial use, and there are still great deficiencies in talent training. For ordinary people, "5 G" may just mean faster internet speeds. The 4 G era has created the live broadcast industry, and the "5 G" era will also create a new industry. However, the development of the "5 G" era also needs the support of talents, and the innovation of the smart classroom teaching mode in the "5 G" era requires compound talents from the Internet industry and the education industry. It is not perfect, resulting in a serious shortage of "5 G" talents and also makes the innovation of smart classroom teaching mode in the "5 G" era temporarily stay in the conceptual stage.

In the 5 G environment, "Internet + education" will introduce more means such as AR/VR technology, which can be presented in a virtual way for the history, training process, and dangerous operations that cannot be presented in the classroom, and even voice can be realized, context simulation, etc. The above-mentioned are not presented vividly in the traditional teaching process. Many teachers still rely on their own explanations and always grasp their central position in the classroom. In this way, students' thinking will be greatly affected, and even If it is solidified, the vitality of the classroom will be insufficient, and the students' enthusiasm for learning cannot be fully mobilized in a timely manner, which will affect the students' own learning efficiency. On the one hand, a smart classroom is a relatively new teaching method. Teachers of different age groups have different views and acceptance of the new teaching method. Some teachers' teaching mode has been fixed, and it is difficult to change their ideas and accept new ideas in a short period of time. [15]; on the other hand, some teachers blindly believe in their own traditional teaching mode, ignoring the characteristics of students in the new era and the changes in social needs to talents, resulting in students not being able to grasp the essence of learning in the learning process. Under the new teaching method, teachers' attitude towards smarter classroom determines the quality of classroom teaching. Although some teachers agree to adopt new teaching methods to carry out teaching activities, more teachers still

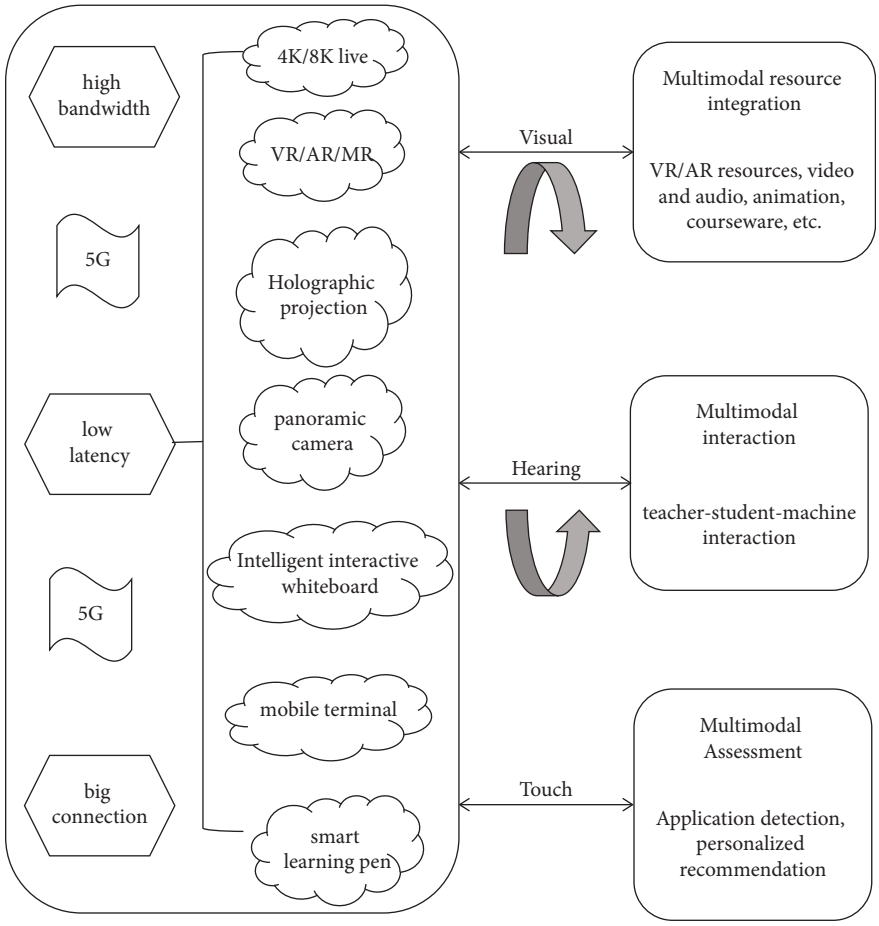

Figure 4: "5 G" multimodal smart classroom model.

adopt the traditional teaching mode, and this attitude has certain obstacles to the development of smart classrooms in schools. These teaching concepts are difficult to understand the obstacles in students' learning and their reasons, and it is difficult to provide accurate practical guidance, but repeated and inefficient practice, which is difficult to reduce the burden on students.

Colleges and universities should select teaching content and optimize teaching resources. Relying on 5 G technology, we carefully design classroom content that is conducive to students' experience, so that students can feel the interest of the content and consciously apply the content in practice. In other words, because 5 G is rich in teaching resources and can optimize teaching links and teaching methods, it can greatly enrich the teaching materials of various disciplines and majors in colleges and universities, so that text, pictures, audio, video, and other content can be properly presented in front of students. Under the background of the 5 G era, college teachers should make preparations for the teaching reform of various disciplines based on the transformation requirements of employment goals, so that students can be placed in a teaching environment that is more conducive to employment exploration. Facts have proved that through the efforts of these aspects, a teaching environment that meets expectations will be formed in time, and the environment construction will serve the teaching model innovation in the 5 G era together with the two key points of employment understanding and skill development. For the construction of a teaching resource library, higher vocational colleges should pay enough attention. Teaching resources should be designed and used according to the specific content of the course and the design of teaching links. To achieve complete matching of resources and tasks or projects, avoid formalized educational information applications.

5. Conclusion

"5 G" is the current social hotspot and a new technology that carries the hope of the country and the nation. It fundamentally impacts the current education model. The innovation of the smart classroom teaching model in the "5 G" era is undoubtedly a subversion of the traditional classroom teaching model. Smarter classroom teaching not only builds a smart learning environment and promotes the embodied experience of students' learning scenarios but also helps teachers monitor students' learning progress and conduct teaching big data analysis. It has also enhanced the technological innovation in the field of education. For this reason, the country needs to further explore the integration of information technology and the education industry, continuously catalyze the maturity of technology, reduce technology costs, and increase the number of "5 G" talent

training and talent reserves. However, in the teaching of colleges and universities, the application of informatization needs to be scientifically and reasonably planned and managed and cannot be blindly followed or used in a mere formality. It should be determined according to the current school conditions and specific learning conditions, and appropriate changes should be made in terms of teaching concepts to adapt to the current development of education. Only in this way can we effectively promote the innovation and development of the smart classroom teaching model in the "5 G" era. Students will naturally have the conditions to move towards applied talents, making education fairness a reality and achieving access to the highest quality educational resources in the shortest time possible. It is believed that in the near future, the smart classroom teaching model in the "5 G" era will also become the mainstream education model in my country's education industry, fully realizing my country's education informatization. It's important to realize the people-oriented concept and help students grow and become talents.

Data Availability

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

Conflicts of Interest

The author declares that there are no potential conflicts of interest.

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Research Article

Safety Production Supervision of Industrial Enterprises Based on Deep Learning and Artificial Intelligence

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Since the beginning of the 21st century, with the continuous growth and improvement of the comprehensive strength of our national economy and the continuous improvement of our modern industrial machinery and equipment, the level of safety technology, production level, and quality management level see continuous steady improvement, resulting in the rapid economic growth of chemical industries in China in recent years. In recent years, chemicals have been widely used and demand is increasing. However, the physical properties of some chemical substances are very unstable and vary according to process conditions, making it difficult to control. At the same time, safety issues have become a major "red warning" for industrial enterprises. Various safety incidents have attracted social attention, and the chemical industry has also learned from them, sounding the safety alarm for itself and reviewing its own shortcomings, and taking improvement measures. Therefore, it is obviously necessary to always emphasize the concept of "safety first, prevention first, and comprehensive management" to prevent enterprise safety accidents. It is necessary to regularly investigate and analyze the situation of safety accidents to summarize and continuously improve. This is the most important thing for enterprises to prevent the continuous occurrence of safety accidents in a good and effective way. Regularly analyzing, summarizing, and improving safety issues are the best way to prevent accidents. Deep learning mainly relies on letting computers or other electronic devices perform iterative learning on a large number of data samples according to the rules defined by the program. The computer after learning will have the analysis ability similar to humans, but its analysis ability is limited to the range of the sample data to be learned. Artificial intelligence technology realizes an operation system that simulates human thinking through the definition of algorithms and programs. The use of deep learning and artificial intelligence in industrial enterprise safety production supervision can realize enterprise safety production supervision, early warning, and intelligent operation. Without the security of the production chain, a business cannot develop. Based on the basic theory of safety supervision and early warning in the field of enterprise safety production and related knowledge of artificial intelligence, this paper studies the work safety in the supervision and early warning mechanism abides by the selection principle of the management system, safety production indicators and indicator system, and conducts work based on the production work data of industrial plants. Reasonable safety supervision and early warning mechanism provide technical assistance for effectively controlling safety accidents in production and management measures to improve enterprise safety.

1. Introduction

1.1. Artificial Intelligence. The current artificial intelligence technology is used in many fields such as robotics, intelligent driving, and medical diagnosis, but in fact, engineers are required to regularly perform operations such as product maintenance and code upgrades [1, 2]. China's focus on AI is how to apply AI widely in industry and contribute to China's productivity strategy. Common deep learning algorithms are shown in Table 1.

A world-renowned photovoltaic cell-based company like Trina Solar, which cited artificial intelligence in the business phase, found the most basic connection points and increased its output by 7%. In the United States, artificial intelligence is currently mainly used for intelligent driving and robot orientation [3, 4]. Tesla, for example, has trained a fully self-

driving-level navigation system. And Boston Dynamics, a robotics company, has been able to create humanoid robots that surpass human combat and off-road capabilities [5, 6]. The agency predicts that the application of artificial intelligence and deep learning technology to the safety production of industrial enterprises will become a trend in the future. The specific situation is shown in Figure 1.

1.2. Safe Production in Industrial Enterprises. Statistical data released by the state show that there have been many major accidents in industrial enterprises in recent years, which undoubtedly makes the implementation of standardization even worse, confirming that my country needs to make progress in the formulation of standards and evaluation [7, 8]. Safety production supervision and management are the most important in the construction of supervision and early warning. The safety production status of the enterprise must be qualitatively analyzed according to the system software and corresponding data, and the same is true within the enterprise. Carefully analyze the safety production supervision and early warning system of the State Administration of Work Safety, update the enterprise safety standards from point to face promptly, and establish the company's safety production goals from the actual situation. Safety learning and training represent the soft power of enterprise safety. It can reduce the occurrence of unsafe behaviors [9, 10]. Repeated, high-demand safety learning and training can also consolidate the safety production level of enterprises. Combining artificial intelligence and deep learning with the construction of a supervision and early warning system can standardize the work mode of on-site supervision and safety management personnel and workers, and bring an information-based operation mode to the safety production management of industrial enterprises.

1.3. Research Status at Home and Abroad. Since ancient times, my country has attached great importance to the monitoring and prevention of natural disasters [11]. My country's Meteorological Administration has set different supervision and early warning signals according to different times and intensities of lightning, strong winds and typhoons, laying the foundation for the classification of common lightning and strong wind warnings [12]. In the 1980s, the relevant departments of the Chinese government, relevant scientific research institutions, and universities jointly participated in the research on the safety evaluation of major hazards. This applied research has greatly changed our country's ability to manage safety in advance, and can objectively and fairly evaluate the safety status of enterprises that are accompanied by major dangers. Since then, various industries such as the metallurgical and chemical industries have formally implemented safety evaluations. The safety evaluation is the qualitative acceptance evaluation of the enterprise's production projects in advance and the status quo evaluation, which is a combination of quantitative and qualitative aspects [13, 14].

In order to reduce safety incidents, the former Ministry of Coal Industry announced that since 1986, safety

Table 1: Common deep learning algorithms.

Number	Algorithms
1	CNN
2	RNN
3	LSTM

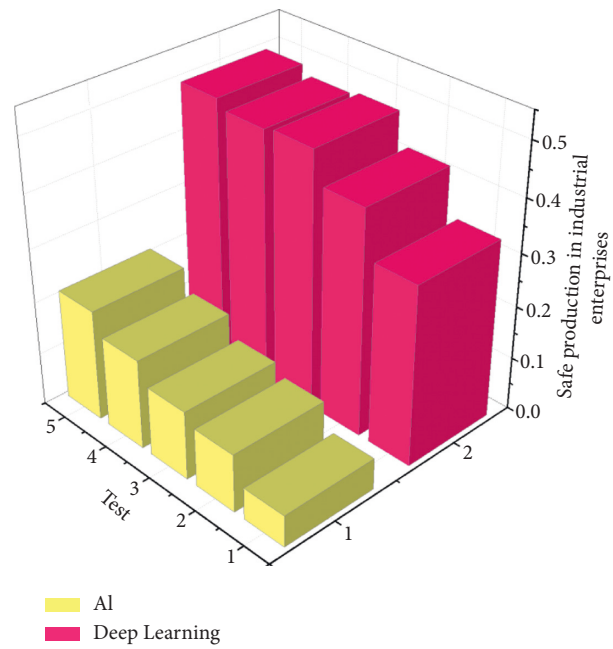

Figure 1: Artificial intelligence and deep learning applied to safety production in industrial enterprises.

standardization operations and production supervision, and early warning will be piloted in coal mines across the country, from low to high to restrain the behavior of managers. Safety supervision and early warning can respond to various emergencies, promote safe production and reduce accidents. After the 1990s, with the popularization of information and Internet technology around the world, power and chemical companies have also emerged in the work of safety standardization and production supervision, and early warning [15, 16]. The emergence of large-scale centralized decentralized control systems (DCS) can not only monitor and control production during the process, but supervision and early warning can also be issued in time, which is convenient for the management of various emergency operations in emergencies, and greatly improves the safety level of the enterprise [17].

The benefits brought by the integration of the world economy did not stop the economic crisis in the early twentieth century. The unstable world situation promoted early regulatory warnings. The research in this field made a leap forward in 1930. In the twenty-first century, Western developed countries have taken the lead in the ability to apply regulatory warning knowledge. In the past decade, European developed countries like to rely on information technology and big data analysis in terms of public security and accidents and share security data for the comprehensive monitoring technology of block security. There is spare

capacity. The current focus is on the establishment and maintenance of information platforms, and the development of software service systems, to provide more extensive technical support for subsequent manual or automatic intervention, so that the safety technology is more perfect [18].

1.4. Research Content. Safety production maximizes cost-effectiveness, and the impact of disasters can be applied to safety systems engineering. The viewpoints and methods of systems theory bring convenience to how to analyze hazard sources and the environment. For production safety, early-warning enterprises should identify, diagnose, and evaluate various accident signs, and use the analysis results as a benchmark to predict the trend of accident signs. It also needs to reflect the characteristics that are different from other supervision and early warning tasks. The focus of this paper is "Combining deep learning and artificial intelligence to establish a safety production supervision and early warning management system for industrial enterprises." Taking sewage industrial enterprises as an example, in the process of establishing an early warning mechanism for enterprise safety production supervision, the following tasks need to be completed. First, it must be based on a supervisory early warning management system for the production safety of wastewater treatment equipment. Summarize the corresponding research status at home and abroad, clarify the problems existing in the current supervision and early warning management system, and solve the relationship between key points and regions, not only focusing on key points but also avoiding one side and ignoring the other side. The second is to be familiar with the safety production system of industrial plants and conduct in-depth investigation and research on the enterprise supervision and early warning system. In addition, it is necessary to be aware of the relationship between social sensitivity and actual harm. Even if there is a certain correlation between them, a socially sensitive public emergency is not necessarily harmful, and vice versa. Although accidents occur frequently, not all accidents are high-risk accidents. While accidents occur frequently, the risks are not necessarily high. In addition, some situations are not necessarily high risk, and there is no unavoidable relationship.

2. The Basic Theory of Safety Production Supervision and Early Warning

Warnings of crises and dangerous situations before the accident are early warnings, that is, regulatory warnings of safety risks. The security risk supervision and early warning of Chinese enterprises are still in the stage of security risk assessment, and this supervision method is usually carried out in stages, except for the safety evaluation of the process (annual or three-year safety status evaluation according to the production characteristics of the enterprise, etc.), these long-term general evaluations or specific time evaluations. The final task of the evaluation is to identify and evaluate these inherent long-term risks and to implement countermeasures to reduce or eliminate them. For the purpose of this task, the boundaries of security risks and security warnings can be imagined. At this time, the investigation of hidden dangers in safety can eliminate hidden dangers in time, and carry out emergency safety training for departments at all levels, which can effectively improve the safety skills of employees. The above statements can predict whether the enterprise's regulatory warning system is comprehensive. In addition to this, a professional organization needs to conduct more than two safety evaluations, and it is also necessary to manage the production process and environment, the safe behavior of workers and leaders, and the use of the equipment and other dangerous states. Data analysis management can provide regulatory warnings to safety management within a certain period (monthly or weekly).

Table 2: PDCA implementation steps.

Step	Details
1	Warn rule planning
2	DO
3	Cheek warn rule
4	Action warn rule

2.1. Early Warning and Mechanism of Work Safety Supervision. The advance warning is to predict in advance a dangerous event with a high probability of happening in the future and to call attention to it. This supervision and early warning mechanism are both sensitive and accurate. The foundation of safety production supervision and early warning is the overall safety production management information sharing platform proposed by the government safety supervision department, but its disadvantage is that the basic data is updated slowly, requiring multiple enterprises and supervision departments. A joint investigation by multiple companies and regulators is required. In order to efficiently predict the actual status of safety management in a certain area, it is necessary to link with the internal mechanism of the enterprise and the data output by the production safety supervision and early warning system. Regulatory warning systems cannot be established overnight. At this time, from the team leader to the employees, the enterprise must clarify the regulatory and early warning requirements from the top down. Only by mastering the lifeline of enterprise production safety supervision and early warning can it be effective in actual situations. The target of supervision and early warning must be established as soon as possible, so that different situations have different requirements, reasonably consider the characteristics of supervision early warning indication and arrange the corresponding supervision warning level and degree, timely feedback on the safety production data of the enterprise, conduct index analysis of the data, and prescribe the right medicine. In the above four aspects, it is necessary to continuously optimize and adjust relevant elements in accordance with the principle of "PDCA" to achieve the effect of premonitoring, early warning, and effective control. The execution steps of PDCA are shown in Table 2.

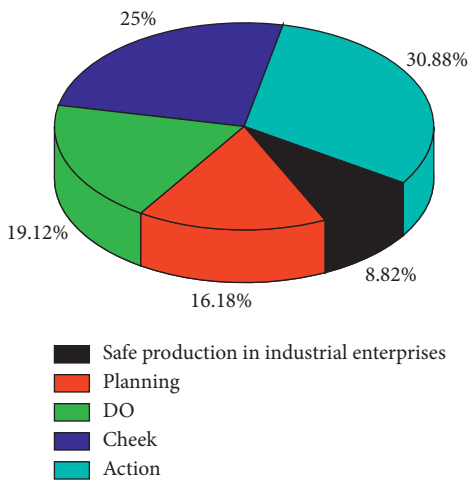

Figure 2: PDCA principles for the supervision of safe production in industrial enterprises.

The PDCA principles for the supervision of industrial production safety are shown in Figure 2.

2.2. Supervision and Early Warning Management of Safety Production. Select the person in charge to inform the relevant personnel, which can be a system user, or can send weekly reports through information exchange, corporate office platform, or corporate mailbox. According to the workshop requirements and the safety management measures of the enterprise, reasonably arrange the index interval value of the corresponding level, and pay attention to be consistent with the situation of the enterprise. For example, serious violations, frequent common accidents, and hidden dangers are not rectified in time, and safety training and emergency training are not carried out, etc. At this time, it is necessary for the safety supervision department and the production organization department to strengthen management measures to restore safety production to a normal state.

2.3. Definition of the Number of Safety Production Supervision and Early Warning Indicators. The experience summed up from the indicator system can play a huge role. It can not only reflect whether the safety production of the enterprise meets the standards but also reflect whether the safety evaluation work of the enterprise is objective. Through this friendly interface, the enterprise can respond more quickly. It is concluded from the literature survey that the cause of the accident is composed of one of the following four elements:

(1) The staff made mistakes in operation or did not work properly

(2) The working safety of the equipment is not good

(3) The environment is not suitable for the current working state

(4) Defects in the management of safety production by staff

Table 3: Four elements of accident occurrence.

Number	Factor
1	Personnel
2	Equipment
3	Surroundings
4	Manage

Its specific summary is shown in Table 3.

According to the principle of four elements of accidents, the supervision and early warning of enterprise safety production are one of the important steps for the effective operation of enterprise production. Only by selecting appropriate index elements and reasonably evaluating the forecast value of supervision and early warning, can enterprise safety production supervision and early warning be truly effective. Specifically, it should be established according to the following principles:

(1) Safe production is related to the latest construction requirements, and Jian has a positive attitude toward the establishment of a supervisory early warning system.

(2) Enterprise personnel actively participate in safety work, link with their own work, and maintain the supervision and early warning system.

(3) It is necessary to regularly check and repair the operation of the early warning system. Identify loopholes in daily management, confirm the effectiveness of regulatory warning instructions, and improve and optimize the operating status of the system. The AI algorithm formula used for safety production supervision this time is shown in

$$P(QE) = P(Q)P(Q \mid \mathrm{E}), P(UY) = P(U)P(U \mid \mathrm{Y}), \quad (1)$$

$$P(C) = P(C_1)P(\mathrm{O} \mid \mathrm{C}_1) + P(X_2)P(\mathrm{Q} \mid \mathrm{X}_2) + \cdots + P(QN)P(\mathrm{Q} \mid \mathrm{G}N), \quad (2)$$

$$P(B_i \mid \mathrm{H}) = \frac{P(B_i)P(\mathrm{B} \mid \mathrm{G}_i)}{\sum j = 1np(D_j)P(\mathrm{F} \mid \mathrm{B}_j)}. \quad (3)$$

3. Establishment of Industrial Enterprise Safety Production Supervision and Early Warning System Combining Deep Learning and Artificial Intelligence

3.1. Enterprise Safety Production Supervision and Early Warning

3.1.1. Necessity of Enterprise Safety Production Supervision and Early Warning. Taking a chemical factory as an example, the company's safety production department was established at the beginning of the company's establishment, to supervise and manage to ensure the realization of safety supervision guarantee, safety production guarantee, and safety technology guarantee. To ensure the basic

safety management work of safe production, in particular, pay attention to safety training and education, investigation of potential safety hazards, and emergency plan management. From 2013 to 2021, the company experienced no injuries or fatalities of all types, mostly fire and equipment incidents.

The safety acceptance evaluation in the operation process will analyze and evaluate the safety of the production machinery and equipment. At the same time, in some special safety management assessments of some enterprises, by assisting the safety technology production management supervision, inspection and management administrative departments to grasp the safety technology production management status and safety implementation management status of the enterprise production safety management institutions through the cleared data, it can make it more It is good to provide a basis for safety management evaluation for the cooperation between production safety management institutions of enterprises and local government safety production supervision, inspection and management administrative departments.

Safety is not absolute, it is relative, there can be no environment without any danger. Minimize accidents as much as possible, prevent possible dangers at all times, learn to identify sources of danger, and increase vigilance. We can avoid it entirely by direct human action control. The current situation of safe production is closely related to the development of our country. Therefore, from another perspective, safe production is another effective method for our country to speed up the pace of development, which makes safe production the fundamental guarantee for the sustainable development of our economy. Try to reasonably use the least resources, reduce the occurrence of accidents, to achieve a relatively safe industrial production system. Only in this way can we prevent and control dangers more effectively, so as to ensure the precision and accuracy of the operation, prevent the occurrence of safety accidents or minimize the losses and impacts after the accident occurs.

3.1.2. Analysis of Main Risk Factors. Deep learning and artificial intelligence must first be able to identify the source of danger before they can further determine the way of supervision and early warning. Hazards are places, areas, premises, equipment, and accident sites that may release energy and substances: some triggers under the system can lead to injuries and accidents. The essence of this approach is the concentration of potential hazard centers or sites, i.e., the site of accident sources, energy cores, hazardous materials, and energy transfer or release; this identified system is at risk, and the hazard area varies from system to system. So, for example, from a national perspective, some companies in hazardous industries such as oil refineries (eg, petroleum, chemical) have hazardous sources. From the perspective of different company management system types, the workshop and company warehouse systems may often generate different risks at the same time, and the workshop management system may also have certain types of risk equipment. Therefore, the system risk assessment and analysis should generally be performed at different functional levels of the system. Hazard sources are generally divided into four levels: the first and second levels refer to negligible hazards that will not cause personal injury and systemic damage; the second level is critical, which may cause personal injury and major damage. The system damage can be excluded and controlled; the third level is dangerous, which refers to a hazard source that may cause personal injury and serious systemic damage and must be controlled immediately; the fourth level is a destructive hazard source, can cause serious effects on people and systems. At present, the main risk factors for safe production in industrial enterprises are divided into the following directions:

(1) Staff. Various electrical appliances and equipment are required to be used together in the industrial processing process. In these corresponding processes, the demand for mechanization and automation is high, and there are high requirements for the safety functions of safety facilities. The staff must have a good understanding of the process and equipment. . Due to the mutual influence of each link, the active microorganisms in the industrial process will die or fail to meet the standard due to the failure of one of the links, thereby affecting the subsequent treatment process.

(2) Working Environment. Many chemical substances and special gases are used in industrial processing, among which liquid chlorine is an explosive and corrosive chemical substance, and volatile gas is toxic, flammable, and very dangerous. There is a problem with the combination of storage and transportation. It may cause various accidents such as human poisoning, casualties, and fire.

(3) Working Equipment. Projects including transformer (distribution) power stations, air compressors, suction pump units, various pipelines, chemical storage warehouses contain strict electrical safety management and require strict management.

After a follow-up survey of industrial enterprises using deep learning and artificial intelligence technology, it was found that after combining deep learning and artificial intelligence algorithms, the identification efficiency of risk sources and risk factors for safe production in industrial enterprises has been greatly improved. The specific situation is shown in Figure 3.

3.1.3. Status of Safety Supervision and Early Warning. Sewer safety production supervision and early warning, on-site fire early warning (fire management center), liquid chlorine monitoring and early warning system (gas monitoring and alarm), production equipment safety supervision and early warning, for example, using infrared for real-time surveillance and regulatory alerts. As the company's safety production supervision and early warning technical standards have not yet been issued, the supervision and early warning mechanism is limited to the supervision and early warning of local links (fire prevention, special gas), and there is no safety supervision and

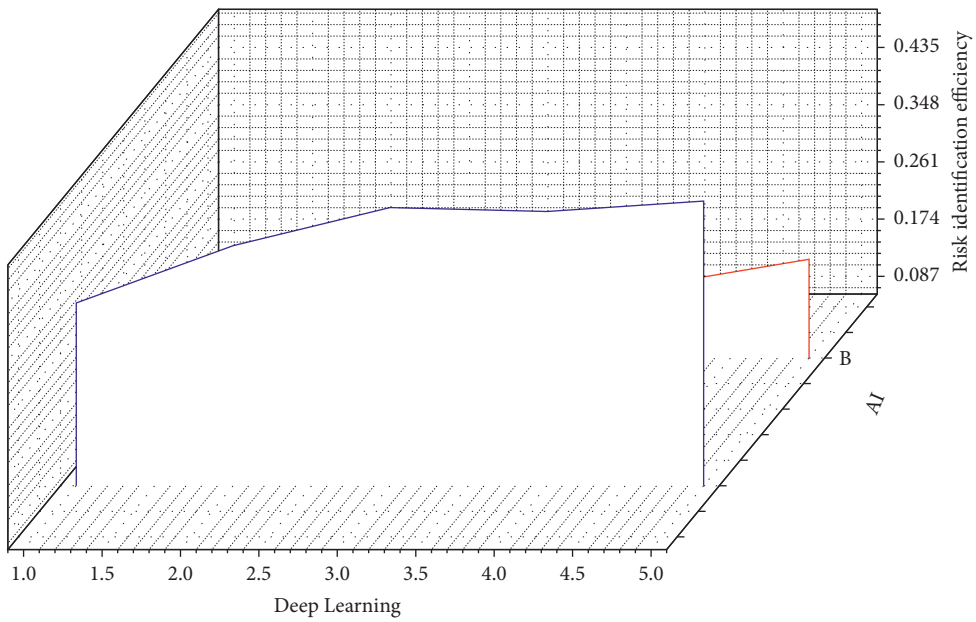

Figure 3: Efficiency of identification of risk sources and risk factors for safety production in industrial enterprises.

early warning system for staff and key equipment on the process production line.

3.2. Problems Existing in Enterprise Safety Production Supervision and Early Warning. Improving enterprise safety management is an important guarantee for safety production supervision and early warning. The relevant supervision and early warning standards promulgated by the state put forward specific requirements for this work. However, most enterprises are still in the conceptual stage of safety production supervision and early warning and do not know how to carry out supervision and early warning. The safety production supervision and early warning of enterprises should not only focus on the prevention of safety accidents such as fire prevention, gas leakage, and production equipment but also pay attention to the prevention of chemical accidents and production accidents.

3.3. Establishment of Enterprise Safety Production Supervision and Early Warning System

3.3.1. Establishing Principles. While combining artificial intelligence and deep learning to realize the intelligence of supervision, through intelligent control, it solves some processes that require a lot of manpower to repeat operations, and it also solves some complex supervision work that requires a lot of manpower, and finally establishes a stable intelligent supervision system.

The supervision and early warning system should cover the processing structures of each process section of the industrial plant, and set up safety production supervision early warning in the places where odors are easily generated, sludge is prone to poisoning, electrical equipment is prone to aging, long-term failure of equipment is not allowed, and fire and explosion are prone to occur. It establishes a complete safety production supervision and early warning system, realizes central control, and monitors the operation status of each production line in real-time. Based on the problems existing in the safety production supervision and early warning of industrial plants and enterprises, a supervision and early warning system is established to provide technical support for the safety production of industrial plants.

Table 4: Regulatory warning locations.

Number	Locations
1	Disinfection workshop
2	Structure
3	Electrical equipment
4	Public equipment

3.3.2. Regulatory Warning Locations. The specific summary of regulatory warning locations is shown in Table 4:

(1) Disinfection workshop: establish deodorization and ventilation systems for the disinfection workshop, and set up gas detection instruments and chlorine concentration monitoring tables

(2) Structures: fire extinguishers, breathing masks, and other devices are arranged next to the sampling ports, escape passages, and electrical equipment control boxes of each structure; flow velocity and pressure gauges are set up in the water pipelines of each structure to monitor the on-site operation in real-time

(3) Electrical equipment: configure special water-based fire extinguishers for various electrical equipment of structures, and regularly check the safety functions of safety facilities

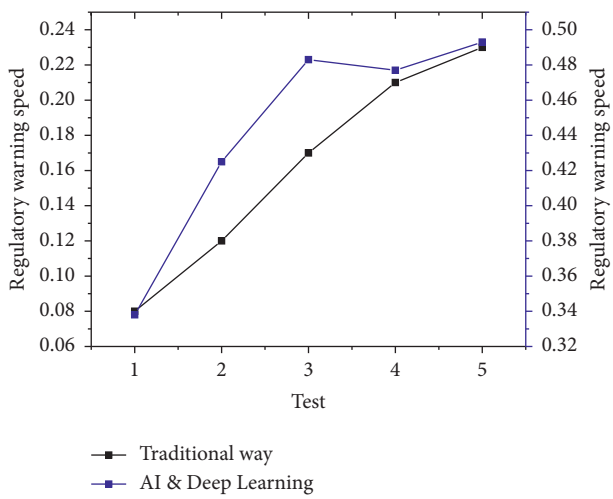

Figure 4: The response speed of the location prompt of the supervision and early warning of the safety production of industrial enterprises.

(4) Public equipment: strictly implement electrical safety management for public equipment, and regularly test its safety

After a follow-up survey of industrial enterprises using deep learning and artificial intelligence technology, it was found that after combining deep learning and artificial intelligence algorithms, the response speed of industrial enterprises' safety production supervision and warning location prompts has been greatly improved. The specific situation is shown in Figure 4.

4. Safety Production Evaluation Method of Industrial Enterprises Combined with Artificial Intelligence

4.1. Safety Evaluation. With the rapid development of society and economy, the production scale of each chemical plant has also increased, and the emergence of various new processes, new equipment, and new chemical products has also made the production process of chemical plants increasingly complex. In such a complex process, safety issues have gradually become difficult to control.

4.1.1. Significance of Safety Evaluation. Since production begins to develop towards large-scale production, once an accident and safety problem occurs in an enterprise, it will affect the development of the enterprise if it is small, and it will have an impact on the current economic situation of our country. Its main meanings are as follows:

(1) To achieve better management. Carry out correlation analysis and evaluation of engineering projects or accidents through the scientific evaluation and analysis methods, and then use mathematical models to calculate the probability of occurrence. Starting from the discovery of safety technology and management operations in the entire production process, identify hazardous and harmful factors to ensure the management of enterprises.

(2) Principle of logical analogy. Analogy is a definition of logical thinking, and analogical thinking is a logical way of thinking often used by people now. Many new knowledge and technology are also reasoned out through this logical way of thinking. It has a kind of contingency, and one phenomenon infers another phenomenon. The analogy can also be divided into certainty and quantitative.

(3) Following the principle of inertia, the large influence of inertia may become larger during the evaluation, and the smaller the inertia, the smaller the influence may be.

(4) Realize the relatively safest system environment and standardization and science to ensure safety. Under the premise of safety norms, ensure safety norms and science. Form regular safety education, safety supervision, and safety operation.

4.1.2. Principles of Safety Evaluation. By studying and analyzing the interdependence relationship and the degree of mutual influence between systems, we can better explore the changing characteristics and trends of the system. There are many factors in the accident. In the safety evaluation, find out the relationship between them and learn from the existing evaluation, then the evaluation will achieve better results. Many new knowledge and methods are also reasoned out in this logical way of thinking.

4.2. Division of Evaluation Units

4.2.1. The Concept of Evaluation Unit. Deep learning technology relies on the learning of multiple safety evaluation methods to realize enterprise safety production supervision. A complete system is composed of multiple different individual projects. In terms of safety evaluation, there are overall evaluation and module evaluation. On the basis of safety analysis In order to better achieve the goals of safety assessment and the requirements of evaluation methods, a complete production process is divided into several different projects in a way that is conducive to safety analysis and evaluation standards and meets scientific standards. These individual projects complement the whole system, but exist independently of each other. These divided items are then called evaluation units.

4.2.2. The Purpose of Dividing the Evaluation Unit. Deep learning needs to start from smaller objects to learn its samples, and when the safety production-related regulatory factors are divided enough, it will help the accuracy of deep learning. When the entire system is used as the main evaluation object, it is generally According to a special principle, the evaluated object is divided and combined into several evaluated units, and then these units are integrated into the main evaluation of the whole system. The main

Table 5: Units for deep learning requirements.

Number	Unit
1	Certificate unit
2	Equipment unit
3	Material storage unit
4	Personnel management unit

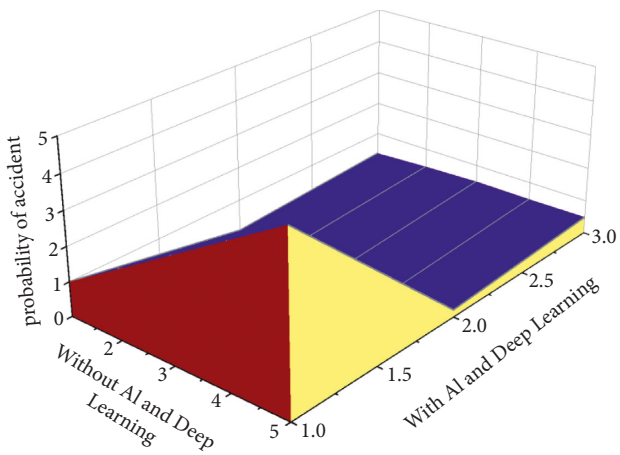

Figure 5: Changes in the probability of occurrence of safety accidents in industrial enterprises.

purpose of dividing the evaluation unit is to carry out the evaluation work more conveniently and improve the accuracy and comprehensiveness of its evaluation. Reasonable division of various evaluation systems to form different types of evaluation units can not only simplify various evaluation work, reduce their workload, and avoid their omissions, but also obtain the concept of comparing (injury) risks between various evaluation system units, so as to avoid risks and the most dangerous factors to express the risk of the whole system in time, exaggerate the risk of the whole system, improve the accuracy and accuracy of its assessment, and reduce the countermeasures of safety investment. According to the standard, each unit is required to conduct a safety evaluation. In the whole system, the evaluation units of the whole system are subdivided into different kinds of systems and evaluation units. The main purpose is to reduce the workload of the evaluation as much as possible while ensuring the accuracy and precision of the safety evaluation, so as to achieve efficient evaluation operations. The accuracy of the evaluation is improved, the security investment is reasonably estimated, and the effectiveness and pertinence of the countermeasures are enhanced. The specific situation of the units divided for deep learning requirements is shown in Table 5.

(1) Certificate Unit. Every qualified industrial manufacturer needs to have a series of certificates in line with laws and regulations before it can be put into production. These licenses and qualifications, certificates, and various other procedures are required by the state to have and pass the audit before they can operate legally.

(2) Equipment Unit. In chemical plants, the storage of various materials and the processing reactions between materials require a lot of chemical equipment to support, There are prescribed methods and prescribed inspection dates for daily use and maintenance, and the locations of equipment with different materials also have different impact and many other issues.

(3) Material Storage Unit. For example, in addition to urea, synthetic ammonia, methanol, the main products of a chemical plant have many related by-products. These many materials with different chemical properties can be regarded as a system during the storage process. This unit is also the easiest Safety accidents such as explosion, poisoning, and corrosion occur.

(4) Personnel Management Unit. In the process of safe and good production, the standardized operation and prudent work attitude of personnel play a decisive role. The responsibility of management personnel and the good cooperation of operators are all necessary to form a relatively safer production environment. After a follow-up survey of industrial enterprises using deep learning and artificial intelligence technology, it was found that the combination of deep learning and artificial intelligence algorithms greatly reduced the probability of safety accidents in industrial enterprises. The specific situation is shown in Figure 5.

5. Conclusion

A leaf also has two sides. Industrial products not only bring a lot of convenience to some of our daily work, but also bring a lot of troubles to some of our daily work due to the many risks and huge hazards in the production and operation of industrial products. . Therefore, in order to promote my country's industrial products to better serve the protection of human health, a systematic technical statistical data analysis should be carried out on the causes of production safety accidents in my country's industrial enterprises, and the laws of technological development and changes in its own existence should be summarized. Finally, the research proposes a more targeted technical improvement and effective preventive measures to gradually improve the safety technology production management level of my country's chemical enterprises.

The fundamental purpose and purpose of safety management risk assessment is to comprehensively evaluate unpredictable safety risk factors through statistical analysis and comprehensive evaluation, and what harmful safety risk factors may exist in risk management projects and financial management systems, which may exist indirectly What safety risks, hazards and adverse consequences, and put forward reasonable and feasible safety risk assessment management countermeasures, guide them to correctly monitor the risk safety of the sources of these risk safety factors, prevent the occurrence of risks and reduce the accident rate, so as to truly achieve safety The fundamental purpose of risk evaluation is to directly reduce the risk

accident rate to the greatest extent, to minimize the indirect reduction of personal economic losses, and to directly affect the legitimate interests of venture investors in the safest way.

The traditional enterprise's safety management-oriented management method often leads to the unsafe accidents centralized management, safety management, and accident control. In other aspects, the daily management of the enterprise is due to the uncertainty of the company's potential safety hazards, which is often caused by the accident. Only then can supervision and early warning be carried out, which belongs to the passive safety management mode.

Based on the theoretical research on supervision and early warning, this paper summarizes the main risk factors that may occur in enterprises. Then, combined with artificial intelligence and deep learning technology, taking the safety production supervision and early warning management system of an industrial plant as an example, it deeply analyzes the production line of the industrial plant. The main hazard sources and the current status of safety supervision and early warning are analyzed and discussed, and precautions are put forward to ensure the smooth operation of the industrial plant. Only by doing a good job in the production supervision and early warning of disinfection workshops, structures, electrical equipment, and public equipment can we ensure the smooth operation of industrial plants. The supervision and early warning involving the establishment of multiple systems in the field of safe production is an innovative measure of the safety management model and relies on a large amount of data to analyze the basic management status quo through numerical analysis, and quantitatively evaluate the safety situation in the next stage. Safety management at the core of work lays the foundation for companies to more strictly control work safety.

Data Availability

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

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Evaluation Method of Performance of Cross-Border e-Commerce System Based on Fuzzy DEA Model

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Cross-border e-commerce trade is an important form of trade that is different from traditional international trade. Nowadays, cross-border e-commerce is more and more widely used in foreign trade activities. Cross-border e-commerce system has its own development constraints, such as the imperfection of cross-border e-commerce platforms, the security loopholes of cross-border payment, the slow development of supporting logistics, and the lag of policies, which will affect its development to varying degrees, thus affecting the performance of e-commerce enterprises in using cross-border e-commerce for foreign trade activities. Therefore, it is necessary to explore the factors of cross-border e-commerce system performance and compare the strength of various factors, which has certain theoretical and practical significance. Therefore, based on the analysis of performance data, this paper will establish a performance evaluation model for an e-commerce system, aiming at providing standards and a basis for performance evaluation of system performance. In order to continuously improve the accuracy of cross-border e-commerce performance evaluation and to achieve the accuracy of cross-border e-commerce evaluation and decision-making, a cross-border e-commerce system performance evaluation model based on the fuzzy DEA model is innovatively proposed. By combining the average analysis results of descriptive statistical data, the regression test is conducted on the performance evaluation samples of cross-border e-commerce systems. The fuzzy feature clustering method is used to classify and identify the performance of big data in the cross-border e-commerce system. According to the fusion results of cross-border e-commerce performance information, the principal component analysis and adaptive game decision are carried out, and the game decision model is established. Combined with the fuzzy DEA evaluation method, the performance of the cross-border e-commerce system can be quantified and evaluated. The F statistical analysis method is used to test the effectiveness of the performance evaluation of the cross-border e-commerce system. From the test results, it can be seen that the performance evaluation accuracy of the cross-border e-commerce system using this model is relatively high, and the confidence level is also relatively good. Finally, according to the conclusion of the study, the author puts forward the counter-measures for future research.

1. Foreword

With the rapid development of the e-commerce industry, the cross-border trade activities of e-commerce are increasingly prosperous, and the turnover of cross-border e-commerce has become amazing, showing a gradually increasing trend of development. The reliability evaluation of cross-border e-commerce system performance is the main factor affecting the stability of cross-border e-commerce ecosystem, and it is also an important reflection of the stability of cross-border e-commerce ecosystem. Based on DEA theory, this paper analyzes the evolution behavior of cooperation among elements of cross-border e-commerce ecosystem and provides new ideas and perspectives for the research on the stability of cross-border e-commerce ecosystem. At the same time, by combining the fusion and analysis of big data information, the specific performance evaluation of the cross-border e-commerce system is carried out, and the performance analysis and related rules of cross-border e-commerce are established. Through online financial supermarkets, third-

party information platforms, online financial management, and other platforms, the performance prediction evaluation of cross-border e-commerce can continuously improve the accuracy of performance evaluation of cross-border e-commerce systems and can also study the performance evaluation methods of the cross-border e-commerce systems, which is of great significance in optimizing the financial allocation system of cross-border e-commerce and improving the profits of cross-border e-commerce. [1].

The essential characteristic of the performance of a cross-border e-commerce system is a group of economic series. By adopting the methods of economic series and big data information processing and analysis, the quantitative analysis of the system performance of cross-border e-commerce can be realized, thus realizing the evaluation and evaluation of the accuracy of the system performance of cross-border e-commerce. Among the traditional methods, the performance evaluation methods of cross-border e-commerce systems mainly include the load-based balanced forecasting method, random vector analysis evaluation algorithm of e-commerce system performance, wavelet analysis-based evaluation algorithm of cross-border e-commerce system performance, time-frequency analysis-based evaluation algorithm of cross-border e-commerce system performance, and so on [2, 3].The performance evaluation model of a cross-border e-commerce system is constructed by extracting quantitative recursive entropy features, and the performance data of the cross-border e-commerce system are quantitatively analyzed recursively by using the nonlinear economic series analysis method. The accuracy of performance evaluation of cross-border e-commerce systems by this method is not particularly high. The fuzzy PID-based performance evaluation method of cross-border e-commerce systems usually uses association rules to extract features so as to realize the performance evaluation of cross-border e-commerce systems. However, there is a certain delay in processing the performance data of cross-border e-commerce systems, which may lead to low evaluation accuracy. In Reference [4], in view of the above-mentioned problems, this paper proposes a performance evaluation model for cross-border e-commerce systems based on a fuzzy DEA model. At the same time, combined with the results of descriptive statistical average analysis, we can carry out regression test on the performance evaluation samples of the cross-border e-commerce system, classify and identify the performance of big data of the cross-border e-commerce system by adopting the fuzzy feature clustering method, conduct principal component analysis and adaptive game decision-making according to the results of performance information fusion of the cross-border e-commerce, establish a game decision-making model, combine the fuzzy DEA evaluation method to realize quantitative evaluation on the performance of cross-border e-commerce system, and adopt the F statistic analysis method to test the effectiveness of performance evaluation of cross-border e-commerce system. Finally, we show the superior performance of this method in improving the accuracy of performance evaluation of cross-border e-commerce systems through empirical analysis.

2. Model Construction and Statistical Average Analysis Method of Statistical Series of Cross-Border e-Commerce System Performance

2.1. Construction of a Model Related to the Statistical Sequence of the Performance of Cross-Border e-Commerce System. The performance data of a cross-border e-commerce system is a set of nonlinear economic series, which can be analyzed and evaluated by the modern statistical series processing method. When modeling the performance data of a cross-border e-commerce system, the statistical series model is adopted to construct the method [5]. This paper analyzes the characteristics of the performance of cross-border e-commerce systems and sets a model for sampling a combination of performance data of m omnidirectionally monitored cross-border e-commerce systems. Given the performance data of a monitored cross-border e-commerce system, it can be expressed as

$$U = \{U_1, U_2, \cdots, U_N\}. \tag{1}$$

Among them, $U_i$is the specific evaluation component of cross-border e-commerce system performance, which is expressed as a D-dimensional random function; each data set U_i is normally correlated, assuming that U conforms to the K distribution function. In this case, the state transition equation of the performance model of the cross-border e-commerce system is expressed as

$$\begin{aligned} x(n) &= s(n) + v(n) \\ &= \omega_{k-1}^{(i)} \frac{p\left(y_k \mid X_k^{(i)}, Y_{k-1}\right) p\left(x_k^{(i)} \mid X_{k-1}^{(i)}, Y_{k-1}\right)}{q\left(x_k^{(i)} \mid\right)}. \end{aligned} \tag{2}$$

$s(n)$ represents the vector combination of cross-border e-commerce system performance data. $v(n)$ represents the interference component.

For the performance data series of cross-border e-commerce systems, feature reorganization is carried out, and any point $\mathbf{X}_n$, the nearest neighbor of the recombination space of the performance data series of the cross-border e-commerce system is expressed as:$\mathbf{X}_{\eta(n)}$, $R_{mn}$is defined as the distance between$\mathbf{X}_n$and $\mathbf{X}_{\eta(n)}$,with i as the abscissa and j as the ordinate, the vector distance representing the nonlinear state parameters of cross-border e-commerce system performance data by euclidean distance is as follows:

$$R_{mn} = \left\| \mathbf{X}_{\eta(n)} - \mathbf{X}_n \right\|_2^{(m)}. \tag{3}$$

We use the algorithm of average mutual information to calculate the embedding dimension of the performance reconstruction space of a cross-border e-commerce system. As m increases to $m+1$, the sliding average window of optimized cross-border e-commerce system performance data is as follows:

$$R_{(m+1)n} = \left\| \mathbf{X}_{\eta(n)} - \mathbf{X}_n \right\|_2^{(m+1)}. \tag{4}$$

The geometric invariants of the cross-border e-commerce system performance economic sequence are calculated, and the obtained equations$s_i = (x_i, x_{i+\tau}, \cdots, x_{i+(m-1)\tau})^T$is called the embedded space state vector of the local cross-border e-commerce system performance nonlinear economic sequence. We set the predictor to calculate$\mathbf{J}_{\mathbf{x}_i}^{(1)}$, and calculate the probability confidence interval of the performance economic series of cross-border e-commerce system as follows: $\left\{\delta \mathbf{x}_{i+1}(j_k) = \mathbf{x}_{jk+1} - \mathbf{x}_{i+1} \mid k \in 1, \cdots, N_b\right\}$, in the m-dimensional cross-border e-commerce system performance data series, the m-dimensional vector formed by combining the above statistical series features is

$$\% \ \mathbf{X}(n) = \{x(n), x(n+\tau), \cdots, x(n+(m-1)\tau)\}. n = 1, 2, \cdots, N. \tag{5}$$

When $R_{(m+1)n}$is larger than R_{mn}, it is considered as the projection of statistical information feature points of cross-border e-commerce system performance, and thus a statistical sequence model of cross-border e-commerce system performance is constructed [6].

2.2. Statistical Analysis of Performance Evaluation. We analyze the characteristics of modeling data for performance evaluation of cross-border e-commerce systems and perform statistical modeling by adopting the nonlinear statistical feature sequence analysis method. First of all, we collect the original performance data of the cross-border e-commerce system, adopt the principal component characteristic analysis model method of the performance evaluation of the cross-border e-commerce system [7], and get the regression test model of the performance evaluation modeling of the cross-border e-commerce system, which can be expressed as

$$\begin{aligned} \min_{0 \le \alpha_i \le c} W = \frac{1}{2} \sum_{i,j=1}^{l} y_i y_j \alpha_i \alpha_j K\left(x_i, x_j\right) \\ - \sum_{i=1}^{l} \alpha_i + b\left(\sum_{i=1}^{l} y_j \alpha\right). \end{aligned} \tag{6}$$

Combined with the auto-regressive moving average (ARMA) model, the performance evaluation of cross-border e-commerce is analyzed by big data [8], and the performance evaluation modeling distribution of cross-border e-commerce systems is obtained as follows:

$$x_n = \varphi_0 + \sum_{i=1}^{p} \varphi_i x_{n-i} + \sum_{j=0}^{q} \theta_j \eta_{n-j}. \tag{7}$$

$\{\eta_i\}$is the mean value of 0, the explanatory control variables with variance areσ^2, and $\varphi_0, \varphi_1, \varphi_2, \cdots \varphi_p$is the performance correlation distribution data of the cross-border e-commerce system. $\theta_1, \theta_2, \cdots \theta_q$is called the average coefficient of descriptive statistics of cross-border e-commerce management. At the same time, combined with the detection statistical analysis method, the characteristic matching is carried out, and an analytic hierarchy process is adopted to construct the statistics of quantitative performance evaluation. We can establish a model of principal component analysis, adaptive game decision, and the quantification and evaluation of the performance of cross-border e-commerce systems [9]. At the same time, we can use the F statistic analysis method to test the effectiveness of the performance evaluation of cross-border e-commerce systems, and we can get the fuzzy comprehensive decision-making function of the performance evaluation of the cross-border e-commerce systems with the following equation:

$$\mu_{B_i} = a_{B_i} + b_{B_i} \Delta + c_{B_i} \Phi. \tag{8}$$

$a_{B_i} = B_i / B_U + B_v$, $b_{B_i} = (B_U - B_i)(B_i - B_v) / (B_U + B_v) B_i$, and $c_{B_i} = B_U B_v / (B_U + B_v) B_i$. According to the above analysis method, combined with the results of descriptive statistical average analysis to test the sample regression of the performance evaluation of cross-border e-commerce system, we adopted the fuzzy feature clustering method to classify and identify the performance big data of the cross-border e-commerce system.

3. Model Optimization of Performance Evaluation of Cross-Border e-Commerce System

3.1. Fuzzy DEA Model and Performance Information Fusion. When using the results of descriptive statistical average analysis to test the regression of the performance evaluation samples of cross-border e-commerce system, we use fuzzy feature clustering method to classify and identify the performance of big data of cross-border e-commerce system, so as to optimize the design of the performance evaluation model of cross-border e-commerce system. In this paper, a performance evaluation model of the cross-border e-commerce system based on a fuzzy DEA model is proposed. The recursive graph of cross-border e-commerce system performance is constructed as $\mathbf{R}(i, j)$, and its calculation formula is

$$\mathbf{R}(i, j) = H\left(\varepsilon_i - d_{ij}\right). i, j = 1, 2, ..., N. \tag{9}$$

$H(.)$stands for Heavside function and $\epsilon$is the neighborhood radius. Through quantitative recursive analysis of performance series of the cross-border e-commerce system, another neighborhood matrix of nonlinear economic series reorganization is obtained:

$$\mathbf{B}_{x_i}^{(1)} = \left(\delta \mathbf{x}_{i+1}(j_1), \delta \mathbf{x}_{i+1}(j_2), \cdots, \delta \mathbf{x}_{i+1}\left(j_{N_b}\right)\right)^T. \tag{10}$$

Because ε is small enough, the fuzzy DEA evaluation function of performance data of the cross-border e-commerce system satisfies

$$\mathbf{B}_{\mathbf{x}_i}^{(1)} = \mathbf{B}_{\mathbf{x}_i}\left(\mathbf{J}_{\mathbf{x}_i}^{(1)}\right)^T \tag{11}$$

The functional of fuzzy DEA evaluation with $\mathbf{B}_{\mathbf{x}_i}^{\dagger}$ as $\mathbf{B}_{\mathbf{x}_i}$, between the statistical feature vectors$\mathbf{x}_i$and $\mathbf{x}_j$, the distance of cross-border e-commerce system performance evaluation is$\delta_{ij} = \|\mathbf{x}_i - \mathbf{x}_j\|$. When $\|\mathbf{x}_i - \mathbf{x}_j\| < \varepsilon$, we can get

$$\left(\mathbf{J}_{\mathbf{x}_i}^{(1)}\right)^T = \mathbf{B}_{\mathbf{x}_i}^{\dagger}\mathbf{B}_{\mathbf{x}_i}^{(1)}. \tag{12}$$

Form a super-neighborhood matrix of cross-border e-commerce system performance evaluation in the following reorganized state space:

$$\mathbf{B}_{x_i} = \left(\delta\mathbf{x}_i(j_1), \delta\mathbf{x}_i(j_2), \cdots, \delta\mathbf{x}_i\left(j_{N_b}\right)\right)^T. \tag{13}$$

When convergence criterion is satisfied, the characteristic quantity$\mathbf{X}_{\eta(n)}$of fuzzy paste DEA model state evaluation is the quantitative recursion point of $\mathbf{X}_n$:

$$\frac{\left|x_{\eta(n)+m\tau} - x_{n+m\tau}\right|}{\left\|\mathbf{X}_{\eta(n)} - \mathbf{X}_n\right\|_2^{(m+1)}} \geq R_{\text{tol.}} \tag{14}$$

$R_{tol} = 15$. According to the fusion results of the performance information of cross-border e-commerce, principal component analysis and adaptive game decision-making are carried out so as to evaluate and test the performance of cross-border e-commerce system.

3.2. Specific Performance Evaluation and Inspection of Cross-Border e-Commerce System. We calculate the performance economic sequence of the cross-border e-commerce system to obtain the set of three state parametersα, u, and $\sum$, for the performance evaluation of the cross-border e-commerce system, namely,

$$\begin{aligned} \alpha &= [\alpha_1, \alpha_2, \cdots, \alpha_k]. \\ u &= [u_1, u_2, \cdots, u_k], \\ \sum &= \left[\sum_1 \sum_1 \cdots \sum_k\right]. \end{aligned} \tag{15}$$

$Z = (U, V)$is assumed to be a collection of performance data u and statistical data vV of the cross-border e-commerce system. Combined with the fuzzy DEA evaluation method, the performance of cross-border e-commerce system is quantitatively evaluated, and the quantitative recursive entropy ratio of cross-border e-commerce system performance is calculated

$$R_m(r, i) = \frac{N(i)}{N - (m-1)\tau}. \tag{16}$$

The embedding dimension of the performance series of cross-border e-commerce systems in vector space is obtained, and the information entropy of the performance evaluation of cross-border e-commerce systems is calculated. The formula is

$$ApEn = \lim_{N \longrightarrow \infty}\left[AV_m(r) - AV_{m+1}(r)\right]. \tag{17}$$

According to the neighboring points of the initial state feature B_0 of the performance economic series of the cross-border e-commerce system, the average value of the performance quantitative evaluation of the cross-border e-commerce system is obtained by using the following formula:

$$AV_m(r) = \frac{1}{N - (m-1)\tau}\sum_{i=1}^{N-(m-1)\tau} \ln R_m(r, i). \tag{18}$$

$ENTR = -\sum_{l=l_{\min}}^{N-1} P(l) \cdot \ln P(l)$. For our single-component cross-border e-commerce system performance economic sampling sequence$\mathbf{x}_i$, we can use the F statistics analysis method to test the effectiveness of the performance evaluation of cross-border e-commerce system [10]. For the clustering between the feature points, for the cross-border e-commerce system performance economic series, the length of its vector feature trajectory is N, and a group of nonlinear statistical series is constructed. Combined with the above formula,

$$\begin{aligned} G\left(U\middle|\mu_k, \sum_k\right) &= (2\pi)^{-d/2}\left|\sum_k\right|^{-1/2} \\ &\times\exp\left[-\frac{1}{2}(U - u_k)^T\sum_k^{-1}(U - u_k)\right]. \end{aligned} \tag{19}$$

$G(U \mid \mu_k, \sum_k)$ is the control parameter value of cross-border e-commerce system performance evaluation; $p(U \mid \Theta)$is the information weighting of cross-border e-commerce system performance evaluation. According to the above analysis, we can establish a game decision-making model of performance evaluation and combine fuzzy DEA evaluation method to realize the performance evaluation of the cross-border e-commerce system.

4. Empirical Analysis and Testing

In order to verify the concrete application of this method in the performance evaluation of cross-border e-commerce systems, we can make an empirical analysis. The software used for data analysis is SPSS19.0. The sampling method of modeling data for performance evaluation of the cross-border e-commerce system mainly adopts the descriptive statistical analysis method, with performance value as the interpreted variable and earnings change and asset-liability ratio as the specific control variables. The detailed results of descriptive statistics for performance evaluation of the cross-border e-commerce system are shown in Table 1.

According to the above-mentioned descriptive statistical analysis results, the performance of cross-border e-commerce is predicted, and the prediction results are shown in Figure 1.

Analysis of Figure 1 shows that the accuracy and stability of cross-border e-commerce performance prediction using this method are higher. The F-test analysis method is used to evaluate the effectiveness of performance evaluation, and the comparison results are shown in Figure 2.

Analysis of Figure 2 shows that the accuracy of performance evaluation of the cross-border e-commerce system by using this model is high, and the confidence level is good.

Table 1: Descriptive statistical results of cross-border e-commerce system performance evaluation.

Variable	Code	Weight of contribution			Inspection value			Statistical value of judgment		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Surplus degree	IKS	2.543	5.891	3.676	5.434	9.454	7.545	4.135	6.655	5.544
Growth	FR	0.643	2.765	1.566	2.545	5.341	3.356	2.544	4.643	3.455
Company size	TP	2.423	5.744	3.454	4.456	8.565	6.655	5.436	6.213	5.565
Profitability	SOL	3.343	4.545	3.466	6.654	10.544	8.564	8.165	9.343	8.256
Asset-liability ratio	Size	2.454	3.656	2.654	5.565	9.564	7.554	5.565	6.245	5.265
Profit	ND	1.546	4.567	3.754	2.144	4.234	6.432	6.656	7.564	6.566

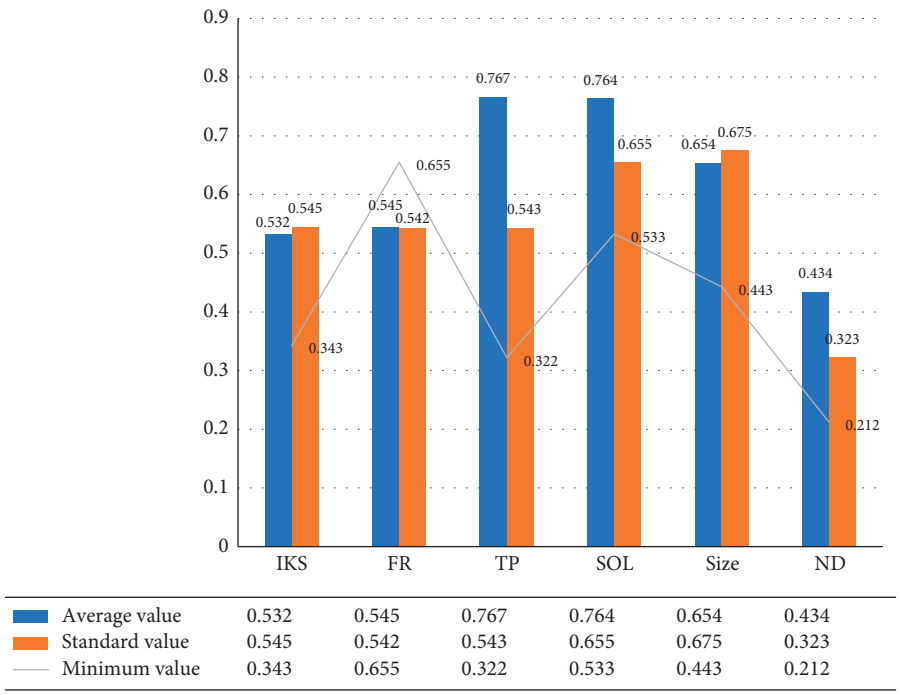

Figure 1: Performance prediction results of the cross-border e-commerce system.

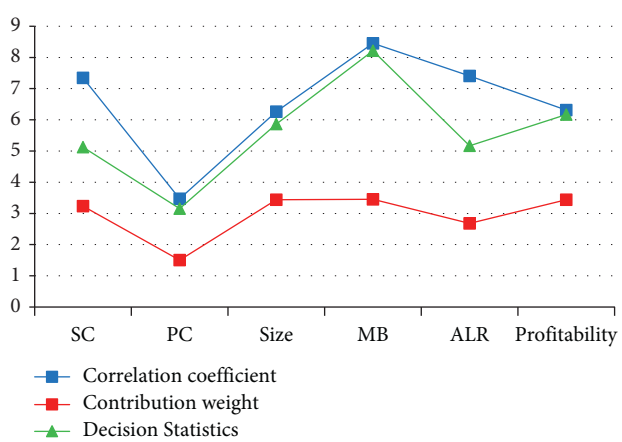

Figure 2: Effectiveness test of performance evaluation.

5. Tag

In today's business model of cross-border e-commerce, the reliability evaluation of the performance of cross-border e-commerce systems is a key measure for e-commerce enterprises to make decision-making arrangements. The performance evaluation model of the cross-border e-commerce system based on a fuzzy DEA model is proposed in this paper. Combining with the results of descriptive statistical average analysis, we test the sample regression of performance evaluation of the cross-border e-commerce system, classify and identify the performance of the cross-border e-commerce system by using the fuzzy clustering method, and conduct principal component analysis and adaptive game decision according to the specific fusion results of performance information of cross-border e-commerce, so that we can establish a game decision model. At the same time, the quantitative evaluation of the performance of the cross-border e-commerce system is achieved by combining the fuzzy DEA evaluation method, and the effectiveness of the performance evaluation of cross-border e-commerce systems is tested by using the F statistical analysis method. Through the research, we can know that the method in this paper has higher accuracy, better stability, and higher confidence level.

In the environment of e-commerce, the indicators of the implementation of the cross-border e-commerce system are established and evaluated. The establishment of an objective,

systematic, and comprehensive evaluation index system is helpful for enterprises to find out their own shortcomings and the gap with other enterprises and make improvements to better implement the performance evaluation accuracy. At the same time, it can increase the competitiveness of enterprises and improve customer satisfaction. More importantly, under the call of low-carbon economy, the performance evaluation still has great potential for development. It is conducive to the reuse of resources, the reduction of waste of resources, and the sustainable development of society. In the future, the further research direction will be to find out the common concerns between enterprises and customers and the establishment of information systems while establishing indicators, so as to better serve customers and adhere to the low-carbon economic development route.

Data Availability

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

Conflicts of Interest

The authors have no conflicts of interest to declare.

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Research Article

Implementation of Remote-Sensing Data Processing Platform Based on Computable Storage

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Previous researches on accelerating remote sensing data processing are based on traditional von Neumann architecture, which separates storage and computation. Under the architecture, data must be obtained from the storage device first and then transmitted to Field Programmable Gate Array (FPGA) through the system bus. The power consumption caused by the data handling is huge, even exceeding the energy consumption required for data processing. In order to reduce the migration of remote sensing data and alleviate the problems of storage wall and power wall under von Neumann architecture, we design a remote sensing data processing platform based on the system architecture of computable storage, which uses Solid-State Disk (SSD) with computing capability to process the remote sensing data and realize accelerated remote sensing data processing. Based on this platform, applications related to remote sensing data processing such as compression, target detection, and image classification are deployed in SSD to improve the information acquisition rate in remote sensing data. Experimental results show that after compression being offloaded to SSD computing performance is improved by 2.27 times compared with the host CPU. Compared with the host GPU, the target detection speed is improved by 6.25% and the power consumption is reduced by 66.7%. Compared with the host, the detection speed of remote sensing image classification is improved by 78.8%, the power consumption is reduced by 70%, achieving the expected classification effect. The Remote Sensing data Processing Platform based on Computable Storage (CSRSPP) distributes various computing tasks to the SSD for execution, which not only improves the processing speed of computing tasks, but also greatly reduces the power consumption of the platform.

1. Introduction

With the continuous development of remote sensing platforms and the enrichment of remote sensing means, the capacity of remote sensing data is increasing geometrically, reaching TB or even PB level, and the types and formats of data also tend to be diversified. Unstructured and massive data bring a series of problems to storage, management, and application [1]. Under the wave of explosive growth of remote sensing data, how to extract the information in remote sensing data quickly and effectively, reduce the redundancy of information, so as to improve the utilization of information is an urgent problem to be solved. Through various data processing methods such as remote sensing data compression, remote sensing image classification, and remote sensing target detection, the deficiency of insufficient information in a single remote sensing image can be effectively compensated and the quality of remote sensing application products can be improved [2]. Meanwhile, storage devices supporting remote sensing data processing are evolving into high-density, high-bandwidth, and low-delay devices, providing high-quality data guarantee for subsequent tasks such as image classification, target recognition, and change detection. Compared with the traditional disks, SSDDs provide higher read/write performance and storage density, with smaller volume, less static power consumption, and better resistance to physical impact. As a mainstream device for information storage, SSDs are widely

used in disaster monitoring, urban planning, and resource investigation, etc [3, 4].

With the development of storage and data processing technology, computer architecture is constantly updated and evolving under the von Neumann architecture. In this architecture, computing, storage, control, and I/O devices are the building blocks of a computer. Computing and storage are separated, developed independently, and optimized separately. Over the past 20 years, the performance of processors used to perform computing functions has maintained the development rate of Moore's Law by relying on process and multi-core technologies, while the improvement rate of memory performance has only maintained at about 7% per year [5], making the traditional von Neumann architecture face great challenges. On the one hand, the imbalance of performance improvement speed between the current memory and the processor leads to the limited memory bandwidth that cannot guarantee the high-speed data transmission. And the processor is always in the state of waiting for data, which further amplifies the storage wall problem. On the other hand, in high-concurrency computing scenarios such as big data and artificial intelligence, data need to be frequently transported from underlying devices to memory, resulting in serious transmission power consumption [6]. The power consumption generated by data migration is even much greater than that of data processing. Boroumand et al. [7] ran the load of Google applications on user devices and found that an average of 62.7% of the energy was spent on data movement between memory and computing units [7]. When scrolling through Google Doc pages, data movement accounts for up to 77% of the energy consumption.

In order to meet the remote sensing data platform with strict requirements on power consumption and size, and accelerate the data processing of remote sensing applications, FPGAs with outstanding features such as low power consumption, low latency, high performance, small size, and reconfiguration have begun to replace GPUs. It is increasingly used in edge-embedded devices to accelerate the inference process of remote sensing data processing algorithms. González et al. [8] proposed an algorithm based on FPGA for automatically detecting targets to address the challenge of poor instantaneity of target detection in hyperspectral remote sensing images [8]. Shimoda et al. [9] proposed a sparse fully convolutional network based on FPGA for semantic segmentation, and adopted a fully pipelined architecture in hardware implementation [9]. Boskovic et al. [10] implemented a multi-mode hyperspectral image target detection system based on FPGA [10], which could switch between three different target detection algorithms freely. However, these studies are based on the traditional von Neumann architecture, and a large amount of data needs to be transported from the underlying storage device to the memory of the host, which causes the problem of storage wall and power wall.

In order to solve the storage wall and power wall problems of the von Neumann architecture, the concept of transferring computation to memory has gained extensive attention in the academic community and is broadly referred to as near data processing method [11]. The memory includes internal memory and external memory [12]. The internal memory can be accessed in bytes. However, the external memory has a large capacity and cannot be accessed at the granularity of byte addressing. Near data processing seeks to minimize data movement by finding the most appropriate location in the hierarchy for computation [13], taking into account the location of data and information that needs to be extracted from the data. In near data processing, computation can be performed in external memory devices, or in cache, main memory, and persistent storage, as opposed to the traditional way in which data is moved to the CPU and computed within the CPU. The fifth generation (5G) communication has the potential to achieve ubiquitous positioning when integrated with a global navigation satellite system (GNSS). Computable storage is crucial to the construction and development of 5G.

As a system architecture for near data processing, computable storage migrates computation to internal storage devices for execution to reduce data interaction between hosts and peripherals. At present, IBM embeds Blue Gene high-performance computing chips inside storage devices in the data center to create storage nodes with computing capabilities [14]. Samsung launches SmartSSD to deal with workload related to data analysis and storage transactions in storage devices [15]. Eideticom has developed NoLoad, which offloads storage functions such as compression onto the accelerator. Alibaba unloads the database scanning and compression operations into storage devices and applies them to the cloud-native relational database PolarDB [16].

In order to speed up the data processing of remote sensing applications and quickly extract effective information from massive remote sensing data, CSRSPP is designed in this paper, which uses storage devices to accelerate the remote sensing data processing, so as to alleviate the problems of storage wall and power wall in the von Neumann architecture. After the remote sensing data processing is unloaded to the storage device, the application performance is improved and the power consumption is greatly reduced.

2. Design of Remote Sensing Data Processing Platform Based on Computable Storage

CSRSPP includes two parts: the host drive and the SSD, and its overall architecture is shown in Figure 1.

The host is equipped with a block device driver to deliver special computing tasks. SSD consists of multiple independent channels which contribute to high parallelism and rich I/O resources. So it can cope with the problems of large single file, large number of files, and low storage efficiency. Five sub-modules are designed in the SSD to support real-time processing of remote sensing data, including command parser, task scheduler, block device driver, application manager, and acceleration module. There are computing devices inside the SSD, which can process the remote sensing data.

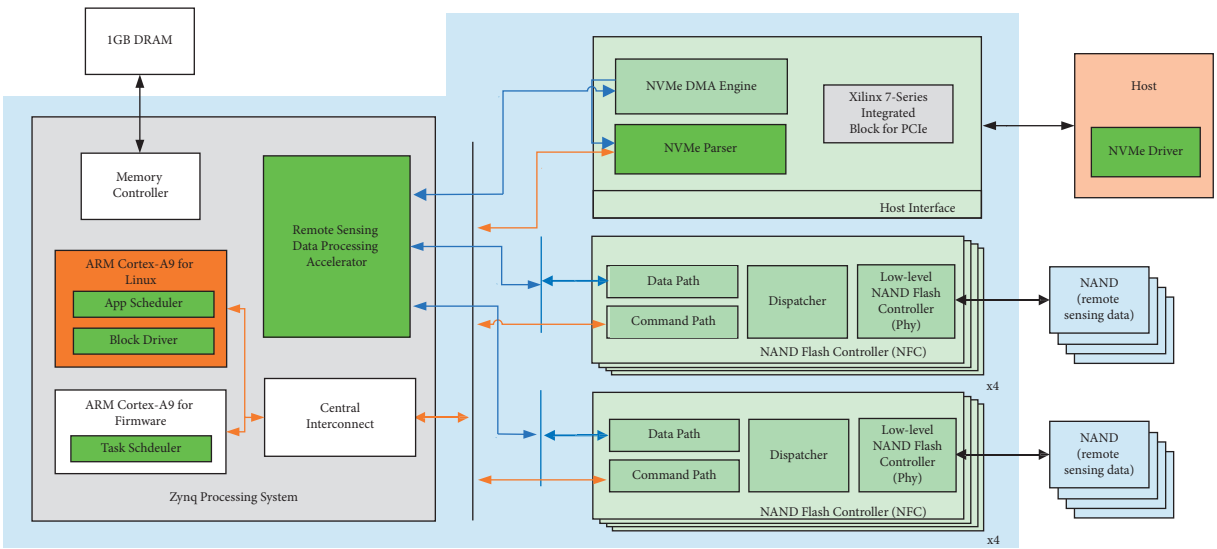

Figure 1: Platform architecture of remote sensing data processing based on computable storage.

3. Operation Principle of SSD

As shown in Figure 2, the SSD consists of host interface logic units, master control chips, Dynamic Random-Access Memory (DRAM) caches, and multiple flash memory chips. The host interface shields the operation on flash memory chips inside the SSD to help the upper-layer storage system seamlessly read and write SSDs. Commonly used interfaces include PCIe, SATA, etc. The main control chip includes processor, memory controller, flash controller, cache manager, providing various methods for processing operations, memory management and organization, and management of flash memory chips. DRAM caches inside the SSD serve to buffer data and accelerate data reading. If the data to be read by the host is in DRAM, there is no need to access the flash memory chips. Instead, the data in DRAM is directly transferred to the host through the Direct Memory Access (DMA) controller. Flash memory chips are used to store data and mounted on different channels. The different channels are connected side by side to the flash controller, enabling parallel access to the SSD.

We use OpenSSD [17] that is an FPGA-based SSD development platform. OpenSSD provides the required IP and basic firmware control logic for the SSD to achieve repeatable programming.

4. Design of Computable Storage System

4.1. Design of Command Parser. The host interacts with the SSD through the NVMe protocol [18]. The NVMe protocol uses multi-queue technology, which can allocate different queues according to task types and scheduling priorities. Each CPU has its own queue to achieve high-performance storage. Each queue of the NVMe protocol is a FIFO pipe that connects the host to the device. The command pipeline sent from the host to the device is called the Submission Queue (SQ), and the command pipeline sent from the device to the host is called the Completion Queue (CQ). The process of an I/O request is that the host first assembles NVMe commands and establishes DMA mappings for transferring data, and then sends the request to the device through SQ. After receiving the request, the device records the corresponding completion result into the I/O completion request, and finally returns the completion result to the host through CQ.

The NVMe protocol uses the doorbell mechanism to inform the SSD controller's CQ whether there is a new request. Each NVMe queue has a doorbell pointer. For SQ, this pointer is the queue tail pointer. After the host submits an I/O request to the SQ, it updates the doorbell pointer in the device register space with the value of the SQ tail pointer. At this point, the SSD controller is notified of a new request and needs to move the NVMe command from the SQ to the command parser for further execution.

After receiving the NVMe command, the command parser needs to parse it. The specific format of the NVMe command is shown in Figure 3. Usually the last 4 fields of the protocol package are not used and can be customized by the user. The 10th and 11th fields are often used, as defined as logical block addresses in read/write commands.

The size of the NVMe command is 64 B, and opcodes larger than 0×80 are reserved options for manufacturers. To support computing tasks of remote sensing data processing, add the following commands: (1) Linux for Remote Sensing Data Processing (LRSDP) heartbeat detection, (2) LRSDP off, LRSDP on, and (3) Computing task delivery. Among them, LRSDP heartbeat detection commands are used to obtain the real-time load of LRSDP in the SSD, LRSDP on and off commands are used to control the startup and shutdown of LRSDP, and computing task delivery commands are used to issue the computing tasks that need to be executed in the SSD.

4.2. Design of Task Scheduler. For the smooth operation of LRSDP, the computing tasks delivered by the host cannot be run directly. On the one hand, the computing tasks delivered by the host may become a system bottleneck due to the time-

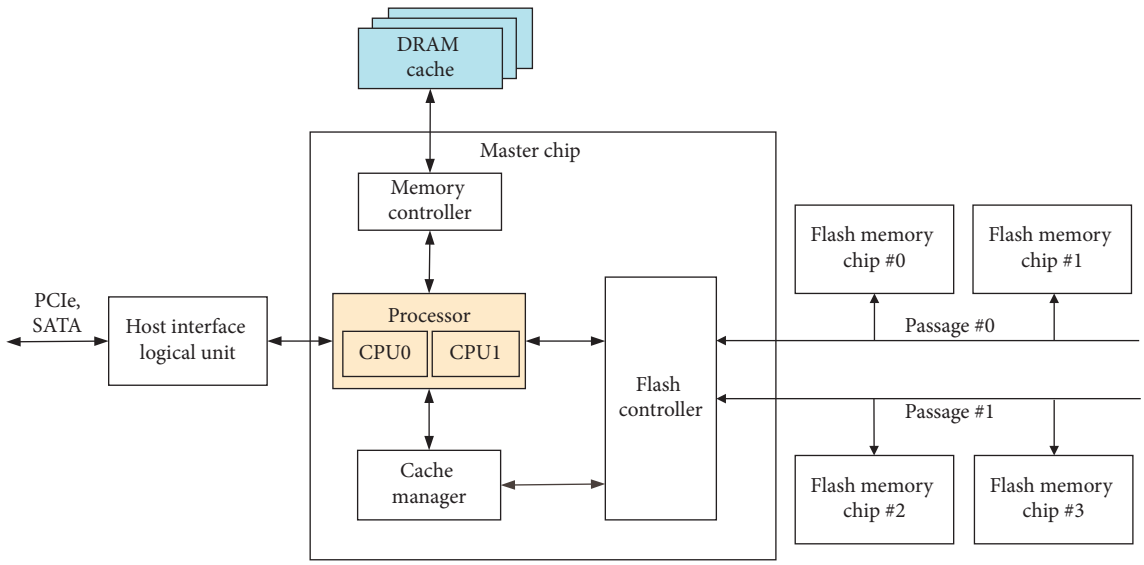

Figure 2: The architecture of SSD.

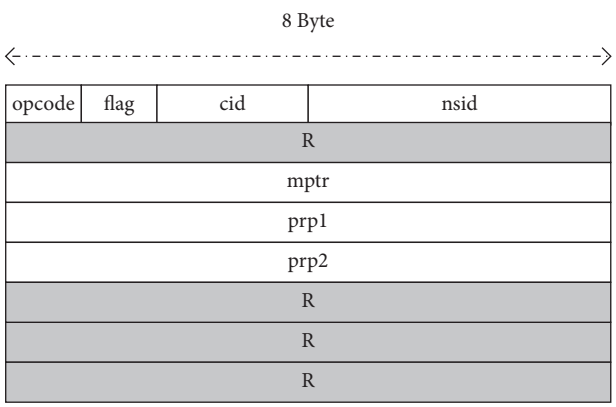

Figure 3: Format of NVMe commands.

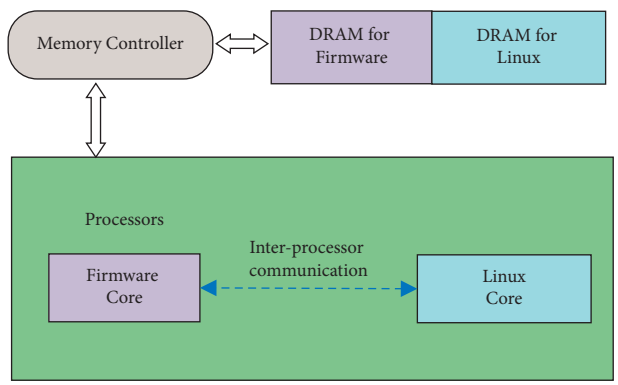

Figure 4: Resource allocation and inter-core communication between firmware core and LRSDP core.

consuming process. On the other hand, the programs executed in the LRSDP may have design flaws, which increase the long-tail latency of the computable storage system. Therefore, the task scheduler is required to schedule the computing tasks delivered by the host. The main job of the task scheduler is to estimate the waiting time of a task. If the expected waiting time is long, the host executes the task or waits for a period of time before delivering the task.

After receiving the request, the task scheduler firstly checks whether the LRSDP has been started. If the LRSDP is not started, the task will be returned to the host. If the LRSDP is started, the depth of the waiting queue of the task and the real-time load of the LRSDP will be evaluated. The real-time load of the LRSDP is obtained through the heartbeat mechanism. The LRSDP periodically informs the task scheduler with the current system information, such as the memory usage and CPU usage. If the queue depth exceeds the threshold or the LRSDP load is heavy, the task is pushed back to the host for processing. Otherwise, the task is inserted into the waiting queue of the task manager, and then sent to the LRSDP for processing.

4.3. Design of Block Device Driver. As shown in Figure 4, it is assumed that there are four processing cores inside the SSD, two of which are used to run firmware and the other two for running LRSDP. The core running the firmware and the core running the LRSDP share the DRAM memory inside the SSD, and they have a different range of physical memory addresses available. Assuming that the low address space is allocated to firmware and the high address space is allocated to LRSDP. The LRSDP block device driver needs to interact with the Flash Translation Layer (FTL) of the firmware through inter-core communication to read and write flash memory information. Therefore, the core of the LRSDP block device driver lies in the inter-core communication.

In a multi-core system, the interrupt controller allows the hardware thread of one CPU to interrupt the hardware thread of other CPUs. This method is called Inter-Processor Interrupt (IPI). The implementation of IPI is based on multi-CPU memory sharing. Using IPI can reduce CPU overload and improve system efficiency effectively. In addition, CPUs in the SSD are generally ARM cores, and the Generic Interrupt Controller (GIC) controller supporting IPI is usually

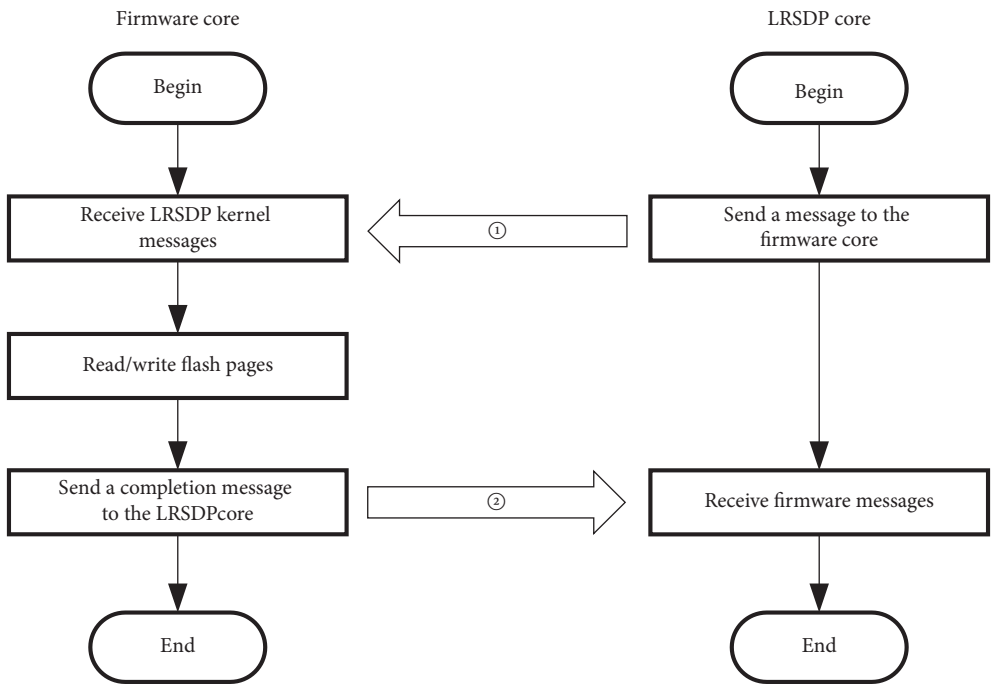

Figure 5: Inter-core communication flow between firmware core and LRSDP core.

configured in the ARM core [19]. Therefore, the IPI between the LRSDP core and the firmware core can be used to communicate and complete data interaction in the computational storage system.

The communication process between firmware core and LRSDP core is shown in Figure 5. The LRSDP core sends packet A to the firmware core, and usually the message length transmitted by the data register is limited. So the valid content sent by LRSDP contains a magic number and the physical address of the actual packet B. The IPI of the firmware core is then triggered to check the validity of packet A's contents. First determine whether the bytes of the packet header match the magic number, if so, continue to read the contents of the packet B corresponding to the physical address. The header of package B contains the opcode and the array length N, followed by the array's content—— [[LBA1, physical address $x1$, sector number $y1$], [LBA2, physical address $x2$, sector number $y2$], . . ., [LBAN, physical address xn, sector number yN]]. Each element of the array consists of the logical block address, the physical address of data read/write, and the number of read/write sectors. The firmware core submits these requests to the FTL I/O queue one by one, and sends an IPI to LRSDP after all I/O requests are completed at the FTL. Finally, the LRSDP core receives the IPI and notifies the file system or application that the I/O is completed.

4.4. Design of Application Manager. The application manager is responsible for the management of LRSDP applications, including the execution of life cycle processes such as saving, starting and stopping applications, and reasonable resource allocation of processes or threads corresponding to computing tasks to prevent a process or thread from blocking the entire system [20].

4.4.1. Application Registration/Saving. The host can register applications with LRSDP, such as issuing script files or executable files. First, the application manager needs to perform trusted code detection on the delivered files to determine whether there is any code that maliciously attacks the operating system or file data. Then, the application manager checks whether the task type delivered by the host already exists in the current system. Finally, the application manager checks whether some parameters given are valid. If all of the above conditions are met, the application manager records the application name and its invocation rules, and saves the application to the root file system of LRSDP for later invocation.

4.4.2. Application Startup and Shutdown. The application starts when a computation task is received from the task scheduler module. First, the application manager creates a process or thread of the corresponding task, and the process/thread enters the running state. After calculating the task result, the process/thread notifies the final processing result to the application manager. The processing results can be recorded in shared memory or files. After the application manager obtains the results, the application is closed and the firmware is notified that the task is completed.

4.4.3. Application Resource Allocation. Although the task scheduler has some control over the computing tasks, the tasks with long waiting time can be directly returned to the host. However, after LRSDP is enabled, measures should be taken when multiple applications preempt the computing resources, memory resources, and I/O resources of the computable storage system. In addition, an application may occupy most of the memory of the computable storage

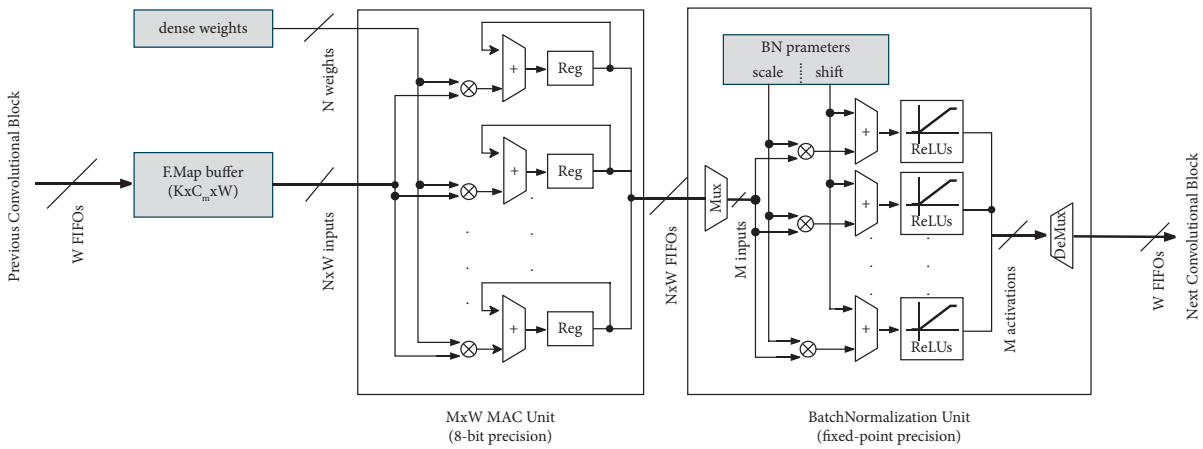

Figure 6: Principle of convolution circuit.

system or occupy the CPU or I/O channel for a long time. Therefore, it is necessary to control the resources occupied by the application.

The host can specify the priority of certain tasks explicitly or adjust the priority of the LRSDP process during the real-time running. In addition, it is also possible to avoid disorderly and unfair resource grabs for the computational storage system by explicitly setting the maximum memory and I/O resources available to a certain application. If there is an abnormal application state, the application manager should end it.

4.5. Design of Application Manager. In the computable storage system, the host can specify remote sensing data processing tasks for acceleration. After the application is started, requests for acceleration tasks are submitted to the acceleration module. The acceleration module completes convolution calculation of all layers in the network model for remote sensing data processing, and its working principle is shown in Figure 6. According to the principle of convolution operation, a feature map vector is convolved with multiple convolution kernel vectors, and the output feature map vector is obtained through the pooling layer [21]. The data input of multiple parallel computing core modules adopts a daisy-chain method, and the feature map vector and convolution kernel vector flow through multiple computing core modules in turn. Therefore, the acceleration module opens up double buffer for this purpose. When the serial number of the convolution kernel vector matches the serial number of the current computing core module, the computing core module caches the vector accordingly, and finally the nth computing core module stores all the weights of the nth convolution kernel. It is used for the calculation of the current batch, and the weight of the nth convolution kernel of the next batch is pre-read, thereby improving the computing performance of the accelerator.

The structure of Convolutional Neural Network (CNN) is getting larger and larger. Due to the resource limitation of FPGA devices, complex CNN models such as Fast R-CNN [22] and ResNet [23], cannot be fully unrolled on hardware, and sometimes even a single convolutional layer cannot be expanded. To solve this problem, the main approach is to map a limited number of processing elements on the FPGA. These processing elements are reused by temporarily iterating over the data. Optimization strategies such as data parallelism, memory access optimization, computational communication overlap, and pipeline optimization are used to maximize the performance of target detection or image classification performed on OpenSSD hardware. In hardware implementation, we use CNN with a simple structure.

5. Experimental Setup

5.1. Experimental Platform. We use the Cosmos plus OpenSSD platform which consists of an XC7Z045 FPGA chip, an Ethernet interface, 1 GB DRAM, an 8-way NAND flash interface, and a PCIe Gen2 8-lane interface. The physical map of the hardware platform is shown in Figure 7.

5.2. Experimental Parameter Settings. The basic parameters of the OpenSSD used in the experiment are shown in Table 1. The flash page size is 16 KB and the logical volume is 1 TB. The read latency of the flash page is 70 μs and the write read latency is 200 μs.

5.3. Experimental Process. Firstly, we create a partition in OpenSSD, and then format it with ext4 file system. Finally, we mount the partition in the host and copy remote sensing data into OpenSSD's NAND flash.

After the remote sensing data is saved to the flash memory, the host initializes the development board with bitstream. After the bitstream initializes the acceleration module on the development board, the host sends a special NVMe command to start LRSDP. After LRSDP is started, the host can continue to issue different types of computing tasks to LRSDP through custom NVMe commands.

When LRSDP receives a computing task, it will continuously transfer data to Remote Sensing Data Processing Accelerator (RSDPA). RSDPA calls the corresponding hardware resources for calculation according to the specific type of computing task. After calculation, the data is stored

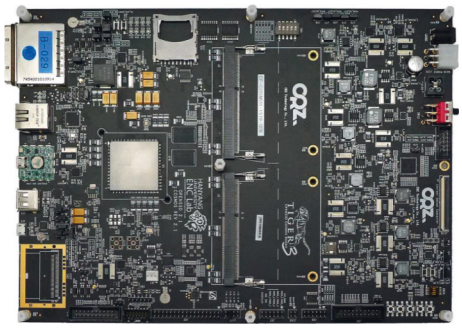

Figure 7: OpenSSD hardware platform.

Table 1: Detailed parameters of SSD.

Parameters	Configuration
Flash page size	16 KB
Page number in flash block	256
Number of flash channels	8
Logical volume	1 TB
Read latency of flash page	70 μs
Write latency of flash page	200 μs
Erasure delay of flash block	2 ms

in Block Random Access Memory (BRAM) of the FPGA, and LRSDP can copy and read the execution results in BRAM to DRAM of OpenSSD. An end signal is sent to notify the host that the computing task is completed. After receiving the end signal, the host can actively read the processing result of the task through the PCIe interface, and read the final data processing through the DMA controller.

6. Results and Discussion

This section comprehensively evaluates the feasibility of CSRSPP proposed in this paper through experiments. Based on different large-scale remote sensing datasets, we design remote sensing data processing tasks by computational storage, and observe the efficiency of the platform in remote sensing data compression, target detection, and image classification. The accuracy rate and the resource utilization rate of the platform are tested to verify the effectiveness of CSRSPP, and compared with the power consumption under the traditional von Neumann architecture.

7. Data Compression

This section explores the performance gains of compressed applications using computable storage technology at different in-disk bandwidths, i.e., testing 3 different channel counts (2, 4, and 8) [24]. The remote sensing images based on BMP format were converted into jpeg format images to reduce the storage overhead of remote sensing data.

The size of the compression experiment test set is about 20.5 GB, all of which are images in BMP format. The experiment was based on the assumption of low time locality of data. Data needed to be read from the flash memory in the SSD each time, and the compressed result was directly stored on the flash memory. The execution time of compression application consists of I/O time and computation time. The shorter the application execution time, the better the compression performance. Table 2 describes the performance of data compression applications at different channel numbers.

Table 2: The execution time of compression application at different channels.

Platform	Channel number	I/O time (s)	Computation time (s)
HOST	2	36.75	204.25
	4	21.63	209
	8	12.2136	200.9643
CSRSPP	2	36.12	60.8
	4	21.21	62.7
	8	11.7936	64.6

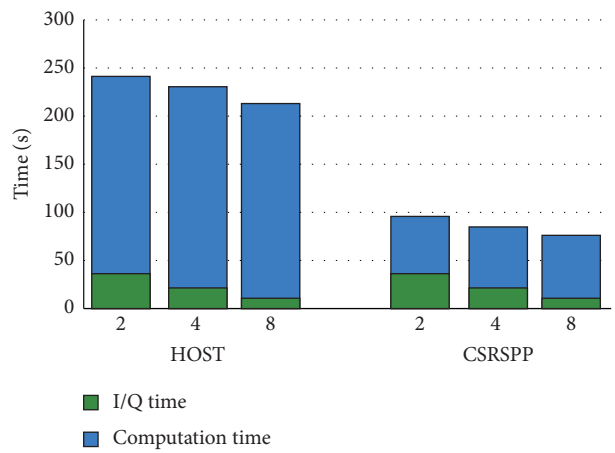

Figure 8: Data compression performance under different channels.

The results of the performance comparison between the host and the CSRSPP performing data compression tasks under different channels are shown in Figure 8.

Combined with the test results in Table 2 and Figure 8, it can be seen that under different channels, the I/O rate of CSRSPP in-disk image reading is 1.7% ~ 3.5% faster than that of off-disk image reading on the host, which makes in-disk I/O process more streamlined than off-disk. The computation speed of CSRSPP in-disk image compression is 2.11 ~ 2.35 times faster than that of off-disk reading on the host. This is because the parallel computing resources of FPGA are utilized, and the pixels of multiple different blocks can be rapidly compressed in parallel.

8. Target Detection

We used the hardware resources of OpenSSD to process CNN in parallel to finish object detection in remote sensing images. The GPU also used the same neural network for object detection.

8.1. Visualization of Detection Results. In the experiment, the dataset for object detection in aerial images DOTA-1.0 published by Wuhan University [25] and the high resolution ship dataset HRSC2016 published by Northwestern

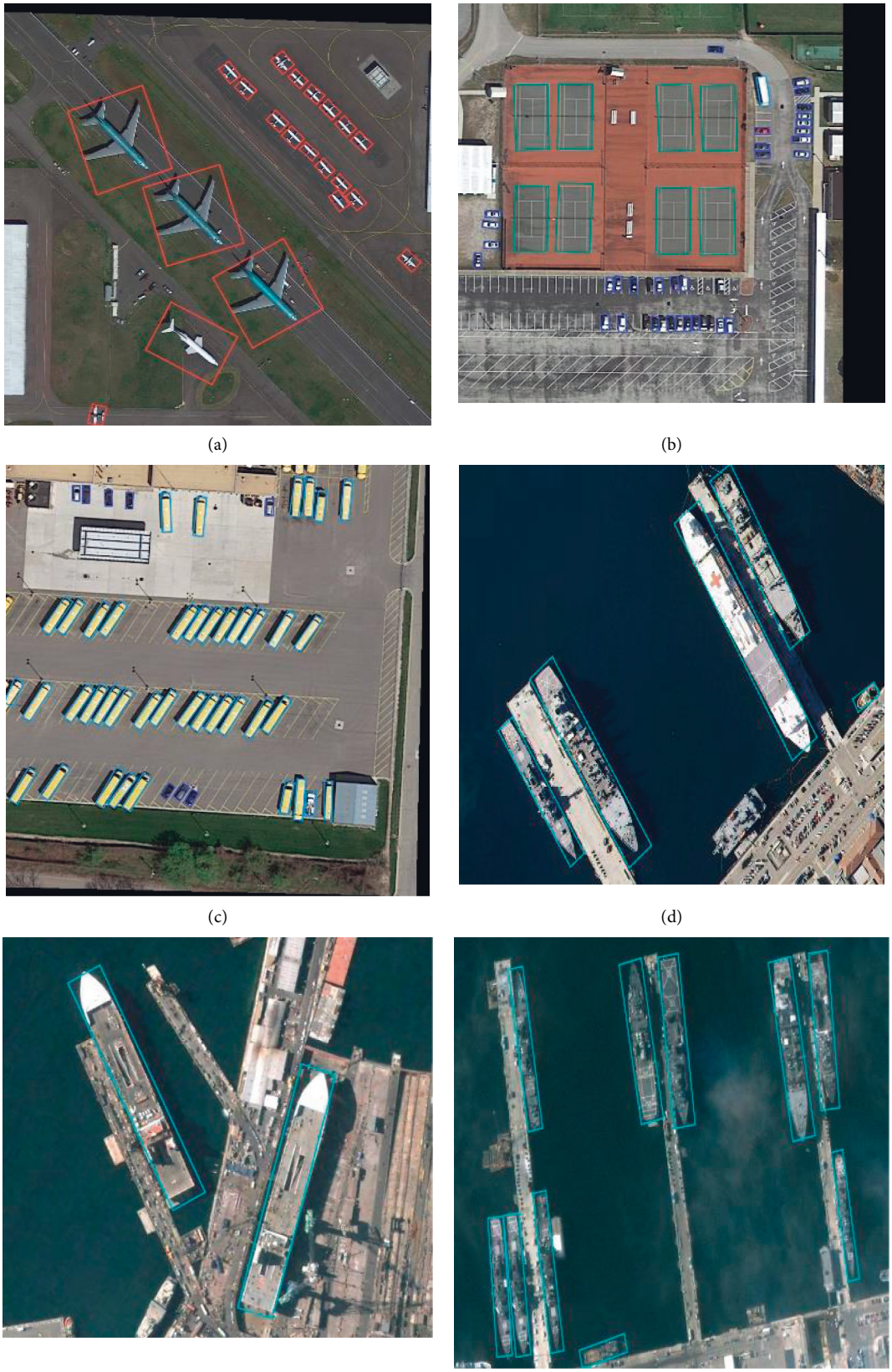

Figure 9: Target detection visualization results based on DOTA-1.0 and HRSC2016 datasets.

Polytechnical University were used [26]. DOTA-1.0 contains a total of 2806 aerial images containing objects of various scales, orientations, and shapes in 15 common categories for training and testing. HRSC2016 has a total of 1079 images, and the only marked target is the ship, which is used for the test of platform detection performance.

The visualization results are shown in Figure 9, where Figures 9(a)–9(c) are generated by DOTA-1.0 dataset, and Figures 9(d)–9(f) are generated by HRSC2016 dataset. It can be seen that the target detection performance of the platform performs well on different datasets.

8.2. Detection Efficiency Test. In this experiment, we tested the target detection effect under the DOTA-1.0 and HRSC2016 datasets to verify the effectiveness and universality of the platform for detection tasks. The mean Average Precision (mAP) and Frames Per Second (FPS) are selected as objective evaluation indicators. The detection results are shown in Table 3.

It can be seen from the objective index results in Table 3 that the accuracy and detection efficiency of the two datasets are both good when CSRSPP accelerators are used to perform target detection, indicating that the platform is effective and universal for target detection tasks. The mAP of DOTA-1.0 dataset is smaller than that of HRSC2016 dataset, because DOTA-1.0 dataset has more image types than HRSC2016 dataset.

8.3. Comparison on Detection Speed. As a comparative experiment, the GPU system used 16 bit floating-point numerical precision on the multiply-accumulate setting and 32 bit floating-point numerical precision on RSDPA. The power measurement included the CPU and other peripherals in the FPGA and GPU, which were measured under load. For comparison, we used full-resolution images for the GPU system as well as the FPGA system.

As shown in Table 4, our FPGA system achieves 34FPS on images with 500×500 resolution, especially with only a 0.4% loss in accuracy and a power consumption of only 20 W. The GTX 1080Ti dedicated accelerator achieves 32 FPS under the condition of 60 W power consumption. Compared with the full-resolution system on GPU, the power consumption of our system is 66.7% lower. For the detection speed of images with 500×500 resolution, the power consumption performance is improved by 2.21 times. Meanwhile, the architecture of computable storage also has better performance by using RSDPA compared with GPU processing. In general, the remote sensing data processing platform based on OpenSSD greatly reduces the power consumption of the entire system on the basis of a slight reduction in speed.

9. Image Classification

In order to verify the information extraction and acceleration effect of CSRSPP on remote sensing data information, CNN was also used to realize remote sensing image classification.

Table 3: Target detection effects under different datasets.

Dataset	mAP (%)	FPS
DOTA-1.0	74.62	56.7
HRSC2016	83.17	52.3

Table 4: Comparison between two platforms on target detection.

Platform	CPU + OpenSSD	CPU + GPU (GTX 1080Ti)
Freq.[H2]	100	1481
Frame resolution	500×500	500×500
Tile size	250×250	250×250
Precision (MACs)	INT8	FP16
Precision (BNs)	Fixed (32 and 16 bit)	FP32
Precision (%)	97.9	98.3
Speed (FPS)	34	32
Power (W)	20	60
Efficiency (FPS/W)	1.70	0.53

9.1. Visualization of Classification Results. The remote sensing data adopted was from the downloaded Landsat-8. The dataset containing 800 remote sensing images was obtained by cropping and sorting, with a total amount of 22.9 GB, and all images were in JPG format. 640 images were used for training and 160 images were used for testing. The visual result of image classification is shown in Figure 10.

Based on the observation of the visualized classification results of remote sensing image classification in Zhengzhou, CSRSPP achieves a good classification effect for remote sensing images on the five basic categories of mountain, construction land, water Body, green land, and bare land.

9.2. Classification Efficiency Test. In order to test the acceleration effect of the platform on remote sensing classification, 16 bit floating-point numerical accuracy was used on the multiplication-accumulation settings of the GPU system and 32 bit floating-point numerical accuracy was used on RSDPA. The power measurement included CPU and other peripheral devices in FPGA and GPU, which were measured under load. Overall Accuracy (OA) and Kappa coefficient were tested. The test results are shown in Table 5.

Table 5 shows that OA and Kappa are slightly lower than GPU due to limited floating-point accuracy calculation in image classification under the OpenSSD platform. However, the classification speed of RSDPA is 78.8% higher than that of GPU, and the system power consumption of OpenSSD is 70.0% lower than that of GPU. The amount of data returned by the OpenSSD platform based on computable storage is also greatly reduced. In the traditional von Neumann architecture, 4.58 GB of data needs to be returned to the memory. However, the OpenSSD platform based on computable storage only needs to transfer 0.77 GB of data, which

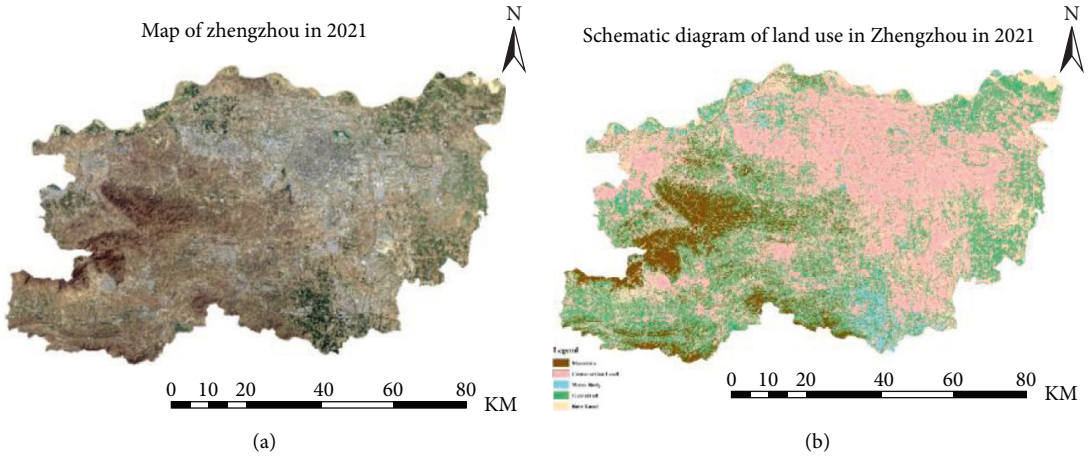

Figure 10: Image classification visualization results based on Landsat-8 dataset.

Table 5: Objective indicator results of image classification.

Index	OpenSSD	GPU
Classification time (s)	468	837
Power	18 W	60 W
OA (%)	84.52	86.44
Kappa	0.81	0.83

Table 6: Comparison on resource utilization of different modules.

Module	#	LUT	FF	BRAM	DSP
Flash controller	8	11031	7539	21	0
NVMe interface	1	8586	11455	28	0
RSDPA	1	76344	19144	157	235
Total	1	212099	152908	384	235

decreases by 83.2% and further reduces the power consumption of CSRSPP.

10. Resource Utilization of the Platform

The placement and routing were completed with Vivado 2018.3. Table 6 shows the hardware utilization of CSRSPP. It reports the resources overhead of the flash controller, NVMe controller, and the RSDPA accelerator module.

However, CSRSPP is more energy-efficient (QPS/Watt) than a GPU-integrated system by 6.56 times. More importantly, the CSRSPP is implemented with FPGA and the operating frequency is only 100 MHz, which can greatly facilitate the construction of 5G. The performance will be further improved if the CSRSPP is implemented with escalated operating frequency or ASIC.

11. Conclusions

In this paper, we design a remote sensing data processing platform based on computable storage, which can proactively perform various remote sensing image processing tasks with low delay, low power consumption, and high precision inside SSD. Based on the OpenSSD platform, we design and implement remote sensing data compression, remote sensing image classification, remote sensing target detection, and other applications inside SSD. Our prototype shows that in the practice of remote sensing data compression, the calculation speed of image compression in CSRSPP is 2.11 ~ 2.35 times faster than that of off-disk reading on host. In the application of target detection, CSRSPP reduces latency by an average of 6.25% and saves power consumption by 66.7% compared to GPU. For remote sensing image classification applications, the detection accuracy under CSRSPP decreases slightly, but the average delay is reduced by 78.8%. CSRSPP distributes various computing tasks to the SSD for execution, which not only improves the speed of information extraction on remote sensing data, but also greatly reduces the power consumption of data migration.

Data Availability

The data that support the findings of this study are available from DOTA-1.0 dataset, HRSC2016 dataset, and Landsat-8 dataset, which are publicly available.

Ethical Approval

The authors declare that they have no human participants, their data, or biological material used in this work.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Z. Q. and J. L. conceptualized the study; Z. Q. and R. Z. developed the methodology; Z. Q. helped with software; Z. Q., X. Y., and R. Z. validated the study; J. L. carried out formal analysis; Z. Q. investigated the study; Z. Q. and R. Z. collected the resources; Z. L. curated the data; Z. Q. wrote and prepared the original draft; X. Y. wrote, reviewed, and edited the study; X. B. visualized the study; R. Z. supervised

the study; X. B. administrated the project; R. Z. carried out funding acquisition. All authors have read and agreed to the published version of the manuscript.

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Retraction

Retracted: Spatial Heterogeneity Analysis of Resource Allocation Efficiency of Sports Venues in China from the Perspective of Polarization Theory

Mobile Information Systems

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

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

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

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

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

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

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[1] J. Cao, J. Geng, and W. Shen, "Spatial Heterogeneity Analysis of Resource Allocation Efficiency of Sports Venues in China from the Perspective of Polarization Theory," *Mobile Information Systems*, vol. 2022, Article ID 6143771, 9 pages, 2022.

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Research Article

Spatial Heterogeneity Analysis of Resource Allocation Efficiency of Sports Venues in China from the Perspective of Polarization Theory

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There are not many analyses of the degree of variation in the efficiency of the allocation of sports venues in China. The results show that the allocation efficiency of sports venues in China is very high. The results show that the efficiency of the allocation of sports venues in China generally shows a fluctuating upward trend, with the average efficiency value increasing from 0.7 in 2013 to 0.9 in 2014, and there are significant differences at the three regional levels of East, Central, and West China and at the level of each province and autonomous region. The efficiency of the allocation of sports venue resources in the three regions shows a geographical pattern of "eastern region > western region > central region." The regional disparity in the efficiency of the allocation of sports venue resources in China gradually increases during the period under study, with the opening and closing values of the kernel density curve for 2013–2017, showing an overall ". The nuclear density curve in 2017 shows an obvious bimodal curve distribution. Compared with other years, it can be clearly seen that there are fewer areas with low values and more areas with high values. The polarization of the efficiency of China's sports venue resource allocation and layout has been revealed, and the core density curve is shown as a whole. It can be seen from the sports venue resource allocation index that during the study year, the changes and fluctuations of each major region were different, and the national Er index showed a trend of "Λ." The shape of the national Er index is "Λ," while the eastern, central, and western regions are in the shape of "N," declining slowly and remaining stable, respectively. The ER index fluctuates the most in the eastern region. Hence, the change in the ER index in eastern China plays a dominant role in the polarization of the overall resource allocation efficiency of sports venues in China.

1. Introduction

During the 14th Five-Year Plan period, the Central Committee of the Party and the State Council attach great importance to the development of sports in China, and it is also a critical period for building a strong sports nation. The content of a sports power should include establishing a national fitness service system, covering urban and rural areas, adhering to the reform and improvement of the national system of competitive sports, constantly expanding opening-up, deepening reform, analysis of institutional factors restricting the development of sports industry and elimination of sports institutional obstacles, and cultivating and enhancing the international influence of Chinese sports. The implementation of national regional development and the promotion of the coordinated development of sports are being deployed and promoted at the same time, and efforts are being made to solve the current problem of unbalanced development of sports resources between regions. As far as sports venue resources are concerned, achieving an increase in the level of sports venue resource allocation is an important reflection of the implementation of the 14th Five-Year Plan for Sports [1]. The management of sports science and technology resources mainly includes the management system of sports science and technology, the management of sports scientific research activities, and the management of sports scientific and technological achievements.

Resources refer to the collection of various elements, such as material, financial, and human resources, possessed within a country or a region, and they can be divided into natural resources, human resources, and processing resources for human development and use [2]. The characteristics of natural resources include the limitation of quantity, the imbalance of distribution, the connection between resources, and the development of utilization. Sports venue resources are the intersection of natural resources and social resources, and their constituent elements mainly include material and financial resources invested in venue construction and personnel and information required for venue management. The Sixth National Sports Venue Census defines sports venues as the collection of human, physical, financial, and information elements invested in the construction and management of sports facilities dedicated to sports training, competition, and fitness activities, with a certain amount of investment, public welfare, or business, including the necessary ancillary functional rooms [3]. The ways to improve the efficiency of sports resource allocation include the optimization of allocation methods and allocation policies.

Existing research on the efficiency of sports venue resource allocation is mainly focused on three aspects: firstly, the connotation, objectives, principles, and modes of sports allocation are discussed at the theoretical level, pointing out that efforts should be made to broaden funding channels and actively strengthen scientific management as the key to sports venue resource allocation [4–6]. The basic national conditions of our country determine that the supply of sports resources in our country will be in a state of short supply for a long time, i.e., the contradiction between the continuous expansion of the demand for sports resources in the development of sports and the relative shortage of national sports resources, and this contradiction will exist for a long time. Therefore, with the vigorous development of China's sports industry and the continuous improvement of sports high-tech level, it is particularly important to carry out scientific, standardized management of sports resources. The second is the policy-level thinking about how to effectively improve the level of sports resources allocation. Scholars generally believe that the level of sports venue resources allocation is the result of the interaction between government policies and market economy. The "Blueprint for Sports Facilities" in Singapore, the "Gold Plan" in Germany, the "Healthy Citizenship Program" in the United States, as well as sports lottery, corporate sponsorship, and other market-based means subsidize the construction of sports venues [7–11]. The development and management of sports venue resources mainly includes sports venue resources, the classification and function of sports venue resources, and the development and management of sports venue resources. These government policies have greatly met the demand of the public for sports activities. The third is an empirical analysis of the spatial and temporal changes in the level of sports resource allocation in cities at different scales, including the measurement methods [12–14], spatial and temporal patterns [15–17], and influence mechanisms of the level of sports venue allocation [18–22].

To avoid the limitations of single-indicator evaluation, scholars regard the process of sports venue resource allocation as a production system with multiple inputs and multiple outputs, and evaluate it by constructing a sports venue resource allocation evaluation system and adopting the data envelopment analysis method, which is a typical and representative research model for efficiency evaluation at present. Data envelopment analysis is a quantitative analysis strategy to evaluate the relative effectiveness of the comparable units of the same type using the linear programming method according to multiple input indicators and multiple output indicators. With the continuous improvement of research methods, scholars have used the DEA model combined with spatial autocorrelation, Theil index, Gini coefficient decomposition, and other methods to analyze the overall characteristics and evolution pattern of the resource allocation efficiency of different regions and different research objects in a multilevel and multiperspective manner, however, research is conducted seldom on the allocation efficiency of sports venue resources. There is a certain complementarity between the Theil entropy index and the Gini coefficient. The Gini coefficient is particularly sensitive to changes in the medium level. One of the biggest advantages of measuring inequality with Theil entropy index is that it can measure the contribution of intra group gap and inter group gap to the total gap. This paper constructs the polarization index of sports venue resource allocation efficiency, analyzes the efficiency of sports venue resource allocation from the perspective of the polarization theory, combines the DEA model and kernel density estimation method, and analyzes the spatial and temporal characteristics of the differences of sports venue resource allocation efficiency among 30 provinces and autonomous regions in mainland China from 2013 to 2017. This study provides a new research perspective and methodology for the systematic study of sports venue resource allocation efficiency. Note that on the basis of univariate kernel density estimation, the prediction model of value at risk can be established. By weighting the coefficient of variation of kernel density estimation, different prediction models of value at risk can be established.

2. Research Methodology and Data Sources

2.1. Research Ideas. The theory of unbalanced growth, proposed by French economist Perrou in the 1950s, focuses on analyzing the unbalanced problems encountered in the process of regional economic development. The difference between the two sectors comes from the different roles played by technology and labor. In the progressive sector, technology plays a decisive role. In nonprogressive sectors, labor plays a decisive role. This paper analyses the efficiency of sports venue resource allocation in China from a polarization perspective, i.e., observing the unbalanced pattern of sports venue resource allocation and the integration of various elements in China from a polarization perspective and looking for a coordinated development path. This paper, firstly, measures the efficiency of sports venue allocation in each province, city and autonomous region of China with the help of the DEA method to grasp the overall situation of sports venue resource allocation. Secondly, the kernel density method is used to analyze the time-varying characteristics of the differences in the efficiency of the allocation of sports venue resources. Finally, the polarization measurement model is used to reveal the spatial polarization

pattern of sports venue resources in China. The characteristics of sports facilities include that there are differences in the requirements for sports facilities. Sports facilities for competition must first meet the rules of sports competition. All sports facilities emphasize the thoughtful and full protection of athletes, i.e., the importance of safety, applicability, and environmental protection.

2.1.1. Super-SBM Model. The DEA method is mainly used to evaluate the relative efficiency of decision units with multiple inputs and outputs. It avoids calculating the standard cost of each service because it can convert a variety of inputs and outputs into the numerator and denominator of efficiency ratio without converting into the same monetary unit. Therefore, using DEA to measure efficiency can clearly explain the combination of input and output. The traditional DEA models, namely the CCR and BCC models, do not consider same proportion change to efficiency bias, and the traditional DEA models measure the maximum value of efficiency, i.e., the efficiency of effective decision units is 1, which cannot rank the effective decision units again. Therefore, this paper measures the efficiency of sports venue resource allocation with the help of super-SBM [23]. In this paper, based on the existing research results, social fund, lottery fund, and government financial input are selected as input indicators, and social sports instructors, the indoor area of large stadiums, and outdoor sports venue area are output indicators, which indicate the efficiency of sports venue resources and sports talents in the process of sports development, respectively. Social funds include the following: social funds are a part of funds, which the state has the right to regulate. Social funds are closely related to social reproduction, and social funds can bring new value in the movement. The efficiency values were measured according to MAX DEA 6.0 and visualized with the help of Arc GIS 10.2. The specific model of super-SBM is as given below. Note that the lottery fund refers to the fund obtained after the realization of lottery sales, which is composed of lottery public welfare fund, reward bonus, and issuance funds.

$$\begin{aligned}
&\min \rho_{SE} = \frac{1 + 1/m \sum_{i=1}^{m} S_i^- / x_{ik}}{1h - 1/S \sum_{r=1}^{s} S_r^+ / y_{rk}}, \\
&s.t. \\
&\sum_{j=1, j\neq k}^{n} x_{ij}\gamma_i - S_i^- \leq x_{ik}, \\
&\sum_{j=1, j\neq k}^{n} x_{rj}\gamma_j + S_r^+ \geq y_{rk}, \\
&\gamma, S^-, S^+ \geq 0, \\
&i = 1, 2, \ldots, q;\ j = 1, 2, \ldots, n\,(j \neq k),
\end{aligned} \tag{1}$$

where ρ_{SE} is the efficiency of sports venue resource allocation. x and y are input and output factors, respectively. m and s denote the number of input indicators and output indicators. k denotes the production period. i and r represent the decision-making units, DMU, of input and output, respectively. $S^+$and S^- represent the slack variables of input and output, respectively. γ is the weight vector. When $\rho_{SE} \geq 1$, the apparent decision unit is relatively efficient and in the production efficient frontier. When $\rho_{SE} \leq 1$, it indicates that the decision unit is relatively inefficient and efficiency loss occurs.

2.1.2. Kernel Density Estimation. Kernel density estimation methods study the characteristics of data distribution from the data sample itself, without taking into account the data a priori. Used to estimate an unknown density function, it is one of the nonparametric testing methods and is highly valued in both statistical theory and its application areas [24]. The methods of kernel density estimation include parametric estimation and nonparametric estimation. Parameter estimation can be divided into parametric regression analysis and parametric discriminant analysis. In parametric regression analysis, it mainly assumes that the data distribution conforms to a specific behavior and then determines the unknown parameters in the regression model. Let the given data $x_1, x_2, \ldots, x_n$ obey the same distribution. Its density function $f(x)$ is unknown. We need to estimate the density function $f(x)$ with the help of the sample. The empirical density function of the sample is known to be the following: $F(x) = 1/n\{X_1, X_2, \ldots, X_n\}$. Then, the kernel density function is estimated in the form of the following:

$$\begin{aligned}
f_n(x) &= \frac{[F_n(x + h_n) - F_n(x - h_n]}{2h} \\
&= \int_{x-h_n}^{x+h_n} \frac{1}{h} K\left(\frac{t - x}{h_n}\right) dF_n(t) \\
&= \frac{1}{nh_n} \sum_{i=1}^{n} K\left(\frac{x - x_i}{h_n}\right),
\end{aligned} \tag{2}$$

where h_n is the window width, and $K(*)$ is the kernel density function. There are more methods to estimate the kernel density function. When the function relationship cannot be judged, Gaussian kernel function is superior to other kernel functions. Hence, this paper kernel density estimation $K(*)$ uses the Gaussian kernel function, which is as follows: $Gaussian = 1/\sqrt{2\pi}e^{-t^2/2}$. The window width is $h_n = 0.9SN^{-0.8}$, where N is the sample size and S is the sample difference. Th kernel density estimation method does not use the prior knowledge of data distribution, and it does not attach any assumptions to the data distribution. It is a method to study the characteristics of data distribution from the data sample itself. Therefore, it is highly valued in the field of statistical theory and application.

2.1.3. Spatial Polarization Measure-ER Index. The Esteban-Ray (ER) index is a typical quantitative analysis method for measuring spatial polarization in theoretical circles, emphasizing the spatial clustering of samples [25]. The basic idea of this index is to compare variables with each other, so as to determine the benchmark of comparison and finally

Table 1: Efficiency values for the allocation of sports venue resources in each municipality and autonomous region, 2013–2017.

	2013	2014	2015	2016	2017
Beijing	0.824	0.913	0.913	1.094	1.299
Tianjin	0.799	1.077	1.021	1.883	1.317
Hebei	0.747	0.897	0.886	0.901	1.023
Shanxi	0.547	0.553	0.576	0.611	0.712
Inner Mongolia	0.325	0.367	0.382	0.526	0.561
Liaoning	0.655	0.674	0.701	0.725	0.780
Jilin	0.646	0.663	0.675	0.693	0.727
Heilongjiang	0.602	0.624	0.626	0.635	0.683
Shanghai	1.070	1.406	1.689	1.692	1.693
Jiangsu	1.125	1.322	1.342	1.324	1.331
Zhejiang	1.240	1.365	1.258	1.274	1.293
Anhui	0.843	0.893	0.902	0.921	0.924
Fujian	1.137	1.243	1.233	1.246	1.256
Jiangxi	0.732	0.732	0.734	0.734	0.738
Shandong	1.137	1.142	1.158	1.155	1.153
Henan	0.556	0.565	0.573	0.583	0.633
Hubei	0.775	0.777	0.774	0.775	0.779
Hunan	0.785	0.796	0.797	0.796	0.805
Guangdong	1.337	1.332	1.463	1.465	1.457
Guangxi	0.535	0.563	0.572	0.577	0.621
Hainan	1.132	1.144	1.032	1.210	1.325
Chongqing	0.979	0.997	1.191	1.179	1.175
Sichuan	0.621	0.654	0.681	0.692	0.752
Guizhou	0.436	0.462	0.525	0.536	0.561
Yunnan	0.462	0.478	0.528	0.572	0.602
Shaanxi	0.254	0.433	0.468	0.570	0.682
Gansu	0.354	0.430	0.455	0.538	0.542
Qinghai	0.300	0.365	0.363	0.468	0.473
Ningxia	0.632	0.643	0.648	0.688	0.687
Xinjiang	0.242	0.346	0.362	0.471	0.467

measure the level of differentiation between variables. Its calculation formula is as follows:

$$f_{ER} = K\sum_{i=1}^{n}\sum_{j=1}^{n} P_I^{1+\sigma} P_j \left|X_i - X_j\right| K = \frac{k}{\mu}, \mu = \sum_{i=1}^{n} P_i X_i, \quad (3)$$

where f_{ER} is the Esteban-Ray index. The larger the value, the higher the degree of spatial polarization of the surface sports venue resource allocation efficiency. $k > 0$ is a standardized parameter. In the process of polarization index measurement, the value of k is adjusted according to the specific data to ensure ERϵ(0, 1). n indicates the number of study areas, P is the weight, and P_i and P_j represent group i and group j, respectively. total samples and number of samples, X_i and X_j represent the average sports venue resource allocation efficiency of group i and group j samples, respectively. σ is the polarization sensitivity coefficient, which takes the value range of $\sigma\epsilon$(0, 1.6).

2.2. Data Sources. The research data was mainly obtained from the 2013 to 2017 China Statistical Yearbook and the Sports Business Statistical Yearbook. This study does not involve China's Hong Kong, Macao, and Taiwan regions, and it mainly focuses on the provinces, cities, and autonomous regions in mainland China, among which data related to the sports business in Tibet is missing, and as the data related to the 2018–2022 Sports Business Statistical Yearbook has not yet been published, the study examines the 30 provinces, cities, and autonomous regions in mainland China, and the period of examination is 2013 to 2017.

3. Empirical Analysis

3.1. Analysis of the Overall Efficiency of Sports Venue Resource Allocation. Table 1 shows the distribution of the spatial pattern of sports venue resources allocation in China's provinces, cities, and autonomous regions from 2013 to 2017, and Figure 1 shows a visualization of the efficiency of sports venue resource allocation in China's provinces, cities, and autonomous regions from 2013 to 2017. Figure 2 reflects the development of the average value of sports venue resource allocation efficiency between China and the three major regions of China over the period under examination.

The efficiency of sports venue resources has been slowly increasing at the national level, from 0.728 in 2013 to 0.904 in 2017, across the 30 provinces, municipalities, and autonomous regions of China, thanks to increased investment from government finance and social funds, as well as government policy support. The average value of the national sports venue resource allocation efficiency during the examination period was 0.826, which is already high as far as the national level is concerned, and although it has not reached the effective frontier surface, it is in a good state of development.

At a local regional level, the efficiency of sports venue resource allocation varies significantly between the eastern, central, and western regions of China, with significant stratification. Although there are large regional differences, all regions are developing well and are on an upward trend. However, because of the different development bases of sports venue resources and the degree of combination of various production factors in the three regions, the average growth rates of the three regions varied significantly, with the average growth rates of the three regions in the East, Central, and West being 4.8%, 2.6%, and 8.0%, respectively, during the examination period. During the examination period, the efficiency of the eastern region was significantly better than that of the central and western regions. The difference in efficiency between the central and western regions changed over time and gradually decreased. Taking the national efficiency of sports venue resource allocation as the benchmark, only the efficiency of the eastern region was higher than the national efficiency average, while the remaining two regions were lower than the national average. At the national level, although the national sports venue resource allocation level reaches 0.826, there is a high degree of regional differentiation in the allocation of sports venue resources in China. The average efficiency of sports venue resource allocation in the three major regions generally shows a spatial distribution pattern of "east > central > west."

At the provincial, municipal, and autonomous region level, the provinces, municipalities, and autonomous regions with high sports venue resource allocation rates during the study period were Beijing, Tianjin, Hebei, Shanghai, Jiangsu,

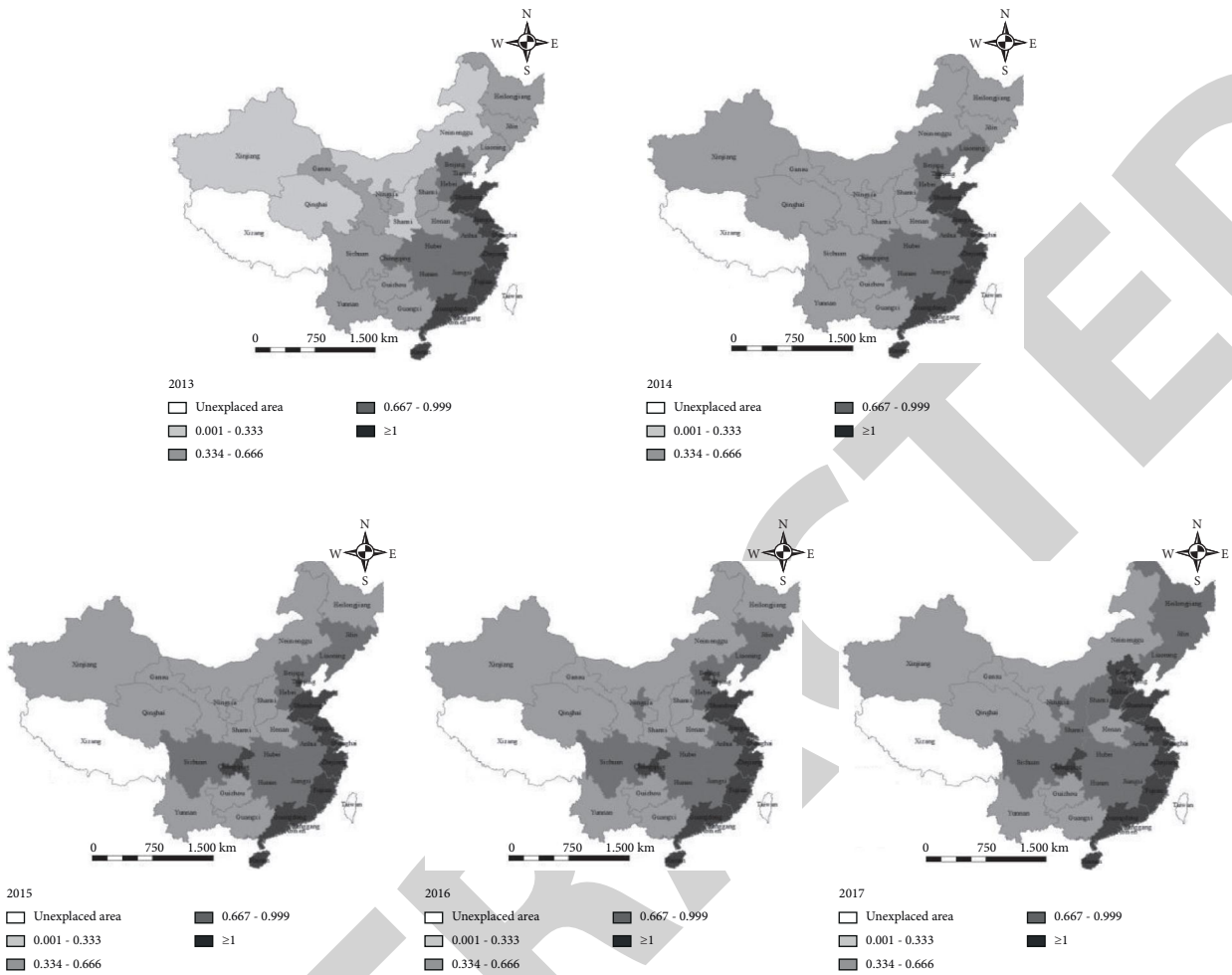

Figure 1: Visualization of the efficiency of sports venue allocation by provinces, cities, and autonomous regions in China.

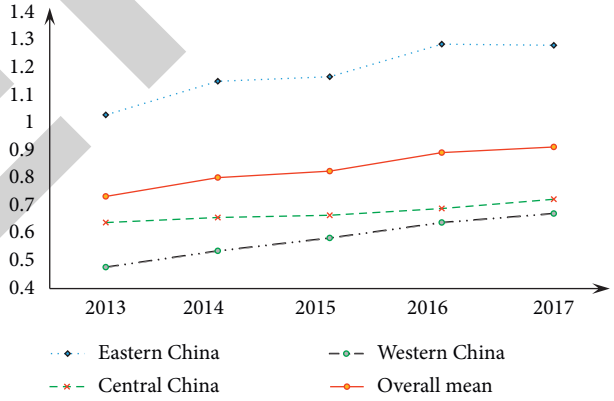

Figure 2: Trends in the average efficiency of sports venue allocation in the three major regions of China.

Zhejiang, Anhui, Fujian, Guangdong, Hainan, and Chongqing, with the above regions mainly coming from the Yangtze River Delta city cluster, Beijing-Tianjin-Hebei city cluster, the four municipalities directly under the central government, and some developed regions in southern China, all of which had efficiency averages above 0.8. Among them, Shanghai, Jiangsu, Zhejiang, Guangdong, Hainan, and Chongqing were all in the production effective frontier of sports venue allocation efficiency and maintained DEA effective during the period examined. Beijing, Tianjin, and Hebei were on the effective frontier most years and generally maintained high levels of efficiency in the allocation of sports venue resources. The regions with poor efficiency performance are Inner Mongolia, Qinghai, and Xinjiang, with efficiency values below 0.5 and far from the effective frontier, which is mainly because of local climatic conditions and

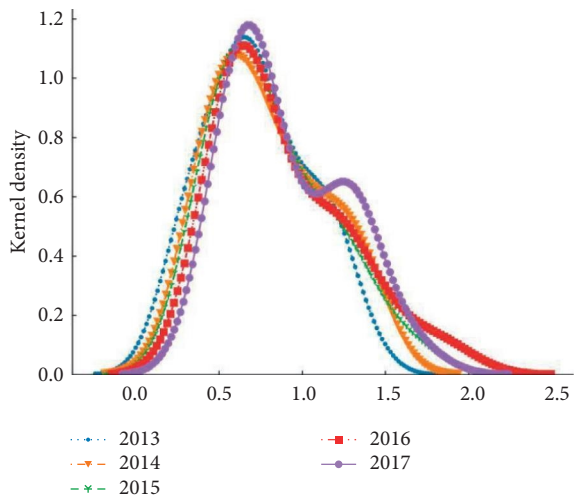

Figure 3: Kernel density estimation of site resource allocation efficiency for sports venues in China.

demographic factors. In terms of the trend of efficiency changes in each province, city, and autonomous region, the 30 provinces and cities studied in this paper generally maintained a slow growth trend from 2013 to 217. From the cross-sectional comparison of each province, city, and autonomous region, it can be seen that the standard deviation of the efficiency value of sports venues in each province, municipality, and autonomous region lies within the range of (0.3081, 0.3800), and the difference between the standard deviations is small, indicating a stable development of the efficiency of sports venue allocation in China. However, the difference between the maximum value and the minimum value is large, and there is more room for improvement in areas with low efficiency in the allocation of sports venue resources.

3.2. Evolutionary Characteristics of the Efficiency of Sports Venue Resource Allocation. Figure 3 presents a two-dimensional plot of the kernel density estimates of the efficiency of sports venue resource allocation in China from 2013 to 2017. The kernel density analysis is presented below in terms of the position, shape, and kurtosis of the curves in the graph.

In terms of position, the opening and closing values of the kernel density curve for 2013 to 2017 show an overall "rightward shift" trend, with a relatively stable position of the density function. The center of the kernel density curve did not change significantly during the period under examination, however, there were significant differences between the zones of variation, indicating large regional differences.

In terms of shape, the kernel density curve from 2013 to 2016 roughly shows a single-peaked distribution, exhibiting a higher level of agglomeration. However, in 2017, the allocation efficiency of sports venue resources showed a significantly skewed distribution, and the shape of the curve did not show a strict single-peaked shape, however, a multipeaked pattern and the sum density corresponding to the first wave was much higher than the nuclear density corresponding to the other

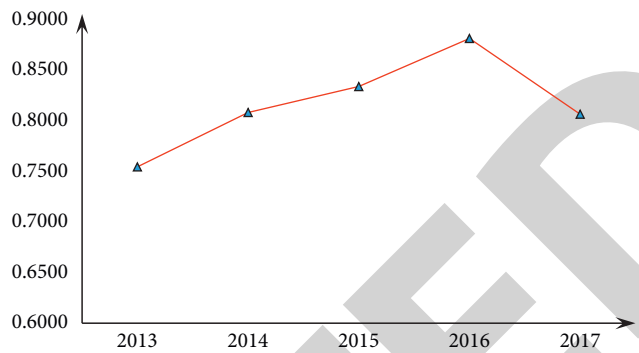

Figure 4: Polarization index of the efficiency of the allocation of sports venues in China.

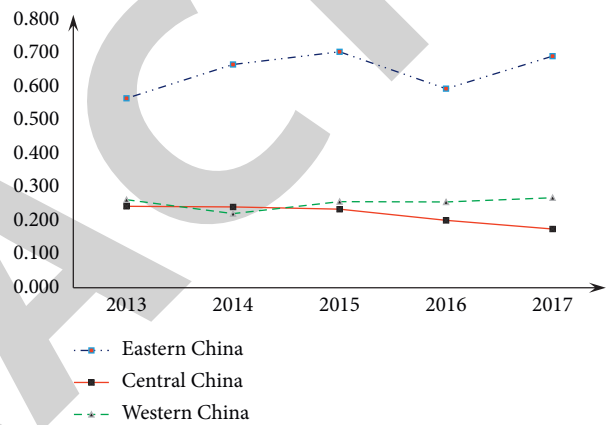

Figure 5: Polarization index of the efficiency of the allocation of sports venues in the three major regions of China.

wave peaks. The above analysis shows that the proportion of provinces, municipalities, and autonomous regions with relatively low efficiency in allocating sports venue resources is much higher than the proportion of provinces, municipalities, and autonomous regions with relatively high efficiency in allocating resources. The kernel density curve for 2017 shows a clear bimodal distribution compared to the other years examined, with fewer areas clustered with low values and more areas clustered with high values. It shows a certain degree of "club convergence," however, the degree of regional differentiation is still high.

In terms of kurtosis, the distribution of sports venue resource allocation efficiency in all provinces, municipalities, and autonomous regions in China during the period under examination shows a spike characteristic, with a clear form of spike performance. Compared with the wave height in the rest of the years examined, the wave height in 2017 was significantly higher, and the area of the allocation efficiency of sports venue resources in each province, city, and autonomous region corresponding to each wave increased.

3.3. Spatial Polarization Analysis of the Efficiency of Sports Venue Resource Allocation. Figure 4 expresses the development trend of the Esteban-Ray index of sports venue resource allocation efficiency for each province, city, and autonomous region in China from 2013 to 2017. To deepen

the understanding of the ER index of sports venue resource allocation efficiency in China, the ER polarization index of sports venue resource allocation efficiency in the three major regions of China (eastern region, central region, and western region) were studied separately, and the ER indices of the three major regions are shown in Figure 5.

From 2013 to 2017, ER ϵ [0.7517, 0.8028] for the allocation efficiency of sports venues in China, with the ER index taking values closer to 1, which indicates a high degree of polarization. The polarization index showed a trend of "fluctuating upward and then slowly decreasing" during the period under study. The above analysis indicates that the efficiency of the allocation of sports venue resources in China evolved from regional agglomeration to regional equilibrium during the study period.

Looking specifically at the three regions of East, Central, and West China, the ER index evolved differently in each of the three regions over the period examined. The average growth rate of the ER index for the efficiency of sports venues in the east, west, and central regions is 4.46%, 8.53%, and −5.61%, respectively, with the ER index in the east showing an "N-shaped" evolution, specifically the amplitude of increase and decrease changes. The ER index in the western region changed to a lesser extent from 2013 to 2014, and the ER index in the region was stable from 2014 to 2017. The ER index in the central region showed an evolutionary trend of decreasing year by year, and from 2013 to 2015, the ER index values in the central and western regions were less different from the evolutionary trend. Index values and evolutionary trends differ to a lesser extent, with significant differences in efficiency values between the two regions in 2015–2017.

From 2013 to 2017, the ER index of the allocation efficiency of sports venues in the eastern region was higher than that in the central and western regions. In the west, the ER index of sports venue resource allocation efficiency was lower than that of the central region only in 2014, while the ER index of sports venue resource allocation efficiency was higher than that of the west at other points in time, thus showing a spatial pattern of "east > central > west" from 2014 to 2017. Allocation efficiency refers to the optimal combination of input factors to produce the optimal product quantity combination. Under the condition of constant input, through the optimal combination and effective allocation of resources, efficiency will be improved and output will increase.

4. Conclusions and Insights

The efficiency of sports venue resource allocation in China generally shows a fluctuating upward trend, with significant and gradually increasing differences among the three major regions. The development of the sports economy and related industries has led to frequent adjustments in the total amount of skilled personnel, capital investment, and the structure of the sports industry in different regions of China. It maps onto the basic carrier of sports venue development—the allocation of sports venue resources. Changing the material circulation path within the sports venue resource allocation system and the information exchange mechanism with the external system eventually leads to fluctuations in the trajectory of changes in the efficiency of China's stadium venue resource allocation and the heterogeneity of its overall distribution state. According to the GIS visualization results and the results of sports venue resource allocation efficiency, the growth change rate of China's sports venue resource allocation efficiency between 2013 and 2017 is specifically shown as "+9%, 3%, 8%, 2%," indicating that the growth change index shows a trend of one high and one low change, and the efficiency growth index is unstable. At the level of provinces, municipalities, and autonomous regions, as well as at the level of the three regions of East, Central, and West, the efficiency of the allocation of sports venues shows a significant spatial unevenness. At the same time, compared with 2013, the range of changes in the kernel density curve of sports venue resource allocation efficiency in 2017 is significantly larger, and the regional gap has widened.

The polarization of the efficiency of the allocation of sports venues in China has become apparent. In general, the polarization curve is in the shape of "∧", i.e., a trend of growth followed by a decline. Because of the unique socioeconomic attributes of sports venues, the overall distribution pattern of the allocation efficiency of sports venue resources is susceptible to the interference of external factors, such as regional economic development and local land policies, and thus shows instability. Especially in the context of regional economic development polarization, the evolution of the sports venue resource allocation system has also shown significant polarization. The analysis of the literature review shows that regional economic development is one of the main influencing factors on the allocation of sports venue resources, thus making the degree of polarization and the specific path of polarization vary from region to region. The results of the Esteban-Ray index show that the polarization index of the efficiency of the allocation of sports venues in China and the three major regions have different trends over the period examined, with the polarization index of the efficiency of the allocation of sports venues in China showing "∧" pattern, while that of eastern China showing an "N" pattern of "rising-falling-rising." Central China shows a slow decline year by year, with an average rate of change of only 6%. Western China shows no significant change and is basically stable. It shows that the regional changes in eastern China play a dominant role in the polarization of the overall efficiency of the allocation of sports venues in China. At the same time, there are obvious differences in the degree of polarization among the three regions, showing obvious stage characteristics.

This paper considers China's sports venue resource allocation system as a whole and examines the regional heterogeneity and polarization pattern of China's sports venue resource allocation efficiency during the period under study. In the process of spatial pattern evolution, excessive polarization of sports venue resource allocation should be avoided as far as possible, and a diversified production factor communication mechanism should be constructed in terms of land resource endowment, capital investment, and local

economic development in different regions, so as to give full play to the energy diffusion effect of the high-level development area of the urban construction land system on the peripheral areas. It should also analyze the path of energy-level upgrading of sports venue resource allocation efficiency in noncore or peripheral areas through industrial structure upgrading, land management system innovation, and legal and rational use of government policies to find the optimal upgrading path. To ensure the rationality of the allocation pattern of production factors in different regions and the allocation of factors at different stages of development in the same region, efforts should be made to narrow the regional differences in the allocation efficiency of sports resources because of economic, social, and natural environment factors, and to promote the balanced development of each region as a whole [26, 27].

Data Availability

The data underlying the results presented in the study are available within the manuscript.

Disclosure

Jian Cao and Jie Geng are co-first authors.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

All authors have seen the manuscript and approved to submit to your journal.

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Research Article

An Optimal SDN-Based Wavelength Allocation and Routing Method for 5G Network

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Optical networks are changing as new advanced technologies emerge. With each passing year, their sizes and capabilities expand. The standard architecture for network control and management cannot handle all of these complexities. The proliferation of cloud services and the massive volume of traffic provided by content delivery networks are driving the present fast increase in Internet traffic. This obviously exacerbates congestion concerns in communication networks, with a focus on the core and backbone components in particular. Software-defined networking (SDN) is evolving into a consolidated network management system that comprises a variety of strategies aiming at network management that are based primarily on one basic principle: decoupling control plane decisions from data plane activities. An essential resource allocation strategy in an all-optical network is routing and wavelength assignment. A novel SDN-based approach is proposed to address the problem of old methods mixed with new architecture in optical networks. The network resources were optimized for optimal scheduling using a binary hybrid topology particle swarm optimization method. In terms of recovery time, blockage rate, and resource consumption, simulation results demonstrate that the suggested technique outperforms previous classical methods.

1. Introduction

The all-optical network has the characteristics of all-optical domain information exchange [1]. It abandons the traditional photoelectric conversion mode, greatly improves the data transmission speed, and effectively increases the capacity of information exchange. It is receiving more and more attention from the industry [2, 3], simultaneous routing and wavelength allocation (RWA) as its resource allocation has always been a research hotspot, and many methods have been proposed [4, 5] to improve the efficiency of resource allocation. With the introduction of software-defined network (SDN), many traditional applications in the industry are facing challenges. It has become a problem that needs to be analyzed at present, so this article conducts research from this perspective.

In an optical network, information is transmitted through different wavelength channels in different links. RWA is a method of selecting appropriate links and matching corresponding channels according to transmission requirements to realize information transmission. It operates in two main ways: static RWA and dynamic RWA. Among them, the static method is relatively stable and the scheduling success rate is high, but it is difficult to adapt to the needs of complex network changes, the resource utilization rate is low, and the allocation method is not flexible enough. The dynamic mode usually operates in an online mode, and can be deployed in a timely manner according to the changes in the network. Different operation modes have different influences on the operation effect of the system, so it has always been the focus of research, and the dynamic mode is the research object of this article.

In view of this, this article proposes an SDN-based multi-objective adaptive routing and wavelength allocation (SO-MO-RWA) method.

The main contributions of this work are as follows:

(i) This method takes into account the need for high-speed transmission and efficient link scheduling in all-optical networks, and takes scheduling time and link quality as joint scheduling goals.

(ii) A 0–1 integer programming RWA problem model is constructed, and binary hybrid topology particle swarm optimization is used to solve the problem.

(iii) The whole method adopts the scheduling method based on SDN, which can obtain the status information of network resources in real time, and realize the dynamic allocation of network resources in an on-demand manner.

The remaining article is organized as follows. In Section 2, the related work is described. In Section 3, the proposed framework is discussed in detail. In Section 4, the proposed system model is discussed. In Section 5, the proposed algorithm is explained and pseudocode. Section 6 provides the numerical results while Section 7 concludes the article.

2. Literature Review

The research content of RWA can be analyzed from the following aspects. First, different evaluation indicators are set from different research angles, such as resource allocation ratio, link damage perception, and blocking rate [6] proposed a minimum-hop fixed-alternating algorithm to reduce the blocking rate based on the research of fixed routing, alternate routing, and adaptive routing methods of RWA. Tyagi et al. [7] studied the connection blocking rate minimization problem in the RWA problem by using an improved water drop algorithm for dynamic optical networks. Abdo and D'Amours [8] estimated the calculated optical path quality on the basis of establishing a linear physical layer damage model, and proposed a dynamic damage-aware RWA scheme. This method collects link wavelength occupancy information and adopts adaptive routing technology to establish suitable links. Marsden et al. [9] proposed a fast computational method for routing and wavelength assignment involving four-wave hybrid-induced crosstalk to minimize the time to establish a dynamic optical path. Wang et al. [10] evaluated the performance indicators of the physical layer impairment RWA (PLI-RWA) algorithm based on the classification of physical layer damage and the comprehensive research on RWA-related algorithms. Velasco et al. [11] designed a probabilistic model to calculate the number of wavelengths used in each link in an optical network, and on this basis, proposed a novel damage-aware RWA algorithm. The above methods can be analyzed and designed according to the state index of the link, but they are mainly based on single-index scheduling and fail to consider the scheduling needs under complex scheduling conditions.

Second, different scheduling methods will have an impact on the operating effect of the system. Yu et al. [12] developed a set of heuristic algorithms for all-optical networks that can solve the RWA issue in polynomial time while consuming less energy from network resources. Jaumard and Daryalal [13] studied the problem of optical path rearrangement in RWA and used the e-optimal method to evaluate the minimum number of optical path rearrangements required to maximize the service level. Virgillito et al. [14] proposed a routing and wavelength allocation algorithm based on prediction and hierarchical graph model, considering the needs and characteristics of service differentiation, and realized routing and wavelength resource allocation through the wavelength number prediction mechanism combined with the hierarchical graph model. Ricciardi et al. [15] can realize the balanced utilization of network resources through dynamic switching between load balancing and energy sensing according to the network load in the process of link resource allocation. Pavarangkoon and Oki[16] proposed a routing and wavelength allocation scheme considering all-optical carrier replication to minimize wavelengths required for multi-carrier distributed networks with wavelength reuse. According to the nondeterministic polynomial (NP) characteristics of the RWA problem in optical networks, Hsu et al. [17] proposed an algorithm based on the maximum disjoint path to achieve routing and wavelength allocation. The above researches have carried out algorithm design according to the problem scenarios studied, but there is still a lack of design and research on specific scheduling methods under the platform structure similar to SDN.

The proposal of SDN provides a good opportunity for the development of optical networks. In recent years, many scholars have also conducted a lot of research on the integration of optical networks and SDN. Aiming at the inefficiency of traditional configurations, Moreno-Muro et al. [18] proposed an efficient topology discovery method based on SDN using the test signal mechanism and the OpenFlow protocol, allowing the transparent optical network (TON) to automatically learn the physical adjacency between optical devices, to improve the efficiency of data transmission. The development of the optical network is accompanied by an increase in complexity, which makes the traditional network control and management framework unable to match it. Literature [19, 20] expound on various management and control mechanisms and applications in SDN optical networks. Yan et al. [21] considered that a full understanding of the current network state is crucial for better realization of software-defined schedulability in a short period of time, and designed a centralized network database that combines network monitoring data and network configuration information to enable network analysis. Applications can better support dynamic programmable optical networks. Zhou et al. [22] proposed a joint SDN controller architecture for optical networks, which fully combines clustering strategies with rich hierarchical path computation to improve routing performance. Considering the exponential data rate growth of the optical network in the future, Mata et al. [23] used cognitive technology to analyze and design

the optical layer and controller of SDN. Literature [24, 25] proposed a data center virtualization architecture with a corresponding all-optical SDN structure, which can provide a data expansion environment on demand, realize dynamic segmentation of network and computing resources, dynamically translate and provide requests from virtual data centers to the optical layer, and provide users with high-bandwidth and low-latency connection services. The above literature has studied the technology integration and application of SDN and optical network from different perspectives, but there is still a lack of research on how to carry out the specific scheme of path resource allocation such as RWA under the new network architecture.

3. Proposed Framework

SDN is a new type of network architecture and its core idea is to change the traditional way of integrating control and scheduling, decoupling control plane and data plane functions, and through network programmability and network function virtualization. It realizes the flexible scheduling of network resources and improves the overall operation efficiency of the system. At the same time, with the continuous improvement of the technical level, the all-optical network is becoming an important information transmission carrier of the global Internet backbone network by virtue of its own transmission characteristics. It is of broad interest [26, 27], and the International Internet Engineering Task Force (IETF) also defines the structure accordingly. The structure of the all-optical network based on SDN is shown in.

The SDN-based all-optical network structure is mainly composed of three layers: the application layer, the control plane, and the data plane. The top layer is the application layer, which corresponds to various application requirements, such as the data center services [28] and cloud tenant applications. The second layer is the control plane, and its core component is the controller. The controller connects with the application layer through the northbound interface and provides different interface protocols to meet the compatibility with different applications. The southbound interface is connected to the data plane. The southbound interface is responsible for docking with infrastructure resources and can support multi-vendor and multi-protocol scenarios. The main protocol is OpenFlow, which adopts the form of character stream and can accommodate transmission formats of different networks and provides a unified data transmission interface. At the beginning of the SDN design, it was mainly aimed at IP networks, and did not consider the signal transmission characteristics of optical networks. Therefore, in recent years, related research has also expanded the structure of OpenFlow [29, 30] to adapt it to the transmission mode of optical networks. The main functional modules of the controller include resource management, topology management, scheduling algorithm module, network service abstraction, etc. The bottom layer is the data plane, which is mainly composed of all-optical network infrastructure, such as optical cross-connector (OXC), reconfigurable optical add-drop multiplexer (ROADM), and wavelength selective switch (WSS). In the process of integration with SDN, many new devices also have built-in OpenFlow protocol [31] to realize direct interaction with the controller, but most optical network devices currently cannot support direct interaction with the controller, so the proposed OpenFlow Protocol Agent (OA) [32] is responsible for the forwarding of information between the controller and the optical switching equipment, and realizes the seamless connection between the signal transmission and the all-optical domain switching under the SDN structure Figure 1.

In traditional networks, users obtain resource information in an end-to-end manner, and resource allocation in all transmission processes cannot be adjusted in real time as needed due to the limitation of the scheduling structure. The network function virtualization (NFV) realizes the abstraction of network resources, realizes network functions through software methods, and completes the deployment of resource service functions, which can not only optimize the transmission path of information flow and flexibly allocate information transmission flow, but also it can shorten the service scheduling period and improve the scheduling efficiency of resources. With the combination of SDN and NFV, the flexibility of all-optical network resource scheduling has been effectively improved, and resources can be allocated on demand without being limited to a certain region, equipment, or a certain supplier. In this context, the IETF gives the service function chain. The concept of service function chaining (SFC) [33] corresponds to the allocation of a series of resources required for end-to-end transmission. Under the all-optical network structure based on SDN, this method can dynamically allocate functional nodes carrying services according to business logic, and realize network function services and resource deployment. During the running process, the service abstraction module of the controller abstracts several resources required by the service according to the business requirements, and provides corresponding service function instances. At the same time, the scheduling algorithm selects resources according to the network status information provided by the resource management module. Perform resource mapping of service functions, realize resource scheduling with different granularities, and adapt to resource selection of optical network links and optical path construction. The resource allocation method of the service function chain has positive significance for the all-optical network, solves the problems of traditional scheduling inefficiency and resource waste, further improves the reconfiguration of network resources, and realizes efficient network management and rapid and effective resource allocation.

4. System Model

In the process of resource virtualization scheduling by SDN, infrastructure resources such as links and corresponding wavelengths carry data traffic. Therefore, in order to provide effective transmission services in the process of service function chain resource deployment, it is necessary to

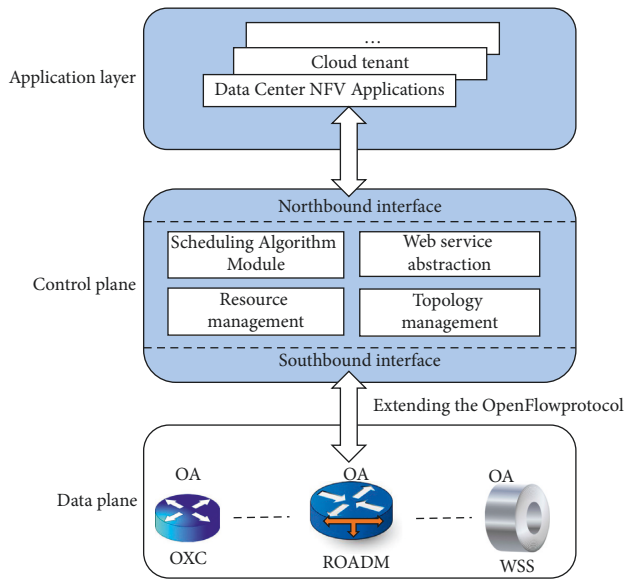

Figure 1: Proposed optical network structure.

comprehensively consider the transmission quality and link quality of optical communication. Factors such as road scheduling efficiency.

4.1. Scheduling Indicator Design. The RWA is considered to be an effective means for all-optical networks to solve resource allocation. In the scheduling process of RWA, the SDN controller adjusts the link resources according to the established scheduling goals of RWA by sensing the physical damage information and resource allocation status of the network link. Based on the characteristics of all-optical network scheduling requirements, this article takes scheduling time and link quality as scheduling goals. Among them, the scheduling time refers to the time spent in a series of processes from accepting requests and executing path planning to resource mapping. When the SDN controller receives a service request, it abstracts the service function of the requested resource using the resource allocation method of the service function chain and generates a series of service function sets (SFS), each of which consists of multiple service function instances (SFI) that can be provided by different service providers, to realize the construction of complete link resources. Therefore, m service function sets SFS_1, SFS_2 ,. . ., SFS_m can be obtained, when scheduling service instances inside the service function set follows a heavy-tailed distribution, and the request time of each service function instance obeys the Poisson distribution, and the corresponding average arrival rate is $\lambda_1, \lambda_2, \ldots, \lambda_n$, according to network traffic characteristics [34]. The appointment time for the service T_i is the service instance that is expressed as:

$$T_i = \frac{\overline{h}_i^2}{2\overline{h}_i\left(1-\lambda_i\overline{h}_i\right)}\left[1+\frac{1-\lambda_i\overline{h}_i}{\lambda_i\overline{h}_i}\right]^{-1}. \tag{1}$$

Among them, λ_i represents the request arrival rate of SFI_i, $\overline{h}_i$ and $\overline{h}_i^2$ represent the first-order moment and the second-order moment of the scheduling time, respectively, as shown in (2) and (3), respectively.

$$\overline{h}_i = \frac{\alpha}{\alpha-1}\frac{k^\alpha}{1-(k/p)^\alpha}\left(\frac{1}{k^{\alpha-1}}-\frac{1}{p^{\alpha-1}}\right), \tag{2}$$

$$\overline{h}_i^2 = \frac{\alpha}{\alpha-2}\frac{k^\alpha}{1-(k/p)^\alpha}\left(\frac{1}{k^{\alpha-2}}-\frac{1}{p^{\alpha-2}}\right). \tag{3}$$

The probability density function of the heavy-tailed distribution is

$$f(x) = \frac{\alpha k^\alpha}{1-(k/p)^\alpha}x^{-\alpha-1}, \quad k \le x \le p. \tag{4}$$

Link quality is an important indicator of network transmission. During the operation of an all-optical network, due to optical propagation characteristics and other reasons, the signal will be affected by optical loss, crosstalk, etc., resulting in signal damage. The SDN controller has a global network view, can perceive the network topology status information in real time, and evaluate the physical damage of the optical path according to the information change, and judge the service status of different links to provide the basis for link allocation. The evaluation models mainly include optical signal-to-noise ratio (OSNR) and Q factor. In practical applications, the Q factor model is widely used due to its good adaptability to different measurement environments. The calculation of the Q factor model will involve different physical damage indicators, so as to comprehensively evaluate the line, including cross-phase modulation (XPM), four-wave mixing effect (FWM), amplified spontaneous emission (ASE), etc., so the SFI_i's link quality calculation is shown in (5) as follows:

$$\begin{aligned} Q &= 10\log\frac{P_s}{\sigma_{\text{total}}+\sigma_0} \approx 10\log\frac{P_s}{\sigma_{\text{total}}}, \\ \sigma_{\text{total}}^2 &= \sigma_{\text{ASE}}^2+\sigma_{\text{FWM}}^2+\sigma_{\text{XPM}}^2. \end{aligned} \tag{5}$$

Among them, σ_{total} represents the standard deviation of cross-phase modulation, four-wave mixing effect, and amplified spontaneous emission, P_s represents the power peak value of the corresponding optical channel, and σ_0 represents the intensity standard deviation when the signal is 0.

4.2. Objective Function definition. Based on the preceding analysis and definition, an SDN-based multi-objective adaptive routing and wavelength allocation model is built. On the infrastructure of different service providers, the unified control logic of SDN is used for scheduling, and the virtualized configuration of service resources is performed by using the characteristics of network programmability, so as to realize the effective deployment of RWA. During the resource deployment process, the following points need to be considered: (1) construction of service function sequence; (2) the choice of service infrastructure provided by different suppliers; and (3) select the matching optical path according to the scheduling objectives and constraints. Combined with the above analysis, this article constructs the resource allocation problem of all-optical network based on SDN as a 0–1 integer programming problem, and its model can be

expressed as $M = (C, I, W)$, where C represents the abstraction by the network as needed constructed service function chain consists of service function sets; I represents the link resource instance inside the service set; and W represents the set of bands available within the link resource. The corresponding objective function is defined as.

$$\begin{aligned}
&\min \sum_{k=1}^{m}\sum_{j=1}^{n_j}\sum_{i=1}^{w_i}\left(\omega_1 T_{kji} + \omega_2 \frac{1}{Q_{kji}}\right)X_{kji},\\
&s.t\\
&1)Q_{kji} \geq Q_{\text{th}},\\
&2)B \geq B_{\text{th}},\\
&3)X_{kpi} = X_{kqi}, \quad p, q \in \{1, \ldots, n_j\},\\
&4)X_{kji} \in \{0, 1\}, \quad i \in \{1, \ldots, w_i\},\\
&\quad j \in \{1, \ldots, n_j\}, \quad k \in \{1, \ldots, m\},\\
&5)\sum_{j=1}^{n_j}\sum_{i=1}^{w_i} X_{kji} = 1, \quad j \in \{1, \ldots, n_j\},\\
&\quad i \in \{1, \ldots, w_i\},\\
&6)\omega_1 + \omega_2 = 1, \quad \omega_1 > 0, \quad \omega_2 > 0.
\end{aligned} \tag{6}$$

Among them, Q_{th} and B_{th} represent the Q factor threshold and bandwidth capacity threshold, respectively. The k, j, i, m, n_j, and w_i, respectively, represent the service function set in the chain, the link resource instance, the resource variable corresponding to the band set available for the link, and the corresponding resource quantities for j-th and i-th instances.

The model integrates the two indicators of link quality and scheduling time to achieve fast and efficient resource scheduling. The corresponding constraints are described as follows: (1) Q factor threshold, the selected link needs to meet the specified threshold to ensure that the channel quality of the selected link meets the transmission requirements; (2) bandwidth capacity threshold, provide effective bandwidth according to business requirements, and ensure the transmission requirements of QoS; (3) wavelength consistency, the link sequence adopts a unified wavelength; (4) the value of X is 1 or 0 to represent whether the corresponding resource is selected or not; (5) guarantee the uniqueness of the allocation of optical path resources; and (6) weight constraints.

5. Proposed Algorithm

Since RWA is an NP-complete problem, the scheduling algorithm directly affects the performance of the proposed SO-MO-RWA algorithm. According to the characteristics of the proposed model, the binary hybrid topology particle swarm optimization (BHTPSO) algorithm [35] is used to solve the path planning problem.

5.1. Description. The particle swarm optimization (PSO) algorithm is widely used in different fields due to its high search efficiency and has also developed multiple versions. Among them, the binary particle swarm optimization (BPSO) algorithm is often used to solve NP optimization of discrete space problems such as integer programming. The BHTPSO is optimized for the shortcomings of BPSO, which is easy to fall into the local optimal solution and slow in the convergence speed, which effectively improves the performance, accelerates the convergence speed while avoiding the local optimal solution, and further improves the efficiency of solving integer programming problems.

Like BPSO and PSO, the BHTPSO is also obtained by discretization based on the hybrid topological particle swarm optimization (HTPSO) algorithm. In BHTPSO, vectors $(\mathbf{X}_i, \mathbf{V}_i, \quad \mathbf{P}_{\text{best}_i})$ represent the position, velocity, and optimal position of the i-th particle, respectively, $\mathbf{P}_{l\text{best}_i} = (p^1_{l\text{best}_i}, p^2_{l\text{best}_i}, \ldots, p^d_{l\text{best}_i}, \ldots, p^n_{l\text{best}_i})$ and $\mathbf{P}_{\text{gbest}} = (p^1_{\text{gbest}}, p^2_{\text{gbest}}, \ldots, p^d_{\text{gbest}}, \ldots, p^n_{l\text{best}_i})$ represent its neighbors, respectively. The optimal position is found by the particle and the optimal position obtained by the entire population. BHTPSO uses a combination of local topology and global topology to search, and the next velocity of the i-th particle is

$$\begin{aligned}
v^d_i(t+1) = {} & w(t)v^d_i(t) + c_1(t)\text{rand}_1\left(p^d_{\text{best}_i}(t) - x^d_i(t)\right)\\
& + c_2(t)\text{rand}_2\left(p^d_{l\text{best}_i}(t) - x^d_i(t)\right).
\end{aligned} \tag{7}$$

Among them, the inertia weight $w(t)$ is

$$w(t) = w_{\max} - \frac{t\left(w_{\max} - w_{\min}\right)}{T}. \tag{8}$$

The next position of the current particle can be obtained according to the group optimal $\mathbf{P}_{\text{gbest}}$, as shown as follows:

$$\begin{aligned}
x^d_i(t+1) = {} & x^d_i(t) + v^d_i(t+1)\\
& + c_3(t)\text{rand}_3\left(\mathbf{P}_{\text{gbest}}(t) - x^d_i(t)\right).
\end{aligned} \tag{9}$$

Among them, the acceleration factors c_1, c_2, and c_3 are calculated by (10).

$$c_j(t) = c_{j\min} + \frac{t\left(c_{j\max} - c_{j\min}\right)}{T}, \quad j = 1, 2, 3. \tag{10}$$

In order to improve the ability to explore unknown solutions, the algorithm expands the search range in the early stage of the search to highlight the effect of the global search. With the increase of the number of iterations, the global search is weakened and the local search is accelerated to obtain the optimal solution. During this period, the optimal solution of each particle needs to be obtained with reference to $\mathbf{P}_{\text{best}_i}$, $\mathbf{P}_{l\text{best}_i}$ and $\mathbf{P}_{\text{gbest}}$.

(1) Initialization: Particle X^i, velocity V_i, position $\mathbf{P}_{\text{best}_i}$, and the number of iterations.
(2) Get $\mathbf{P}_{l\text{best}_i}$, update particle velocity.
(3) Calculate the next position of the particle through the velocity $v_i^d(t+1)$, the group optimal position $\mathbf{P}_{\text{best}}$, etc.
(4) If the conditions are met, end the operation to derive the optimal solution, otherwise update $\mathbf{P}_{l\text{best}_i}$, $\mathbf{P}_{\text{gbest}}$, and go to step 4.
(5) Update parameter w.
(6) Update parameters c_1, c_2, c_3.
(7) If the optimal position does not change in multiple iterations, add the E value to jump out of the local search, and perform step 1.

Algorithm 1: Proposed SO-MO-RWA scheme.

In the discretization process of the BHTPSO algorithm, the velocity of the particle is calculated by (11). The speed of the particle is directly related to the position change, that is, 0 means that the current position of the particle does not need to be changed and 1 is the opposite.

$$S(a) = |\tanh(a)|. \tag{11}$$

In order to avoid the phenomenon of stagnation in multiple iterations and the inability to obtain the optimal solution, the E value shown in (12) can be added to (11) to jump out of this iteration and continue to accelerate the convergence.

$$E = \operatorname{erf}\left(\frac{NF}{T'}\right) = \frac{2}{\sqrt{\pi}}\int_0^{NF/T'} e^{-t^2}\,\mathrm{d}t. \tag{12}$$

Thus, the next position of each particle is shown as follows:

$$\begin{cases} a_i^d(t+1) = v_i^d(t+1) + c_3(t)rand_3\left(p_{\text{gbest}}^d(t) - x_i^d(t)\right) \\ S\left(a_i^d(t+1)\right) = E + (1-E)\left|\tanh\left(a_i^d(t+1)\right)\right| \\ x_i^d(t+1) = \begin{cases} \text{complement}\left(x_i^d(t)\right), rand_4 < S\left(a_i^d(t+1)\right) \\ x_i^d(t), \text{otherwise} \end{cases} \quad i = 1, 2, \ldots, N. \end{cases} \tag{13}$$

In the process of solving the proposed method, each particle X^i represents a link candidate solution, and the objective function is used as the fitness function. The calculation steps are described as follows in Algorithm 1.

5.2. Parameter Optimization. Parameter optimization requires particle swarm optimization to select suitable parameters for specific problems to improve the computational efficiency of the model (Figure 2).

(1) Inertia weight: for the value range of the inertia weight, this article selects the four intervals [0.1, 0.2], [0.3, 0.6], [0.7, 0.9], and [1.0, 1.2] for experiments, as shown. The test results of different interval values show that in the continuous iterative process, they show different variation amplitudes, and when the parameter values are [0.1, 0.2] and [0.3, 0.6], the operating effect of the system is optimal. Furthermore, the impact when parameter value is [0.1, 0.2] is better than [0.3, 0.6].

(2) Acceleration factor: there are three acceleration factors in this algorithm: c_1, c_2, and c_3. According to experience, when the values of particle swarm optimization c_1 and c_2 are close to or equal to the value of the system, the system works well, so the parameters are set in three cases, and two of them are set to equal values, which are 1.5 and 1.5, respectively; 2.5, the other is to equalize c_1, c_2 and differentiate the value of c_3. As shown in, the test results show that when the value of c_3 is differentiated, the operating effect of the system is better than the case where the three values are the same.

(3) Number of particles: in order to test the effects of different numbers of particles on the system, this article selects 4 particle numbers of 30, 50, 70, and 100 in a gradient. The parameter settings such as acceleration factor and inertia weight are consistent in scenarios with different particle numbers, as shown in. The experimental results show that when the number of particles is $N = 100$, the system works best, that is to say, when the number of particles is large, the operating efficiency of the algorithm can be improved.

(4) Maximum particle update speed: in the maximum particle update speed test, the three values of 3, 6, and 9 are uniformly selected, as shown in. When $v = 6$, the test results are better than the other two cases, indicating that the update speed should be kept at a relatively moderate value is preferred.

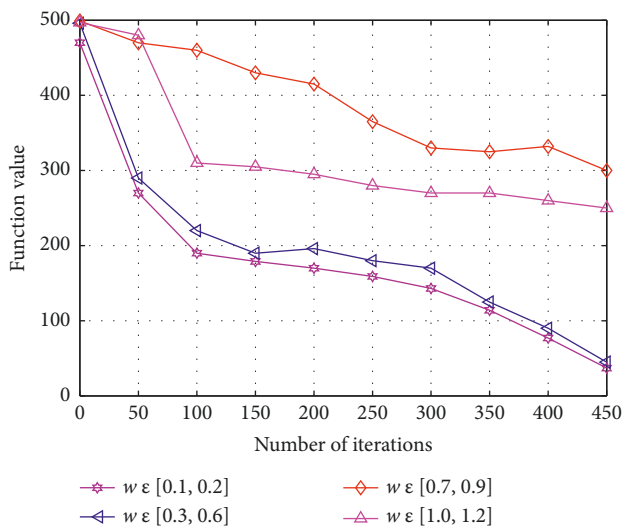

Figure 2: Inertia weight parameter test.

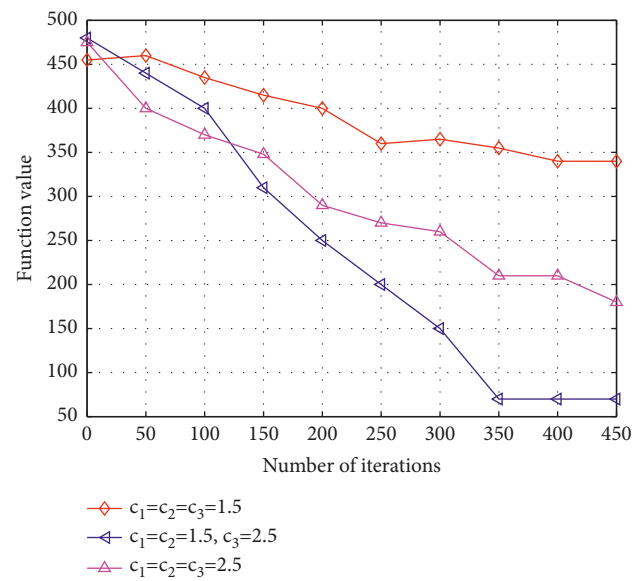

Figure 3: Acceleration factor parameter test.

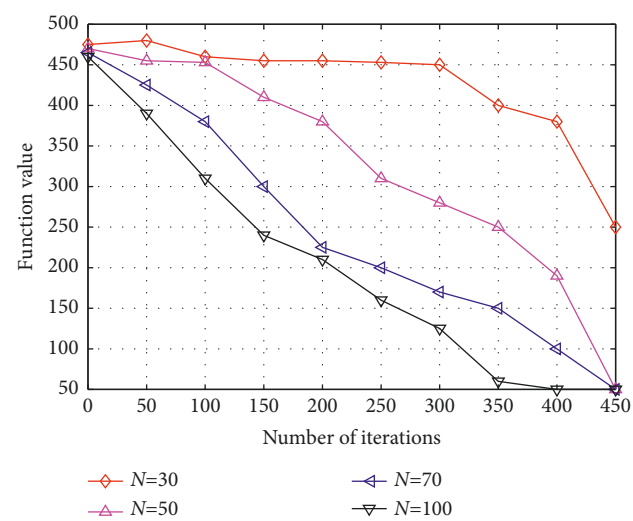

Figure 4: Particle number parameter test.

Compared with the BPSO algorithm, the BHTPSO algorithm further improves the performance of obtaining the global optimal solution. Figure 3 When solving integer programming problems, the BHTPSO algorithm can find the optimal feasible solution in the solution space according to the corresponding search strategies and rules. Compared with the traditional method, the BHTPSO algorithm can face the situation that the solution space is too large and the complexity increases, making it difficult to calculate. It can better adapt to the change of the solution space and obtain a better approximate optimal solution. At the same time, in order to effectively evaluate the accuracy of the calculation results of the algorithm, this article chooses to compare with the implicit enumeration method. As a classification of branch and bound method, implicit enumeration method is mainly used to calculate 0–1 integer programming problem, and this method can usually obtain the optimal solution of the problem. Based on the model defined in this article and the setting of parameters, the calculation result of the implicit enumeration method is 40.78. In order to ensure the validity of the calculation result of the BHTPSO algorithm, the interval estimation method is used to statistically analyze the effective range of its numerical value, and the confidence level is set to 0.95. Figure 4 According to the statistics of the operation results, the optimal solution obtained by the BHTPSO algorithm conforms to the normal distribution $N(\mu, \sigma^2)$ with the parameters $\mu = 41.17$ and $\sigma = 0.42$, and the confidence interval is [41.02, 41.31], that is, the BHTPSO algorithm solves the accuracy of the difference between the optimal solutions in the range of 0.6%~1.3%. It is often close to the optimal solution, which shows that the algorithm can effectively solve the 0–1 integer programming problem Figure 5.

The complexity of the BHTPSO algorithm is mainly composed of two parts, one part is the scale of the problem itself, including the dimension D of the solution, the number of iterations I, the number of particles N, etc. In addition, it also includes the operation steps of various parameters of the particles in the solution process. It can be seen from the relationship that the complexity of the algorithm can be expressed as a function of the size of the problem, so the complexity can be expressed as O(D.I.N).

5.3. Model Process. The function realization of the whole model in this article requires the scheduling cooperation of multiple modules, and the scheduling process is shown in Figure 6. First of all, the system can perceive various link damages and status information of link scheduling at the bottom layer in real time. The information is aggregated into the resource management module and the multi-scheduling indicator information is provided to the BHTPSO algorithm for calculation. At the same time, the perceived resource dynamic request is transformed into a set of different functional components of the service function chain through network abstraction. After the

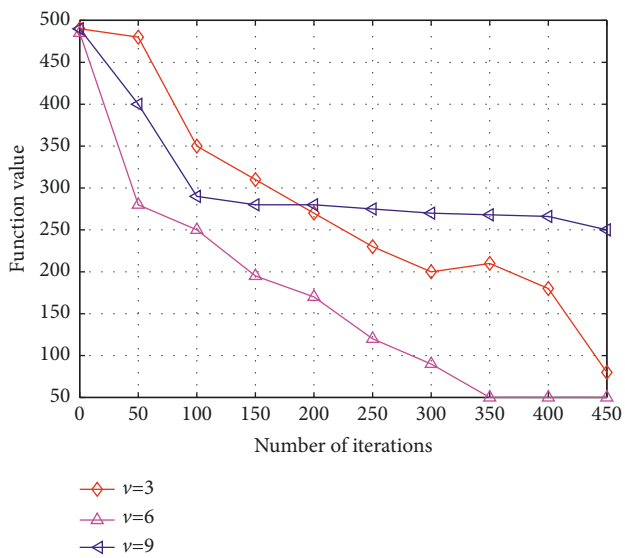

Figure 5: Maximum particle update speed parameter test.

optimization of the scheduling algorithm, a reasonable resource scheduling scheme, and finally, realize the resource reconstruction of the network by resource mapping through topology management. The SFC is transferred to BHTPSO scheduling algorithm, then its topology management is performed and finally, the patch optimal path switching is realized. If the link is damaged, then it is sensed and its information is feedback to the BHTPSO scheduling algorithm to determine the optimal route.

6. Simulation Results

In this article, a corresponding test platform is developed to simulate the proposed method. The test platform uses the discrete event simulator OMNeT++ to design the components and functions of the network. The test platform is configured with Intel i7, 8 GB DDR4 memory, Windows 7 64 bits. The network topology selects the European all-optical network standard test topology Pan-European [36], as shown in Figure 7, which includes 40 bands, 33 links, and 17 nodes, and the extended OpenFlow protocol is used to realize the communication between components. The relevant parameters are shown in Table 1.

The impairment-aware-based routing and wavelength assignment (IA-RWA) has always been considered as the main resource allocation method for optical networks. Two typical methods used in this article, the wavelength assignment by random-fit (IA-RWA-RF) and wavelength first impairment-aware-based routing and wavelength assignment by first-fit (IA-RWA-FF) were compared with the proposed method. The main routing algorithm adopted by the two methods is short-path priority, and resource allocation is realized in combination with their respective wavelength allocation forms.

6.1. Time of Recovery. It refers to the time from the perception of abnormal damage to the completion of system scheduling to realize resource reconstruction. For a large-capacity and high-speed transmission network such as an all-optical network, a shorter recovery time can further reduce the impact on the system and ensure the quality of service. This indicator is mainly to evaluate whether the system has the scheduling ability of efficient and flexible allocation of resources. For this reason, different numbers of failed links are set under different load conditions to test the scheduling effect of the system under different loads and failed links. At the same time, each case was tested 30 times, and the average value was taken as the valid test result. The experimental results are shown in Figures 8 and 9, respectively.

First, in the case of low load, as shown in Figure 8, when the number of failed links is in the range of (1) and (4), due to more available resources, the time used for IA-RWA-RF scheduling is slightly less than IA-RWA-FF with the increase of the number of failed links, the time used by IA-RWA-RF shows a continuous growth trend. Within the range of failed links in (5) and (10), the recovery time increases from 4.45 to 6.91 ms, and the growth rate reaches 55%. Compared with IA-RWA-RF and IA-RWA-FF, the SO-MO-RWA has a smaller variation in the time spent, and the curve is also flatter. Also in the range of (5) and (10), its recovery time ranges from 2.92 to 3.65 ms, an increase of 25%. Second, at higher loads, as shown in Figure 9, IA-RWA-RF takes more time than IA-RWA-FF, and both are higher than SO-MO-RWA. The experimental results show that in the range of (6) and (10) failed links, the three methods show certain differences, IA-RWA-RF from 5.13 to 7.91 ms with a 54% change, IA-RWA-FF from 4.64 to 6.25 ms with a 35% change, and SO-MO-RWA from 3.71 to 4.09 ms with a 10% change.

It can be seen from the test results that under different load conditions, the time spent by the proposed method is less than that of existing algorithms. The reasons are as follows: first of all, in terms of scheduling structure, SO-MO-RWA adopts the SDN controller to obtain the running status information of the link in real time through a unified control interface, and adaptively adjusts the link resources to ensure the continuous and effective service. Second, in terms of scheduling method, the virtualized resource scheduling method enables fast and flexible resource deployment and optimizes network resource configuration for business needs. Finally, the SO-MO-RWA takes the scheduling time as the goal, and selects an efficient global optimization algorithm to match the resources of the scheduling goal, which further improves the execution efficiency of the mapped resources and shortens the scheduling time. In contrast, the other two methods use short-path priority, which is simple but has local characteristics. It is necessary to further allocate optical paths on the basis of routing to achieve complete resource scheduling. The efficiency of resource allocation is relatively low, and it cannot be guaranteed that multiple paths occur and scheduling performance in case of link failure.

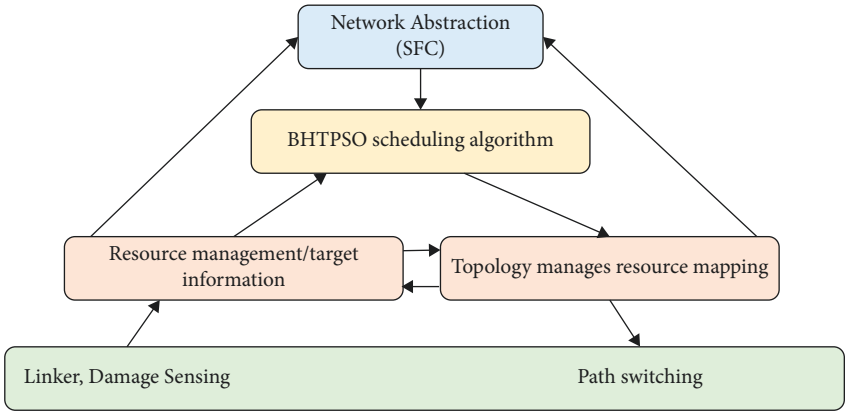

Figure 6: Proposed algorithm flowchart.

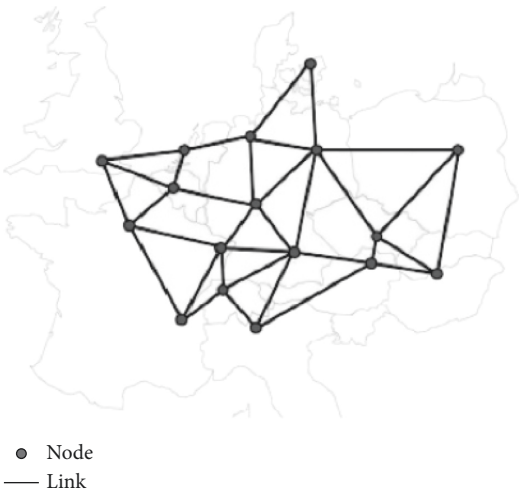

Figure 7: Deployed topology.

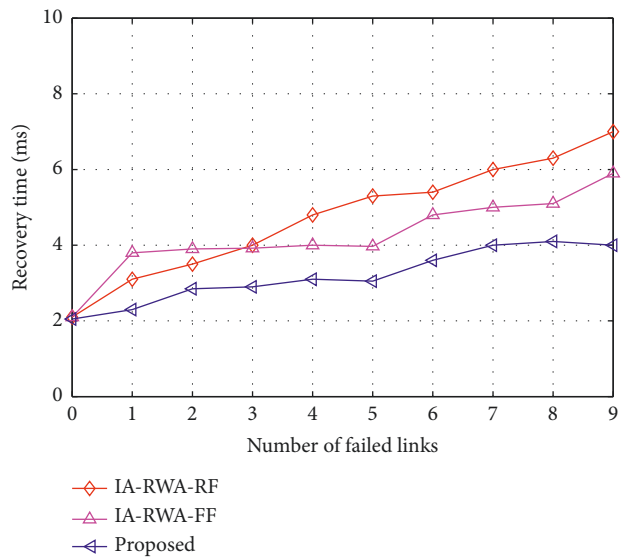

Figure 8: Recovery time under 100 Erlang conditions.

Table 1: Experimental parameters.

Parameter	Value
c_1	1.5
c_2	1.5
c_3	2.5
w_i	10~40
w	0.4~0.6
n_j	2~4
m	5~10
ω_1	0.6
ω_2	0.4
Number of iterations	500
Number of initial particles	100

6.2. Blocking Rate. The bandwidth resources of the optical network are composed of different wavelength channels, and different transmission requirements will allocate different bandwidths. In order to meet the requirements of wavelength consistency, different links should select the same wavelength channel to transmit signals. When some links cannot allocate effective resources, the scheduling will be blocked, and the blocking rate reflects the allocation of

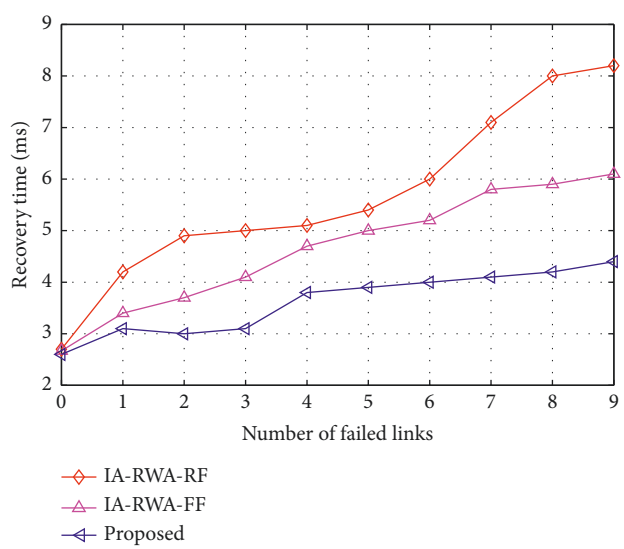

Figure 9: Recovery time under 300 Erlang conditions.

effective link resources. Since the resource scheduling methods of different algorithms directly determine the channel allocation method, this indicator is also an important indicator for evaluating the resource allocation performance of the scheduling algorithm. As shown in Figure 10, as the network load continues to increase, the three methods have different magnitudes of increase. Among them, due to the greater randomness of channel allocation, the load of IA-RWA-RF in (40, 200) blockage rate in the interval increased obviously, which was higher than that of IA-RWA-FF. Compared with these two algorithms, the index change of SO-MO-RWA is relatively gentle. In the load interval of (90, 160), its blocking rate changes from 2.19% to 2.47%, with an increase of 12.8%. The blocking rate of IA-RWA-RF and IA-RWA-FF increased from 2.52% to 4.24% and 4.03% to 6.67%, respectively, with an increase of 68% and 65%, respectively. At the same time, in the load interval of [170, 200], the SO-MO-RWA index does not show a significant increase with the increase of the load, while the increase of the other two algorithms changes more obviously. Therefore, the test results show that in the whole test interval, SO-MO-RWA has a lower blocking rate than the other two algorithms.

The reasons for the analysis are as follows: first, the SDN controller can manage the network topology information in a unified manner, aggregate the underlying link damage information and the state information required for link switching from a global perspective, and then perform link selection for the service resource sequence with traffic planning, matching effective resources to avoid blocking. Second, the optimal deployment of resource sequences is realized through the service function chain method, which guides the rational allocation of link resources and improves the efficiency of resource allocation. Finally, this article constructs the link resource allocation problem as a 0–1 integer programming problem, takes the link transmission requirements as constraints, and uses an improved binary particle swarm optimization algorithm for global optimization, which further improves the allocation efficiency of effective resources and the success rate of link establishment. The IA-RWA uses Markov chains to construct the path resources. Compared with the global resource allocation method based on SDN, this probability model has certain uncertainties. The uncertainty is more pronounced, so the blocking rate increases significantly as the load increases in the experiment.

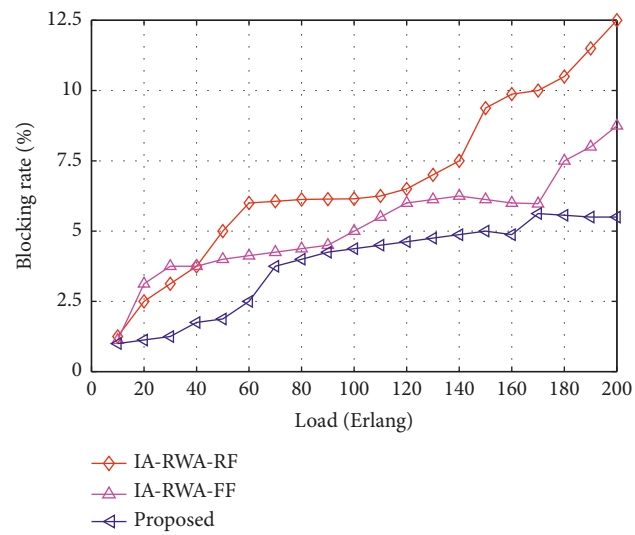

Figure 10: Comparison of blocking rate.

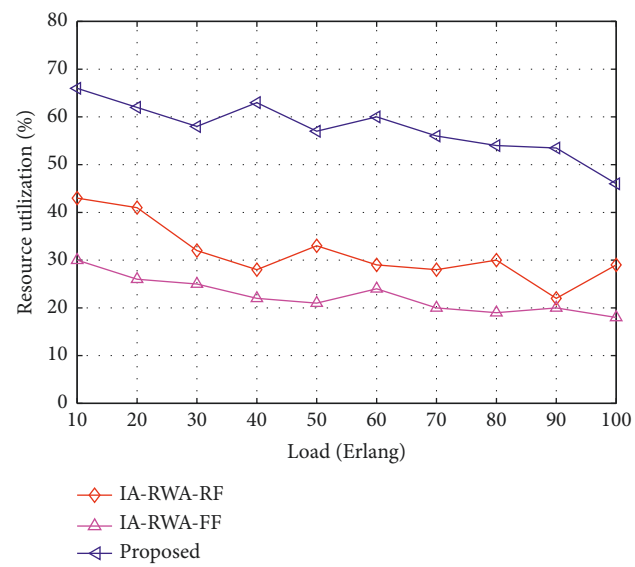

Figure 11: Comparison of resource utilization.

6.3. Resource Utilization. Resource utilization is an index to evaluate the utilization efficiency of components involved in information transmission. Resource utilization is closely related to the way the network operates. In the IA-RWA scheduling methods represented by IA-RWA-RF and IA-RWA-FF, network scheduling and physical topology are tightly coupled, and resource scheduling lacks flexibility, which leads to the integration of resource allocation into more redundant resources further reducing network resource utilization. Figure 11 tests the resource utilization of the three algorithms. Under different load conditions, the resource utilization corresponding to the IA-RWA-RF and IA-RWA-FF algorithms is in the range of 19% to 41%, while the resource utilization of SO-MO-RWA is much higher and the range is 40%~64%. The results show that the proposed method has higher performance than the other two during the same load condition. Although as the load increases, more resources are required to participate in scheduling, and the resource utilization decreases, but the relative trend does not change.

This is due to the decoupling of the relationship between control and data forwarding under the SDN architecture, as well as the application of service function virtualization, which greatly improves the flexibility of network resource allocation and enables targeted resource allocation, thereby effectively improving resource allocation. At the same time, the SDN unified control logic can carry out policy planning

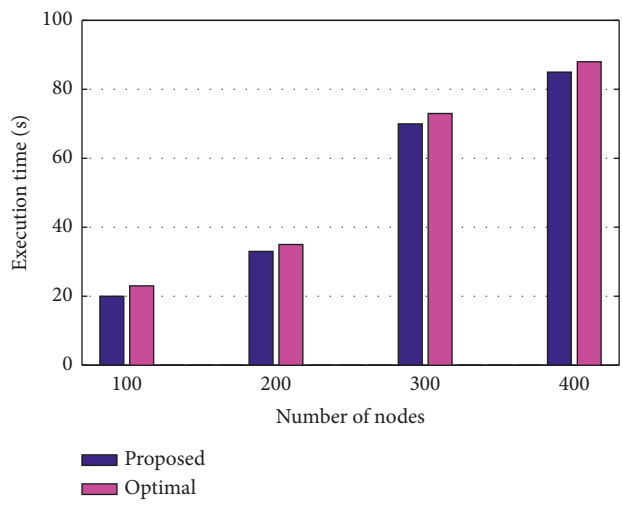

Figure 12: Comparison of execution time.

according to the global information, and formulate the corresponding resource demand plan, thereby improving the allocation and utilization of resources. The SO-MO-RWA optimizes resources and improves the effectiveness of resources and paths. Compared with the local optimization scheduling strategies of the other two methods, SO-MO-RWA has more advantages in resource utilization. In addition, SDN can support scheduling of different granularities, has better adaptability to different resource scheduling requirements, and match resources on demand according to scheduling requirements, effectively improving resource utilization.

6.4. Execution Time. compared the execution time of the proposed algorithm with optimal method. As can be seen from Figure 12, the execution time of both methods increases with an increasing number of nodes. Furthermore, the execution time of the proposed method conforms with the optimal method which validates its effectiveness Figure 12.

7. Conclusion

In this article, adaptive multiobject routing and wavelength allocation method is proposed for all-optical networks based on SDN. This method considers multiple scheduling objectives of scheduling time and link quality. The resource allocation structure defines the RWA problem as a 0–1 integer programming model. Simultaneously, the improved binary particle swarm technique is employed to solve the built model, which enables routing and wavelength allocation under SDN. The experimental results show that the proposed scheme outperforms the existing methods in performance indicators such as recovery time, blocking rate, and resource utilization. This shows that SDN-based routing and wavelength allocation have better performance than traditional methods, and also provides a new idea for further research on optical networks. In the next research work, we will consider designing an autonomous scheduling scheme for different requirements under the condition of all-optical network failure.

Data Availability

The data used for the findings of this study is available upon request from the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

Access Control Model Scheme based on Policy Grading in Natural Language Processing Blockchain Environment

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In order to solve many problems such as secure storage of access policies and distrust of third parties in complex and dynamic big data environment, a hierarchical access control model under block chain environment (BP-ABAC) is proposed. Access control policies are stored in blockchain in the form of smart contracts, and access control policies are classified in contract design. Users can obtain the access permission of the corresponding policy set according to the rating evaluation. Access to a resource is obtained when the request attribute matches the policy in the policy set. The simulation results show that the model can grant corresponding access control permissions according to different users' access requests, improve the time efficiency and accuracy of the access control process, and improve the security and privacy of the storage of access policies and the interaction of data sharing.

1. Introduction

At present, all walks of life begin to transform to information technology and network, which brings an era of data sharing and data application of big data [1]. Big data has huge commercial value and has become a very important economic asset.

Access control mechanism is a kind of technology to maintain information data security, privacy information protection, and secure data sharing. It can restrict illegal access to key resources, prevent malicious users from entering the system [2], and prevent legitimate users from accessing and using system resources illegally [3], so as to protect the security of data storage and processing in the information system [4].

Attribute-based access control (ABAC) is an access control model based on the user subject, data resource, operation, and system environment. It makes full use of the attribute set owned by the subject requester to decide whether to grant access to the resource of the object. Blockchain technology can be said to be a distributed shared ledger technology built on a variety of technologies. Using hash calculation and digital signature technology [5], block chain has a good, complete, and immutable information data record system. Compared with the centralized data management of the traditional access control model, blockchain access control adopts decentralized or weakly centralized data management [6].

In view of the shortcomings in the existing technology, this scheme based on ABAC model, combined with blockchain technology and policy grading, proposes an access control model (ABAC) based on blockchain and policy grading [4] (BP-ABAC) for policy grading in the blockchain environment [7]. This scheme combines access control policies with smart contracts and classifies policies in contracts [8]. Rank the data requester and obtain the access permission of the corresponding policy set according to the result of user rank evaluation [9]. Block as a decentralized, distributed policy storage system. Through the combination of the two, the scheme has good query efficiency, dynamic, and security [10].

2. Methodology

2.1. ABAC Model and Related Definitions. Attribute-based access control (ABAC) is not based on user identity, but by many entity attributes to carry out policy matching and policy decision, finally authorized to allow or deny user access control requests to resources. ABAC model has four main attributes, including subject attribute, object attribute, operation attribute, and environment attribute. The formal definition is as follows:

Definition 2.1: Basic element: the component of ABAC model is *A* quad (*S*, *O*, *E*, *A*), in which the four letters *S*, *O*, *E,* and *A,* respectively, represent the meaning of subject attribute, object attribute, environment context attribute, and operation attribute.

Definition 2.2: Attribute access request (AAR): It means that when the access process occurs, the subject attribute (SA), supported by the environment attribute (EA), performs related operations on the resource object attribute (OA), namely: AAR = {sattr, oattr eattr, pattr}.

Definition 2.3: Access control policy: the decision is made according to the preset access decision rules of the relevant attributes of the access request, and the decision results are mainly permit (refuse) unknown (unknown) status.

In the face of the present multifarious information system, there are substantial breakthroughs in the fine granularity of access control and the large-scale dynamic expansion of users. The idea of entity attribute is introduced to access control policy, model, and implementation mechanism. No matter subject, object, operation, and environment attributes are uniformly described, corresponding authorization, and access control constraints are established to ensure good flexibility and scalability.

2.2. General Framework and Workflow of BP-ABAC. The proposed access control framework of policy grading in the blockchain environment is shown in Figure 1. On the basis of the traditional ABAC model, it is combined with blockchain and smart contract, and on the premise of user level and policy level, it can control the access to data information resources. In the early stage, according to the collection of attributes and the integration of relations between attributes, related operations such as description, integration, and management of access control policies in blockchain transactions are carried out. This section describes how to publish, update, and revoke access control policies. At the same time, relevant policy sets and user-level permissions are published on the blockchain in the form of smart contracts. BP-ABAC frame diagram is shown in Figure 1:

The modules in Figure 1 are all implemented in the way of smart contract in blockchain. The functional modules are explained as follows:

(1) Policy information point (PIP): obtain entity attributes of subject, resource, and object and upload access control rights of resources.

(2) Policy administration point (PAP): manages and maintains the policies published by resource owners and the entire policy set.

(3) Policy decision point (PDP): determine whether the subject has relevant access permissions according to the level of the subject and make authorization decisions according to the entity attributes of the subject, the access control policy of resources, and the current state of the system.

(4) Policy enforcement point (PEP): responsible for receiving resource requester's access request and generating AAR in combination with entity attributes. Accept the policy decision point's decision on the resource requester and enforce the PDP's decision to permit or refuse access.

The steps of the BP-ABAC access control process are described as follows:

(1) When the PEP module receives the access request from the resource requester, it analyzes and generates the AAR according to the entity attributes in the access request and the attribute information obtained from AA and sends the AAR to the PDP module

(2) After receiving the AAR, the PDP module initiates policy information query through the smart contract and requests to judge whether the resource requester user is legitimate. If not, the access request is terminated.

(3) If it is valid, obtain the level permission of the user as a request to obtain the attribute information of the resource requester from PIP module and a request to obtain the access control policy of the resource from PAP module. The access control policy set is matched based on the user level. If the policy set of the same level fails to match, the system obtains the policy set of the next level for policy matching.

(4) THE PDP module compares the attribute of the access control policy of the resource with the attribute information of the resource requester and sends the decision result to the PEP module

(5) The resource requester performs relevant authorization (permit or deny) operations on the data resources requested by the subject according to the decision result of PEP

2.3. BP-ABAC Smart Contract Design. Smart contract in access control under blockchain environment mainly consists of four parts, which are contract participant, contract resource set, automatic state machine, and contract transaction set, respectively. The data information is described in the form of events, and the data sent is the corresponding transaction. The entire transaction is saved, and its state is handled on the blockchain. When the transaction and related event data information are introduced into the smart contract, the resources in the contract will update the status, so as to trigger the state judgment mechanism of the smart

contract. If the automatic state machine meets the trigger conditions of some instructions, the state machine will select the corresponding contract instructions to execute according to the previously preset information.

2.3.1. Contract Participant Module. Add User() function: mainly adds the user's identity attributes to the smart contract and sends the user's information to the blockchain for preservation. For later, PIP contracts to invoke user properties.

The Delete User() function: revoking the access control permission of the user or deleting the user completely for some reason. The function is used to delete the corresponding user attributes in the blockchain.

2.3.2. Contract Resource Collection Module. Add Resource() function: the owner of the resource sends the access control permissions related to the shared data. Through this function, the access control policy is stored in the blockchain. When the smart contract is triggered, the PAP transmits the policy information needed to access the object resources. The function pseudocode is shown in Table 1.

Delete Resource() function: for some reason, the resource owner wants to take back the access control permission of the shared data. Through this function, the relevant data information in the blockchain can be deleted to complete the cancellation of the share permission policy.

2.3.3. Automatic State Machine Module. Automatic state machine can generate control signals according to the control protocol, so that it can carry out state transfer in accordance with the preset state, and then complete the control center of specific operations. The triggering process of the state machine is shown in Figure 2.

The Judge Level() function: first checks whether the access is valid. Second, the user level of the resource requester is determined based on entity attributes, and the state machine is triggered according to the result to query the policy or policy set matching the corresponding level.

The Policy Set() function provides attributes required for access control and sets access control policies for shared data. It provides attributes and policies for the following Compare Policy() function.

2.3.4. Contract Transaction Set Collection Module. Compare Policy() function: it is mainly responsible for comparing the entity attribute information of the data resource requester with the entity attribute information of the access control policy of the resource publisher. By judging the similarity of each attribute information of the data resource requester, it can judge whether the resource requester can obtain the access control permission of the object resource and perform related operations. The pseudocode of the Compare Policy() function is shown in Table 2.

Get Permission() function: grants access to the object resource to the resource requester and uploads the "transaction" to the blockchain, mainly based on the result returned by the Compare Policy() function in the PDP contract.

Table 1: AddResource() function.

```
INPUT: Resource Name, Resource Id, Action, Subject id
OUTPUT: Add resource success/failed
//Add or delete a policy resource
  (1) if input==null
    (2) return error
  (3) end if
  (4) err = ARIstub.Get State (Resource id)
  (5) if err! = nil
    (6) return resource not exist
  (7) end if
  //Store policies in the blockchain
  (8) Resource Bytes = json.Marshal (resource)
  (9) err = ARIstub.Put State (Resource Id, Resource Bytes)
  //Return the result of adding a policy
  (10) if err = nil
  (11) return Add resource success
  (12) else if
    (13) return Add resource failed
  (14) end if
```

Execute Request() function: when the resource requester performs access operations (permit, refuse, unknown) on the resource object based on the result of the Get Permission() function in the PEP contract.

2.4. Design Hierarchical Policy. Each policy has different trust values for different entity attributes, which are influenced by access requests and system interactions. When an access request accesses an object resource properly or maliciously, the trust value of the corresponding policy is raised or lowered. When the trust value of a policy increases or decreases to a certain value, it is mapped to different trust levels. The trust value of each policy is calculated according to the initial trust value and the historical trust value, which is used as the mapping basis of the policy trust level.

2.4.1. Initial and Historical Trust Values. Each time when the policy owner issues the access control policy, the system will perform weighting calculation according to the correlation degree R (s, e) between the main attribute and environmental security of the policy, the correlation degree R (o, e) between the object attribute and environmental security, and the correlation degree R (a, e) between the operation behavior and environmental security of the policy, where α, β, γ are the weight ratio of the attribute weighting value. Get the initial trust value of the policy.

$$\text{Current}_{T(u)} = \frac{\alpha R(s,e) + \beta R(o,e) + \gamma R(a,e)}{\alpha + \beta + \gamma} c. \quad (1)$$

The first historical trust value is generated when an access control policy is authorized for the first time. As the number of subsequent policy access authorization increases, the historical trust value of the policy changes according to the time slice.

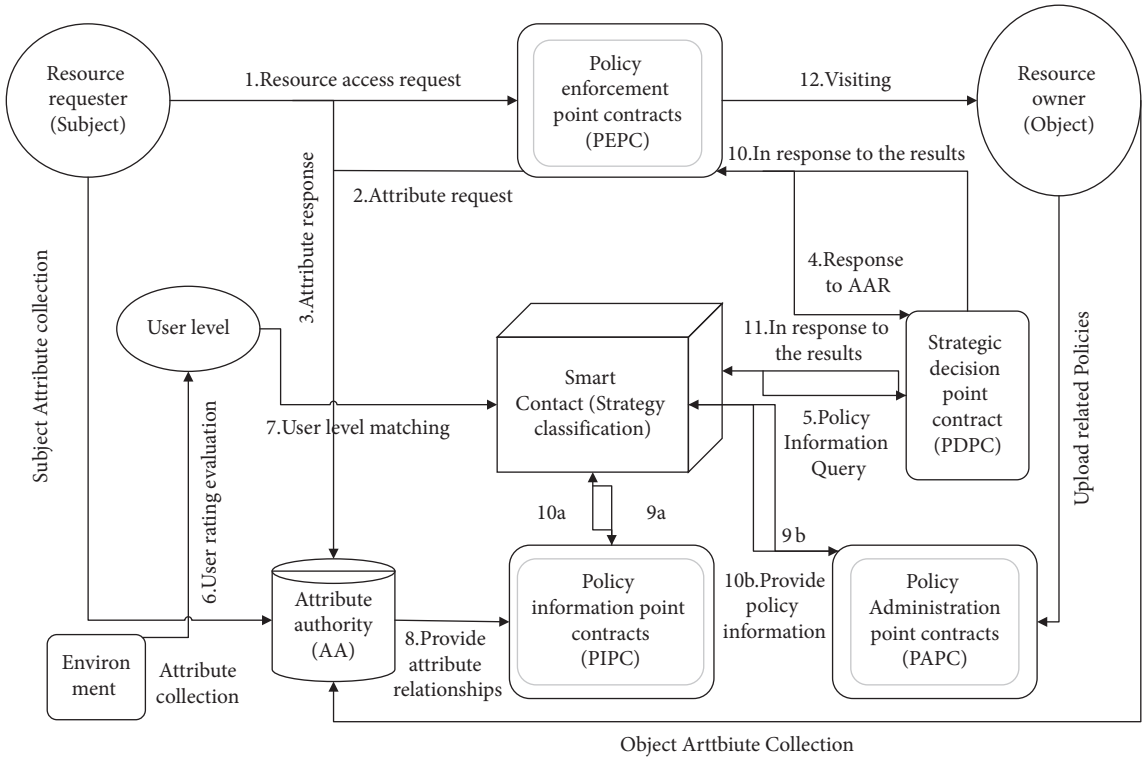

Figure 1: Block diagram of the policy grading access control model in blockchain environment.

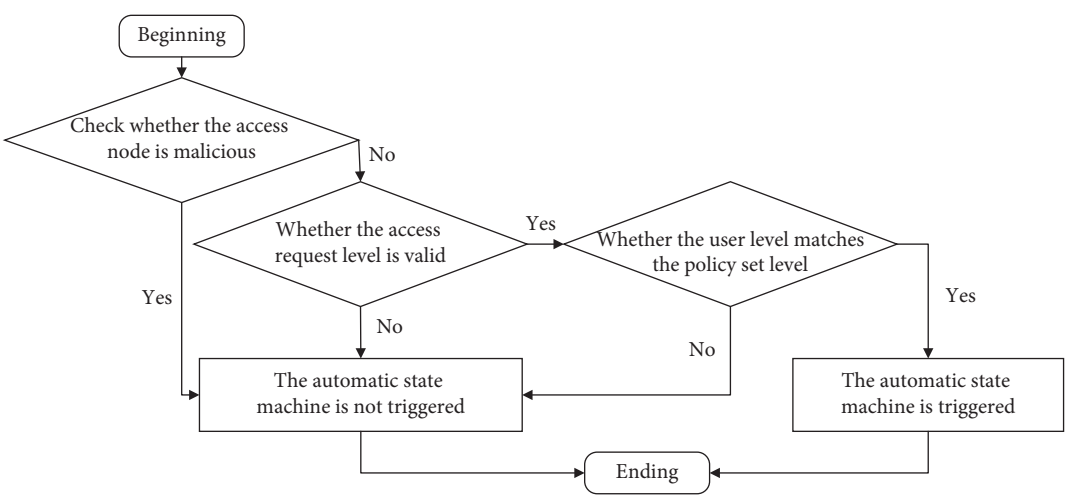

Figure 2: State machine trigger flowchart for smart contracts.

$$\text{History}_{T(u)} = \frac{\sum_{i=1}^{n} \text{current}_{T(u)} * W_t^T * t_i)}{\sum_{i=1}^{n} t_i} n > 0. \quad (2)$$

Here, W_t^T represents the weighted value of interaction behavior in the time slice t_i authorized by the policy. t_i indicates the slice of time that the access request and policy match until authorization is complete. If the access request is the first access, that is, when $n = 0$, there is no historical trust value $\text{History}_{T(u)} = 0$.

2.4.2. Final Trusted Values and Mapping. The final trust value can be obtained from the initial trust value and the historical trust value:

$$\text{Final}_{T(u)} = a * \text{Current}_{T(u)} + b * \text{History}_{T(u)}. \quad (3)$$

Here, a represents the weight of the initial trust value, b represents the weight of the historical trust value, and the two satisfy the relationship of $a + b = 1$. In the final trusted value calculation, $\text{Current}_{T(u)}$ has more reference value than

Table 2: ComparePolicy() function.

```
Algorithm 2: ComparePolicy()Function
INPUT: PolicySet()//Function to provide properties, policy parameters
OUTPUT: allow Access, Access Time
  (1) if input==null //whether attribute information is obtained
      (2) return error
  (3) end if
  (4) result Iterator = ARIstub.Get History For Key(Resource Id)
  (5) for resultIterator.next do //Get the attribute element in the sequence
     (6) query Set = resultIterator.Next()
     (7) Json.unmarshel(query Set.value, & plo)
     (8) policy_set = pol
  (9) end for
  (10) Allow Access = false
  (11) for j = 0; j < len (policy_set); i++ do //Matches policy information
      (12) if input ∈ policy_set[j]
        (13) Allow Access = true
     (14) Access.Time = policy_set[j].Access time
      (15) break
  (16) end for
  (17) return AllowAccess, AccessTime //Return the policy comparison result
```

$\text{History}_{T(u)}$, so $a > b$. According to the policy value of $\text{Final}_{T(u)}$, the corresponding policy trust level can be obtained through mapping. The final mapping table of trust value and trust level is shown in Table 3.

According to the actual situation, the scheme temporarily divides the trust value into 5 intervals and the corresponding policy level into 5 trust levels. The access control policy can be classified into the above 5 categories according to the trust value calculation and different trust levels contain different policy sets. Resource visitors can obtain access authorization by matching corresponding policies according to the trust level. The user rating of resource visitors is similar to the policy trusted value calculation, so it will not be elaborated too much here.

Scenario assumption: when the access requester sends an access request, the system assigns an initial trust value $\text{Current}_{T(u)}$ based on the entity attribute of the request, and then starts to access the resource. Assuming $\text{Current}_{T(u)} = 1$, the weighted value W_t^T at $t1$ is 0.85 obtained through the interaction of historical behavior data of visitors, and the historical trusted value $\text{History}_{T(u)} = 0.85$ is calculated from Formula (2). Suppose the initial creditability weight $a = 0.66$, and the historical creditability weight $b = 0.34$.

$\text{Final}_{T(u)} = 0.949$ can be calculated by formula (3). As $0.949 \in [1.0, 0.9]$ can be obtained from the mapping table in Table 3, the request visitor matches the policy set with policy level 5 and performs policy traversal matching for N policies. If the AAR attribute matches an access control policy successfully, the AAR is granted the corresponding access permission. If malicious operations are carried out in the access process, the weighted value W_t^T will be reduced, thus affecting the historical trust value and weight value. In this way, malicious nodes can effectively prevent them from using the accumulated trust value of security operations to conduct serious malicious operations on access rights when they reach the maximum value or meet the trust value of corresponding operations. Therefore, the behavior control of node access process is strengthened, and the security of access control process is improved.

Table 3: The mapping table of trust value and trust level.

Reliability interval	Reliability level	Reliability intensity
[1.0–0.8]	5	Trustworthy
[0.8–0.6]	4	Reliable
[0.6–0.4]	3	Dependable
[0.4–0.2]	2	Undependable
[0.2–0.0]	1	Unreliable

3. Results and Discussion

3.1. Simulation Experiment Analysis and Security Analysis

3.1.1. Simulation Experiment Analysis of Policy Query. In order to test the efficiency of access control policy retrieval based on block chain and policy hierarchy, this paper uses JAVA language to describe smart contract in Windows10 system with i7-8700 processor and 16G memory. The test is carried out according to the standard policy test package provided by XACML. The data set was used in HP LABS, and the experimental code was written based on cpABE-0.11 library. The authorization center is emulated by virtual servers. The access request AAR composed of all attributes forms an association attribute set: TT_AARA *r* Set. The association attribute set formed by the attributes in the access control policy is TT_policyA *r* Set. If the TT_AARA *r* Set matches the TT_policyA *r* Set property Set, Execute Request() executes the Permit authorization operation. If the TT_AARA *r* Set does not match the TT_policyA *r* Set property Set, If Refuse or Unknown is returned, it indicates that the access is rejected or the access request is incomplete and relevant authorization operations cannot be performed.

The traditional retrieval method, literature [11], literature [12], literature [13], and the retrieval method of this

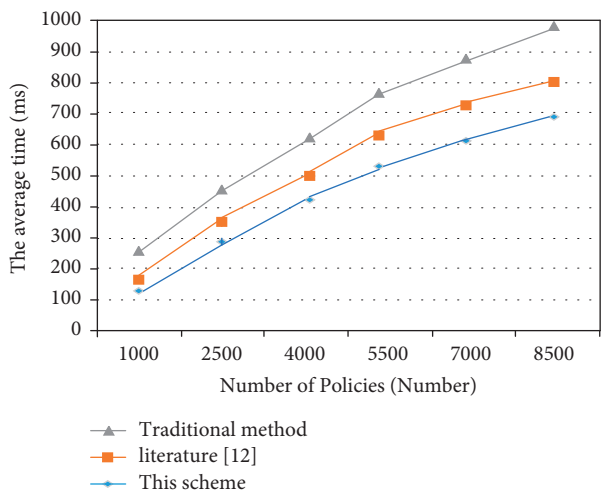

Figure 3: Policy query comparison diagram.

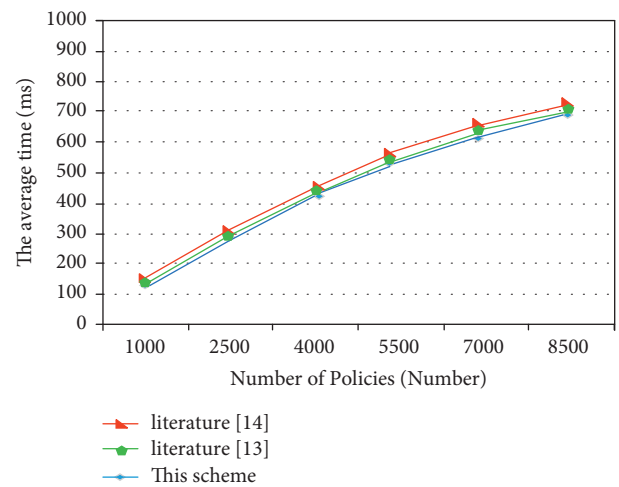

Figure 4: This scheme is compared with the attribute security value policy query.

paper are tested under different strategy scales. The policy size is 1000, 2500, 4000, 5500, 7000, and 8500 samples in a total of 6 groups of single test set. The strategy scale experiment at each level was carried out 6 times, and the average value of the 6 experiments was taken. In the experimental results, different curves represent the query efficiency of different retrieval methods under different strategy scales. Comparison of policy query is shown in Figure 3.

According to the comparison in Figure 3, with the expansion of the policy scale, the query efficiency of traditional access control, literature [11], and this scheme tends to expand gradually. Through the average calculation of six values, the query efficiency of this scheme is improved by about 33.0739% compared with the traditional access control method. Compared with reference [11], this scheme improves the query time by 16.2400%.

In order to further verify the reliability of the scheme in policy query, this scheme is compared with the attribute decentralized access control model in reference [12] and the attribute security value based access control in reference [13]. The comparison results are shown in Figure 4.

As can be seen from the figure, compared with reference [13], this scheme improves access control by about 8.6948% and access time by 2.79% compared with reference [12]. Therefore, by comparing with several schemes with different characteristics, it can be seen that, in general, this scheme has obvious advantages over the above three methods in query efficiency.

3.1.2. Simulation Experiment Analysis of Strategy Decision. With the expansion of strategy scale, the correctness of strategy decision is a problem worth paying attention to. As the scale of policies increases, the probability of conflicts between policies increases. In view of such problems, this paper has not introduced the policy conflict solution and will study and improve such problems in the subsequent part of the work. So, Figure 5 is the outcome of this scheme and the traditional access control success rate comparing, strategy by

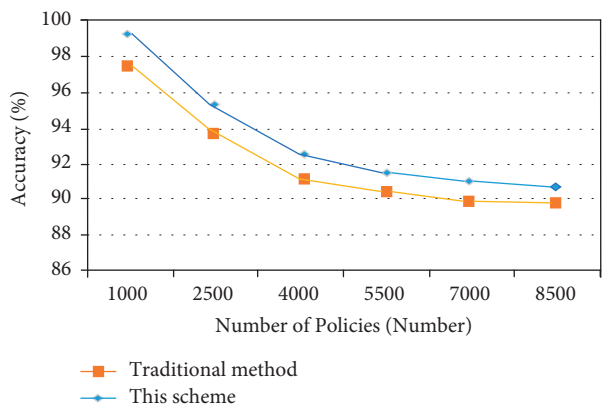

Figure 5: Strategy decision success rate comparison chart.

the preceding query result has to query, the success can be judged on the basis of strategy, according to the access control request is successful or not, and access to the success of subject to authorization due to expected result finally consider whether the results are in strict accordance with the access control policy enforcement. Get the result of judging the accuracy of the data. The comparison in the figure shows that the difference of accuracy between the two is in a controllable range. The comparison of success rate of strategy decision is shown in Figure 5.

3.2. Block Antiattack Analysis. The main challenge based on blockchain is that the consensus mechanism is threatened by security. In order to analyze the antiattack of blockchain itself, the proof of work mechanism of consensus mechanism is mainly used to analyze the security problems faced by blockchain, and the attack model proposed in literature [14] is analyzed. There is a competitive relationship between the trusted chain generated by trusted nodes and the attack chain generated by malicious nodes. This competition can be described by a binary tree "random walk" process. In contrast, when the trusted nodes produce a large number of

trusted chains, the trusted chain adds a block; otherwise, the malicious node adds a block to the attack chain. In order for the blockchain to be threatened, the length of the attack chain generated by the malicious node is greater than the trusted chain generated by the trusted node. The probability problem of malicious nodes chasing z blocks is similar to the gambler's bankruptcy problem. Therefore, the probability of success of malicious nodes chasing z blockchains is

$$q_z = \begin{cases} \left(\frac{q}{p}\right)^2, & p > q, \\ 1, & p \le q. \end{cases} \tag{4}$$

In which p is the probability that the trusted node obtains the next accounting right, q is the probability that the malicious node obtains the next block accounting right, q_z is the probability that the malicious node successfully catches up with the difference of z blocks, and the higher the z value is, the lower the probability of success. Assuming that the expected average time for trusted nodes to generate a block, the potential block catch-up progress of malicious nodes is extremely consistent with the mathematical law of Poisson distribution, and its expected value is

$$\lambda = z * \frac{q}{p}. \tag{5}$$

If the probability of success of malicious nodes attacking blockchain is needed, that is, the attack chain produced by malicious nodes exceeds the blockchain length of trusted nodes. It is necessary to know the Poisson distribution probability density of the block length generated by the malicious node and the probability that the malicious node can successfully trust the node's trust chain at this moment, and then multiply the two p_α to get

$$p_\alpha = \sum_{k=0}^{\infty} \frac{\lambda^k e^{-\lambda}}{k!} \begin{cases} \left(\frac{p}{q}\right)^{(z-k)}, & k \le z, \\ 1, & k > z. \end{cases} \tag{6}$$

The size of the block difference between the malicious node and the trusted node can influence the probability of the malicious node successfully tampering with the block, and the relationship between the two is shown in Figure 6.

According to the figure analysis, when the block difference is set to a certain value, the probability of malicious nodes successfully tampering with the block will be significantly improved with the improvement of computing power. When q is less than 0.5, the block difference is inversely proportional to the probability of the malicious node tampering with the block. Only when the malicious node q is greater than or equal to 0.5, can it obtain the accounting right of the next block and grasp the overall trend of blockchain data. However, it is very expensive to control more than 50% of the computing power of blockchain, so it is difficult for attacks to succeed. Therefore, block chain can achieve good security in the process of access control.

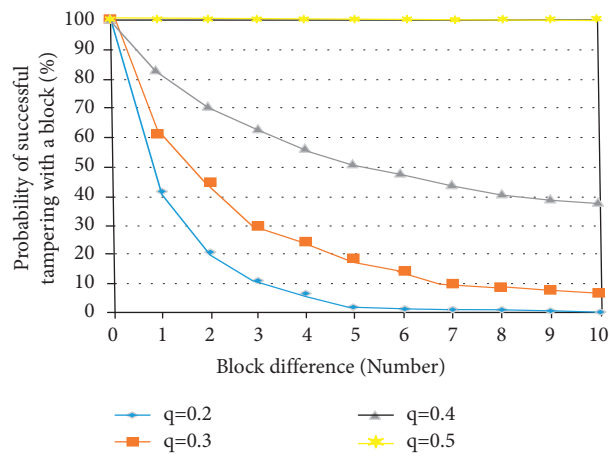

Figure 6: Probability of successful attack.

3.3. Security Analysis. The BP-ABAC model proposed in this scheme is based on attribute-based access control (ABAC), which makes the access control process more flexible and secure through the combination of blockchain and policy hierarchy. Compared with the traditional access control model, this model has the following advantages:

In terms of policy and access process: compared with traditional access control, this model does not need to establish a central database node to store policies, and the characteristics of blockchain make policies more tamper-proof. Access control policies issued by resource owners are voted and graded by all network nodes. During policy matching, you only need to query the corresponding tiered policy, which enhances the flexibility of authorization and ensures the consistency of policy updates and access records.

Constrained: each time the resource requester visits, the user is evaluated, and the current access control state will be changed only when the condition triggering the state set is met. By monitoring the status of the access control process, when the access control is complete, the policy is re-evaluated and graded. Compared with the traditional model, the constraint is increased, and the strengthening of the constraint can reduce the hidden trouble of illegal access.

Decision form: traditional access control models mostly use centralized third-party trust platform to make decisions, and the security of the entire access control process depends on the reliability of the third party. Uploading the access control policy to the blockchain can effectively curb the unauthorized operation of visitors. Attackers need to control more than half of the network nodes before they can have an impact on decision-making behaviors, avoiding the situation of incorrect authorization or paralysis of the access control process caused by the destruction of the central node.

This part configures the software and hardware tools and environment needed in the early stage of the experiment and gives a comprehensive and detailed introduction and related instructions to the whole experiment process. Simulation experiments are carried out on the efficiency and accuracy of

policy query of the BP-ABACA model in this paper. Based on different policy scales, six groups of experiments are selected, and the average value of the six times is taken to investigate the influence of human factors. In addition, in comparison with the traditional ABAC model, It is found that the result is better than the traditional access control model, and then compared with the prefix markup method and the access control based on attribute security value, the results also show that the proposed scheme has improved. In order to analyze the antiattack of blockchain itself, the security line analysis of blockchain is mainly based on the proof of work mechanism in the consensus mechanism. However, it is extremely expensive to master more than 50% of the block chain's computing power control. Finally, the security of the whole model is explained from the aspects of policy and access process, attribute, or policy constraint and decision form. Therefore, it is difficult for malicious node attacks to succeed, and the whole access control model has certain security.

4. Conclusion

ABAC has unique advantages in access control. In this era when privacy protection is becoming more and more important, access control system also needs to be further strengthened to adapt to the current environment. When the subject accesses the data share, the access identity and the rationality of the access authority need to be solved in a more in-depth authentication. Second, the legitimate habits of the access subject and the rationality of the access control policy need dynamic management and authentication mechanism. Not being able to stop losses immediately to a certain extent when data are leaked and the issue of retrospective responsibility division both need to be improved. With the development of block chain technology, its own consensus authentication mechanism can record the entire operation or sharing process of information resources, and the traceability of block chain ensures the security of information, which largely solves the credit problem.

This scheme proposes a block chain and policy hierarchical access control (BP-ABAC) model based on ABAC model. By using the decentralized and immutable characteristics of block chain, it gets rid of the limitation of traditional third-party trust mechanism and improves the reliability, security, and transparency of access control. According to the reference of smart contract, the whole access control authorization process is automated, which makes the access control model more flexible. Through trusted values, the user hierarchy and grading strategy makes the access control policy set and attribute request matching convenient fast, make the whole access control policy decisions and authorization process has a higher efficiency, ensure the requester legitimacy resources, prevent the excessive authorized and unauthorized access, to ensure data privacy and security in the process of access to a shared. It can effectively authorize subjects, realize data sharing between subjects and objects, and ensure the security of access control process.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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