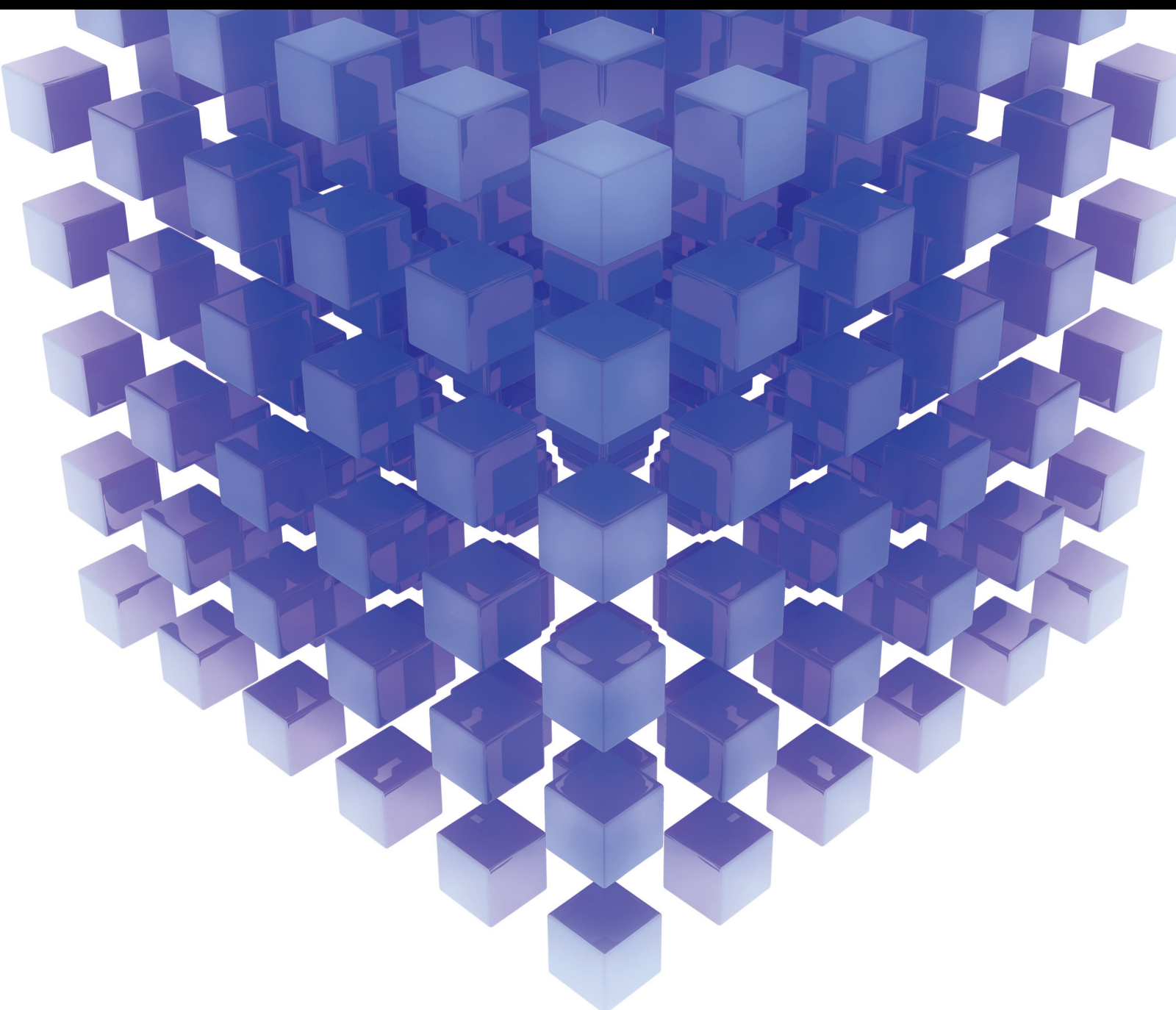


Theory and Application of Swarm Intelligence and Machine Learning

Lead Guest Editor: Lianhui Li

Guest Editors: Lianhui Li, Jianguo Duan, and Rémy Houssin





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Mathematical Problems in Engineering

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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
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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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Retraction

Retracted: Three-Dimensional Numerical Simulation of Soil Deformation during Shield Tunnel Construction

Mathematical Problems in Engineering

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Retraction

Retracted: Evaluating and Exploring the Effectiveness of Journalism and Communication Discipline Construction in the Context of Smart Era

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Retraction

Retracted: Exploring the Hot News on the Internet Based on Recommendation Algorithm for College Students' Ideological and Political Education

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Retraction

Retracted: The Construction of Innovation and Entrepreneurship Incentive Mechanism for College Students Based on Hierarchical Analysis

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Retraction

Retracted: Quantitative Evaluation Model of Stock Market Liquidity by Macroeconomic Factors

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Retraction

Retracted: Study of Surface Roughness of Cutting Isothermally Hardened Ductile Iron in Tosa Knife Forging Technique Based on Intelligent Calculation

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Retraction

Retracted: Practical Thinking of Neo-Confucianism in Qing Dynasty from the Scope of Practice Based on Deep Learning

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Research Article

Study on Influencing Factors and Estimation Model of the Water Supply and Drainage Structure Cost in Substation

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This paper made an in-depth analysis of the articulation between a substation's design parameters and water supply and drainage structure quantities and costs, innovatively built a hierarchical structure model of influencing factors of quantities, and eventually extracted the key parameters affecting quantities. Meanwhile, the influence path of the price level change on the water supply and drainage structure costs was also analyzed in this paper. The BP neural network model and linear regression model were employed to estimate the ontology engineering cost and the price difference due to preparation time, so as to realize the purpose of quickly estimating the cost of substation water supply and drainage structure by knowing a few key parameters. Through calculation and stimulated analysis, the error of the model is controlled within $\pm 3\%$, which provides an effective tool for quickly estimating the cost of substation water supply and drainage structure. Therefore, this model has practical significance and application value.

1. Introduction

The water supply and drainage structure are one of the important components of the substation project. How to quickly and reasonably make accurate predictions and estimates of its cost is an urgent problem for constructors, designers, builders, and other participant units. At present, there is still a lack of an explicit model about the relationships among design parameters, price levels, and the corresponding cost. To calculate the cost of the water supply and drainage structure, it is necessary to first calculate the detailed quantities according to the design plan and then the cost personnel calculate the project cost based on the budget regulations [1] of the power industry. This conventional way to calculate the cost gains low efficiency, though high quality is promised, and is not suitable for the business requirement of rapidly estimating the cost.

The cost of the water supply and drainage structure in the substation is mainly composed of four aspects, which are quantity, price, fee, and quota, and the cost's influencing factors can also be attributed to these four aspects, i.e., quantity, price, fee charging, and quota [2]. Within the year

of the adopted samples, the project quotas are subject to the unified version of the quotas, the fee charging is implemented according to the unified budget-making regulations, and the quotas and fee charging standards are relatively fixed. Therefore, the influencing factors for cost changes are mainly attributed to the quantities and the price level. The dimensions of analysis are divided into two aspects: the main quantities, such as the quantities of firefighting, water supply, and drainage, and the water source, and the price level, such as the price of equipment, main materials, labour, and machinery. This paper specializes in the analysis of the impact of changes in major quantities and price levels on the cost of water supply and drainage structure to achieve a rapid and reasonable estimation of the cost.

2. Analysis of the Influence of Design Parameters on Quantities

The water supply and drainage structure in the substation studied in this paper refers to the works of water supply, waste water discharge, and water quality improvement, mainly divided into water supply works and drainage works.

In normal times and unexpected situations such as fire, the water supply and drainage structure are supposed to safely and reliably provide sufficient water based on the users' requirements for water quality and pressure. A thorough analysis of the design parameters that affect the quantities of the water supply and drainage structure in a substation can make the influence of the complex design parameters on the quantities more concise, thus identifying a few key parameters that have a greater impact on the quantities.

2.1. Analysis of the Factors Influencing the Quantities

2.1.1. Quantities of Firefighting and Water Supply System. The water in the substation is mainly for firefighting and domestic use.

The firefighting water consumption of the main transformer is related to its voltage level and external size. Main transformers with voltage levels of 220 kV and above should adopt a water spray fire extinguishing system. Fire-fighting water spray needs to cover the external surface of the main transformer. The larger the surface area of the main transformer is, the more water the firefighters use. Main transformers with voltage levels of 110 kV and below are not equipped with a water spray fire extinguishing system, and there is no water consumption for their firefighting.

The water consumption of the building's firefighting is directly connected with the building's fire hazard. The higher the fire hazard is, the more water it uses. For substations of the same scale, when the main transformer and power distribution devices are laid out indoors (referred to as "whole-indoor layout"), the fire hazard of buildings is the highest and the water consumption for the building's firefighting is the largest; when the main transformer is laid out outdoors and GIS is laid out indoors (referred to as "semi-indoor layout"), the water consumption for building's firefighting takes the second place; when the main transformer and power distribution devices are laid out outdoors (referred to as "outdoor layout"), the fire hazard of the building is the lowest and the water consumption for firefighting is the smallest [1].

The amount of domestic water used in a substation is directly related to the number of personnel on duty. The higher the voltage level is, the more personnel are on duty, and the higher the domestic water consumption is.

The diameter of firefighting and water supply pipelines is positively related to water consumption; the length of pipelines is positively related to the floor area of the substation; the floor area of the substation is associated with the substation's prospective scale and layout; and the length of the firefighting pipeline of the main transformer is positively related to the current scale of the main transformer in this period.

2.1.2. Quantities of Water Source. The quantities of the water source are highly correlated with the substation's water consumption, geographical location, and geological conditions [3]. The water yield of the water source should satisfy the need for production water supply in the substation.

According to the substation's groundwater condition and its distance from the location of municipal water, a comprehensive judgment is made to choose the plan of digging a deep well or introducing tap water from outside.

2.1.3. Equipment of Water Supply and Drainage Structure. Equipment of the water supply and drainage engineering refers to pneumatic water supply installation, deep well fire pump set, submersible sewage pump, and other equipment related to water supply and drainage structure, which is generally set up according to the prospective scale of the whole substation and is positively related to the water consumption of the prospective scale of the whole station.

2.1.4. Water Pump House and Firefighting Pool. The water pump house and firefighting pool, designed according to the prospective scale of the whole substation, are positively related to the water consumption of the prospective scale of the whole substation. The more amount of water it uses, the larger the building volume of the water pump house and the firefighting pool is, and the larger the quantities are.

2.1.5. Quantities of Drainage System. The drainage system is divided into the indoor drainage system, an in-station drainage system, and an outside-station drainage system.

The length of in-station drainage pipes is positively related to the floor area of the substation. The rain inlets are arranged on both sides of the road. After being collected by rain inlets, the rainwater is discharged to the rainwater inspection wells at the lowest part of the substation through drainage pipes and continues to be discharged to the outside of the substation. The diameter of the drainage pipes is positively related to the drainage volume, which is positively correlated with the local hydrometeorological rainstorm intensity as well as the water consumption of the substation.

The diameter of the sewage drainage pipes is positively related to water consumption. Oil-immersed electrical equipment is equipped with the accident oil pool and oil drainage pipeline. The diameter of the oil drainage pipeline is positively related to the accidental oil discharge amount, and the length of the oil drainage pipeline is positively correlated with the scale of oil-immersed equipment, such as the main transformer, and their distance from the accident oil pool.

The indoor drainage system is positively related to the water consumption of the building, and its quantities are small. The quantities of the outside-station drainage system are associated with the geographical location of the substation. The farther the suitable drainage point is from the substation and the worse the construction conditions outside the station are, the larger the quantities are.

2.2. Hierarchical Structure Model of the Factors Influencing the Quantities. The factors influencing the quantities of a substation's water supply and drainage structure have an obvious hierarchy. According to the successive logical relationship between the design parameters and the forming

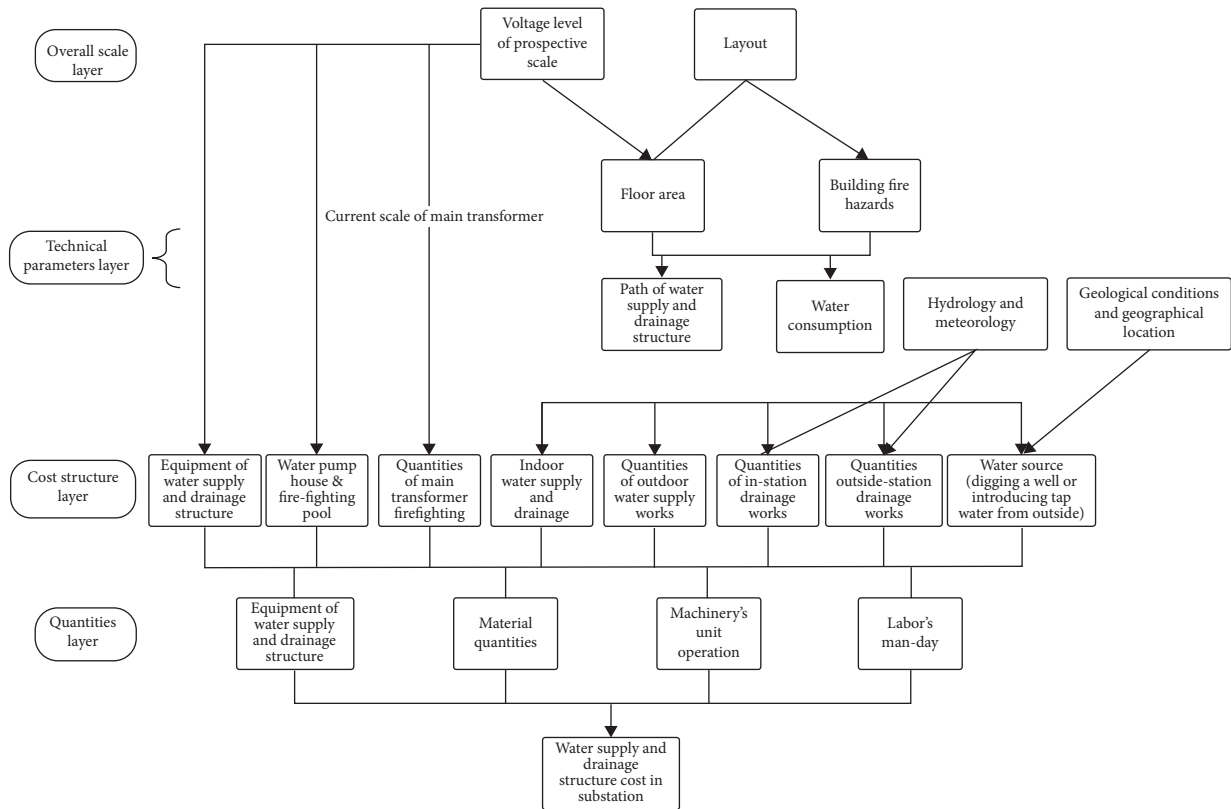


FIGURE 1: hierarchical structure of the factors influencing quantities.

process of quantities [4], the influencing factors are summarized into four layers: the overall scale layer, the technical parameters layer, the cost structure layer, and the quantities layer. Each layer has a clear logical relationship and lucid functional route, as shown in Figure 1.

Except for the water source and outside-station drainage, which are related to the substation's geological conditions and geographical location, for the quantities of in-station water supply and drainage structure, only the diameter of the substation drainage pipeline is related to the hydrology and meteorology, and the other quantities are eventually determined by four design parameters, namely the voltage level, the prospective scale, the layout, and the current scale of the main transformer. Through the statistics of the sample data of a province in the past five years, these four design parameters can determine 98% of the quantities of water supply and drainage structures except for the water source and outside-station drainage [3].

3. Analysis of the Impact of Price Level on Project Cost

The cost of the water supply and drainage structure in the substation is composed of the ontology engineering cost and the price difference due to preparation time. The ontology engineering cost is affected by quantities determined by the design parameters; the price difference due to preparation time, based on the ontology engineering cost, is affected by the price level [5].

3.1. Price Level of Equipment. The total price of equipment for water supply and drainage structures is affected by changes in its price level. However, there are few types of equipment for water supply and drainage structures in substations, and the price level of equipment is relatively stable [6]. Therefore, the total price of the equipment is greatly affected by the quantities and less affected by the changes in the equipment's unit price.

3.2. Price Level of Materials. Quantities of water supply and drainage structures can eventually be classified into various types of construction materials. The price level of materials directly affects the price difference due to preparation time in the project cost, and the material price difference is the main content of the price difference due to preparation time.

3.3. Price Level of Labor's Man-Day. The China Electric Power Project Cost Administration will regularly measure the impact of changes in labor and machinery costs on the base price of quotas and issue documents in the form of adjusting the price level of quotas as the basis for the price difference due to preparation time in the project budgeting period.

Take the price level of Beijing in 2022 as an example. According to the regulation on the adjustment of quotas' price level issued by the China Electric Power Project Cost Administration in January 2002, the labor cost of a substation construction project in Beijing is adjusted by 10.25% on the basis of the budget price of quotas and included in the

price difference of labor's man-day, while in Shandong province, it is adjusted by 9.46% and included in the price difference of labor's man-day.

3.4. Price Level of Machinery's Unit Operation. The market price of the main machinery's unit operation for the construction project is regularly released by the China Electric Power Project Cost Administration, and the theoretical calculation method of the mechanical price difference is the same as the material price differences.

4. Estimation Model of Cost of Substation Water Supply and Drainage Structure

4.1. Construction of Ontology Engineering Cost Estimation Model

4.1.1. Network Structure's Construction and Selection. The construction of an estimation model of the water supply and drainage structure cost in the substation is based on the actual project data from the past three years, and its main influencing factors [7] are explored. Each influencing factor is taken as the input variable x_i of the model. By establishing a nonlinear mathematical model between the model and the cost, the output variable y_1 , ontology engineering cost, is obtained.

The model is constructed by selecting the three-layer BP neural network as the predictive model. The main factors affecting the ontology engineering cost can be obtained by analyzing the historical data, and then the number of input-layer nodes is measured. The main factors that have an impact on the cost of the substation's water supply and drainage structure are voltage level (x_1), prospective scale (x_2), the current scale of the main transformer (x_3), and layout (x_4). Therefore, the number of input-layer nodes is determined to be four. The ontology engineering cost (y_1) is regarded as the output node, and its number of it is set to one. Usually, the number of nodes in the implicit layer between the input layer and the output layer is set as 10, 15, 20, and 25. According to the setting principles of nodes in the implicit layer of the BP neural network model, the more input and output units there are, the more hidden nodes exist. At the same time, the approximate process should be guaranteed to be complex and complete. There are many input units and nodes involved in this study, and their results are required to be normalized into one output unit after iterative prediction. Therefore, the number of nodes in the implicit layer is set to 25, which means the structure of the BP neural network model is 4-25-1. The model structure is shown in Figure 2.

4.1.2. Data Processing and Algorithm Training. Since the above-mentioned influencing factors of ontology engineering cost are represented by text-structure data, they need to be preprocessed to be converted into algebraic form to participate in the input of the BP neural network. The model chooses to process the data conversion of different

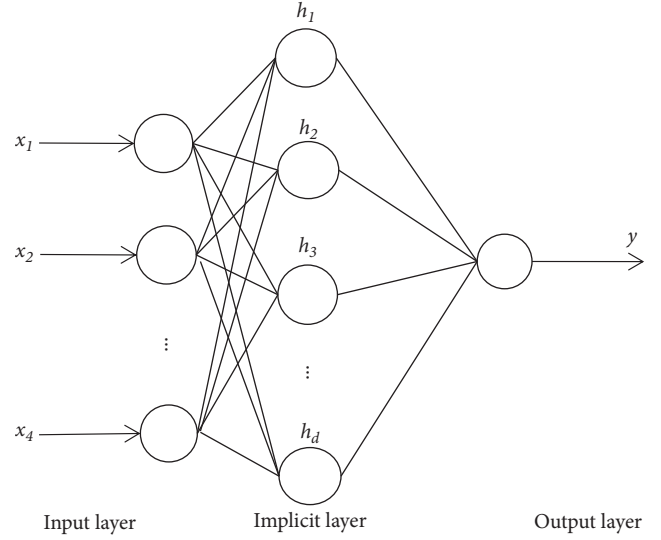


FIGURE 2: A network structure diagram of the model.

influencing factors' internal elements. The specific pre-processing principles are as follows:

- (i) Numbers 1, 2, and 3, respectively, represent the voltage levels of 110 kV, 220 kV, and 500 kV, and the weighted average of their proportion of the cost in the substation project is processed;
- (ii) Numbers 1–20, respectively, represent the combinations of the number of main transformer groups of the prospective scale and the circuit number of the high-voltage-side outgoing line. The statistical data shows that the corresponding cost of the prospective scale of different combinations meets the law of normal distribution.
- (iii) Numbers 1, 2, and 3, respectively, represent the number of main transformer groups of the current construction scale, and the weighted average of the current scale of main transformers of different groups is processed.
- (iv) Numbers 1, 2, and 3, respectively, represent the layout modes, where the indoor mode is regarded as the base as a reference item, and the semi-indoor and outdoor modes are, respectively, determined by the scale factor.

The model algorithm training is mainly divided into two processes: forward propagation and backward propagation. Between them, the forward propagation process is mainly used to calculate the final actual output after entering data and passing them through the input layer, implicit layer, and output layer, respectively. The backward propagation process represents the deviation between the actual output and the desired output in the output layer and reversely adjusts the parameters of each layer according to the deviation value, which can finally control the deviation within an acceptable range.

(1) Forward propagation process. In this model, the nodes of the input layer, implicit layer, and output layer are respectively set as n , d , and m , and the vector sets are expressed as $x \in R_n$, $x = (x_1, x_2, x_3, x_4)$, $h \in R_d$, $h = (h_1, h_2, \dots, h_d)$, and

$y \in R_m$, $y = y_1$. The node calculation formulas and data transfer functions of the implicit layer and output layer are shown in the following equation:

$$h_j = f\left(\sum_{i=1}^n W_{ij}x_i - b_i\right), \quad (1)$$

$$F_k = f\left(\sum_{j=1}^d W_{jk}h_j - b_k\right), \quad (2)$$

$$f(x) = \frac{1 - \exp(-x)}{1 + \exp(-x)}. \quad (3)$$

In the formulas of equations (1)–(3), W_{ij} and b_j are the weights and thresholds between the implicit layer and the input layer, respectively; W_{jk} and b_k are the weights and thresholds between the implicit layer and the output layer, respectively.

The calculation function of the output nodes' error is shown in the following equation:

$$e = \frac{1}{2} \sum_k (t_k - F_k)^2 = \frac{1}{2} \sum_k \left\{ t_k - f\left[\sum_{j=1}^d W_{jk}f\left(\sum_{i=1}^n W_{ij}x_i - b_j\right) - b_k\right] \right\}^2. \quad (4)$$

In the formula (4), F_k and t_k are the actual output values and desired output values, respectively.

The calculation function of total error is shown as follows:

$$E = \sum_{i=1}^p e_i < \theta. \quad (5)$$

In the formula (5), p is the number of samples, and θ is the acceptable deviation.

(2) *Backward propagation process.* In order to better test the deviation between the actual output and the desired output, it is necessary to iterate the output weights and thresholds repeatedly and finally obtain the correction results of both. The deviation calculation formula and the calculation formula for the correction of weights and thresholds in each layer are shown as follows:

$$\delta_k = (t_k - F_k)F_k(1 - F_k), \quad (6)$$

$$W_{jk}(n_0 + 1) = W_{jk}(n_0) + \mu \sum_{p_i=1}^p \delta_k, \quad (7)$$

$$b_k(n_0 + 1) = b_k(n_0) + \mu \sum_{p_i=1}^p \delta_k, \quad (8)$$

$$\delta_j = h_j(1 - h_j) \sum_{k=1}^m \delta_k W_{jk}. \quad (9)$$

In the formulas (6)–(9), n_0 is the number of iterations.

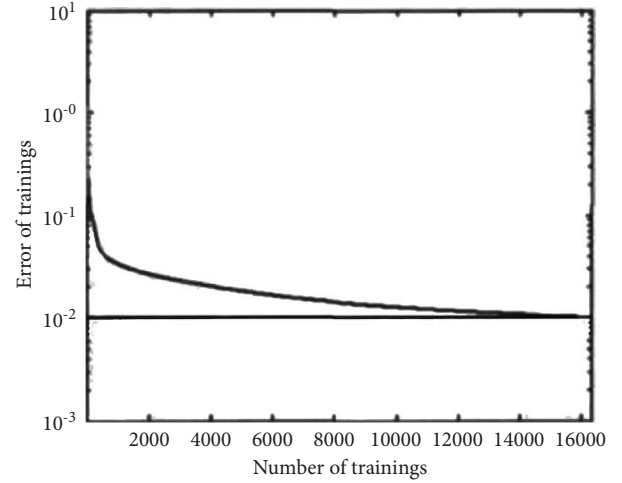


FIGURE 3: Algorithm training curve.

4.1.3. Algorithm Training and Deviation Analysis. Based on the above models to train the data, the correction algorithm satisfies the gradient descent with the momentum algorithm, which can optimize the learning rate of the BP neural network. Referring to the relationship among the numbers of nodes in each layer, the maximum number of cycles of algorithm training is set to 20,000, the initial learning rate of training is set to 0.03, and the deviation value is set to 0.02. The optimal learning rate is finally obtained after 15,792 times. Figure 3 shows the curve of the algorithm training obtained by MATLAB simulation.

The BP neural network is tested, and the estimation result of ontology engineering cost is obtained by denormalization of the 5 sets of predicted data. It can be seen from Table 1 that the deviation between the estimated value and the actual value is less than 8%, which is in line with the error range in the comparison and selection process in the decision-making stage. Therefore, the estimation model of ontology engineering cost of the substation's water supply and drainage structure based on the BP neural network is feasible (see Table 1).

4.2. Estimation Model Construction of Price Difference Due to Preparation Time

4.2.1. Regression Model Construction of Price. There are about 360 kinds of materials used in the water supply and drainage structure engineering, of which three types of materials, namely, concrete, steel, and pipe, account for about 85% of the total material cost. Concrete materials include concrete, medium sand, gravel, cement, bricks, etc.; steel materials include reinforcing bars, iron pieces, steel pipe, section steel, channel steel, angle steel, etc. [8]; pipe materials include reinforced concrete pipe and UPVC pipe of various pipe diameters, etc. The concrete materials account for about 28% of the material cost, the steel materials account for about 49%, and the pipe materials account for about 8%.

TABLE 1: Results and analysis of denormalization processing.

Input layer				Output layer	Actual value	Error %
Voltage level	Prospective scale	Current scale of main transformer	Layout	Cost of ontology		
0.38	0.26	0.31	0.16	590	608	−0.03
0.29	0.17	0.22	0.09	470	457	0.03
0.41	0.3	0.27	0.21	709	695	0.02
0.35	0.21	0.29	0.14	557	546	0.02
0.39	0.27	0.34	0.18	638	644	−0.01

By analyzing the material information prices from 2018 to 2022, there is a regression relationship among the prices of materials of the same kind. The three types of materials are represented by the most used material, and other materials of the same kind establish a regression relationship with it. Concrete C30 is chosen as the representative of concrete materials, a round steel bar $\Phi 12$ is chosen as the representative of steel materials, and reinforced concrete pipe DN300 is chosen as the representative of pipe materials. Based on this, the calculation formula of the price difference due to preparation time y_2 is listed as follows:

$$\text{Material price difference} = \sum_{i=1}^n (p_i^1 - p_i^0) q_i. \quad (10)$$

In the formula (10), p_i^1 is the local current market price of the i th construction material, p_i^0 is the budget price of the quota of the i th construction material, and q_i is the quantity of the i th construction material.

$$y_2 = \sum_{i=1}^n (c_i - 1) q_i p_i^0 + m y_1 + n y_1. \quad (11)$$

In the formula (11), c_i is the proportional coefficient of market price p_i^1 and budget price of the quota p_i^0 of each material; q_i is the quantities of each material; p_i^0 is the budget price of the quota of each material; m is the price difference coefficient of labor cost based on the ontology engineering cost; and n is the price difference coefficient of machinery one-shift cost based on the ontology engineering cost. q_i can be obtained by decomposing the ontology engineering cost y_1 . The price difference of construction machinery is generally smaller, less than 1%, and it is consistent with the changing trend of the unit price of machinery for one-shift installation. Therefore, m and n are implemented in accordance with the coefficients of labor cost and installation machinery cost of the documents issued by the China Electric Power Project Cost Administration.

4.2.2. Calculation of Regression Coefficient. The market prices of materials originate from the official cost information websites that release the prices each month from 2017 to 2021, and a one-dimensional linear regression model

of the prices among similar materials is constructed [9]. Because of the large variety of materials included, only representative material regression coefficients are listed in this paper.

The calculation results of the regression coefficient of concrete materials' unit prices with the unit price of concrete C30 as the independent variable are shown in Table 2.

The calculation results of the regression coefficient of steel materials' unit prices with the unit price of round steel bar $\Phi 12$ as the independent variable are shown in Table 3.

The calculation results of the regression coefficient of the unit prices of pipe materials with the unit price of reinforced concrete pipe DN300 as the independent variable are shown in Table 4. It can be seen from the data in Table 4 that the simulation calculation results of the regression coefficient fluctuate greatly, which is due to the objective differences in the influence of materials and pipes' diameter on the simulation of the regression coefficient. Generally speaking, in the case of the same material, the larger the pipe's diameter is, the greater the regression coefficient is; in the case of a similar diameter of pipes, the regression coefficient of UPVC material is higher than that of reinforced concrete.

4.3. Simulation of Hydraulic Cost Estimation Model. The test of the regression model is based on the comparison and analysis of the actual data of substation projects from 110 kV to 500 kV in previous years, and the project features cover the construction scale of common substations, so as to verify the accuracy of the BP neural network, regression model, and project cost estimation results. The simulation results of the substation water supply and drainage structure cost estimation model are shown in Table 5. After the induction and analysis of the existing data samples, the statistical mode is distributed under the voltage level of 200 kV, so more data of 220 kV are selected in the simulation link, and the experimental results can better test the prediction effect and accuracy of the model built in this study.

Figure 4 shows the radar plot of the error between estimated values and actual values. From the relative error between the estimated values and actual values, it can be seen

TABLE 2: Regression coefficients of concrete materials' unit prices.

Independent variable		Dependent variable		
Concrete C30	Concrete C25	Medium sand	Cement 32.5	Gravel 40
1	0.961	0.285	0.802	0.287

TABLE 3: Regression coefficients of steel materials' unit prices.

Independent variable		Dependent variable		
Round steel bar $\Phi 12$	Galvanized steel pipe DN200	Galvanized steel pipe DN100	Sheet steel	Round steel bar $\Phi 8$
1	1.342	1.421	1.086	1.055

TABLE 4: Regression coefficients of unit prices of pipe materials.

Independent variable		Dependent variable		
Reinforced concrete pipe DN300	Reinforced concrete pipe DN500	Reinforced concrete pipe DN800	UPVC DN75	UPVC DN200
1	1.728	3.492	0.594	2.255

TABLE 5: Simulation results of a substation water supply and drainage structure cost estimation model.

Voltage level			500 kV		220 kV		110 kV
Design parameters	Prospective scale	Main transformer (group)	4	3	4	3	3
		High-voltage-side outgoing line (line)	8	3	12	6	2
	Current scale of main transformer (group)		1	2	2	2	2
	Layout		Outdoor	Full-indoor	Full-indoor	Semi-indoor	Semi-indoor
Actual data	Ontology engineering cost (CNY 10,000)		618.14	551.46	669.63	461.57	189.69
	Project area		Dezhou, Shandong province	Beijing	Beijing	Beijing	Linyi, Shandong province
	Price difference due to preparation time	Price-adoption time	July 2021	January 2021	July 2021	December 2021	January 2021
	Price difference due to preparation time (CNY 10,000)		87.03	83.23	120.79	88.31	23.28
	Total cost of water supply and drainage structure (CNY 10,000)		705.17	634.69	790.42	549.88	212.97
	Ontology engineering cost (CNY 10,000)		629.19	556.51	656.50	466.62	191.71
Estimated data	Price difference due to preparation time (CNY 10,000)		91.08	87.29	119.77	92.37	24.29
	Total cost of water supply and drainage structure (CNY 10,000)		720.77	643.80	776.27	558.99	216.00
	Error of total cost		2.14%	1.44%	-1.79%	1.66%	1.42%

visually that the error of the cost estimation model is controlled within $\pm 3\%$, and the model passes the test. It demonstrates that the reasonable estimation of the water

supply and drainage structure costs in the substation can be completed based on the key design parameters and the main market price level.

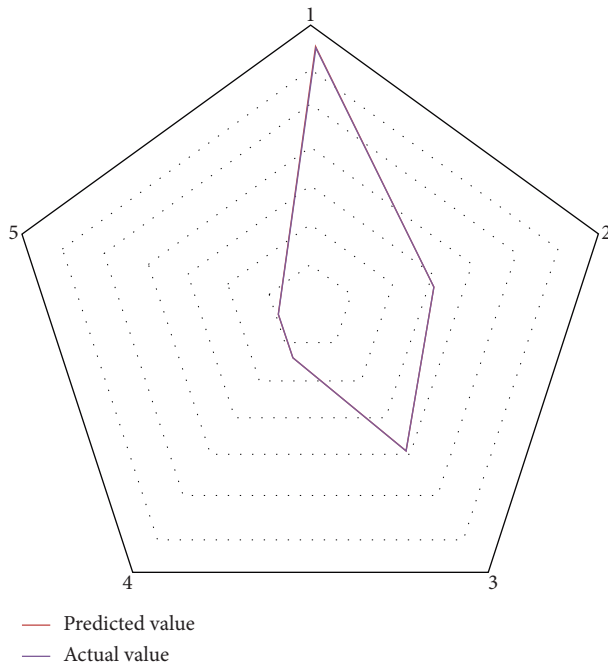


FIGURE 4: Radar plot of the error between estimated values and actual values.

5. Conclusion

By analyzing the influence of design parameters on quantities in the substation project, this study has built a BP neural network model based on the four design parameters: the voltage level, the prospective scale, the current scale of the main transformer, and the layout, achieving a reasonable estimation of ontology engineering cost. An estimation model of price difference due to preparation time considering market price changes is also built, and the regression method is applied to measure the regression coefficient of the price of materials of the same kind, achieving a reasonable estimation of the price difference due to preparation time. Through calculation and stimulated analysis, the model passes the test, and the error is controlled within $\pm 3\%$. The cost estimation results are in line with the actual cost requirements, and this model solves the practical problem of rapidly estimating water supply and drainage structure costs for the participant units. On the basis of the cost model of the water supply and drainage structure, the next step of the study is to focus on the further exploration of the potential of design parameters in the rapid estimation of project cost, realizing more efficient practice and application of the cost model.

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 there are no conflicts of interest.

Acknowledgments

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Research Article

Analysis of Business Environment and Medical Insurance Coverage Rates in the Destination of China's Migrant Population: Based on Geographically and Temporally Weighted Regression Model for Panel Data

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Health risk is an important issue in the process of population spatial mobility, and it is also an important issue in the process of urbanization in China. Using the dynamic monitoring data of China's migrant population and 31 provincial business environment data from 2011 to 2018, this study systematically investigated the spatial distribution and evolution characteristics of the migrant population's participation in medical insurance in the destination areas and combined it with the Geographically and Temporally Weighted Regression Model for Panel Data (PGTWR) to analyze the impact of the regional business environment on the medical insurance coverage rate of the inflow area. The results are as follows: first, the spatial pattern of the insurance coverage rate is high in Eastern China and low in Western China. The areas with high insurance coverage rates are mainly distributed in the three major economic circles of China and provinces such as Shandong and Xinjiang. Second, there is significant spatial autocorrelation in the coverage rate, which shows that cities with high participation rates tend to form agglomeration areas in geographical space, and so do cities with low participation rates. The coverage rate of the popular areas is scattered, while the unpopular areas are concentrated. Third, the estimation results of the Geographically and Temporally Weighted Regression Model for Panel Data show that the macroeconomic and infrastructure indicators in the business environment have a greater impact on the insurance rate, while the impact of policy environment indicators is relatively weak. However, the overall improvement of the business environment can significantly improve the probability of the migrant population participating in medical insurance in the inflow area.

1. Introduction

China is currently experiencing the largest population movement in its history. Data from the seventh national census show that the total migrant population in China will reach 376 million by 2020, accounting for 26.6% of the total population. With the continuous acceleration of China's urbanization process, the migrant population will still maintain a large scale of growth. In the traditional market economy theory, the micromigration decision of the floating population mainly depends on the net economic benefit difference, i.e., wage difference. However, the labor force will encounter a range of risks and uncertainties in the process of

spatial mobility. Therefore, in reality, the factors that determine the inter-regional migration decision of the floating population are more complex: on the one hand, the migration decision takes into account comprehensive income, and family members' consideration of education, medical care, and social security are also important; on the other hand, the migrant population is not highly educated, lacks certain professional labor skills, and is often engaged in jobs with relatively dangerous occupations, long working hours, and poor working environments, which have greater health risks than residents. Therefore, the migrant population has a strong desire to obtain social security and medical benefits in the cities where they lived and worked [1, 2].

In the past 20 years, China's social security system has been continuously improved, and by the end of 2015, before the Chinese government integrated the two systems of new rural cooperative medical care and basic medical care for urban residents, the number of China's medical insurance participants reached 1.336 billion, and the participation rate has been maintained at over 95% since then, basically establishing a "low-level, broad-coverage" medical insurance system. Unfortunately, however, influenced by various factors such as the household registration system, the migrant population, as an important group for economic construction, still cannot have the same social insurance treatment as residents. By 2017, the participation rate in the destination of the migrant population was only 27.6% as per data derived from the China Migrants Dynamic Survey, far below the national average level of medical insurance participation rate, and there are significant geographical differences. Therefore, it is of great significance to deeply analyze the spatial distribution pattern of the migrant population participating in medical insurance in the destination areas and explore the main influencing factors to promote the transformation of medical insurance from full system coverage to full population coverage.

An important difference between the floating and local populations in China's urban labor market is social insurance participation. Existing research has focused on floating access to social insurance and participation rates [3–5], especially for the large rural migrants, the urban-rural divide caused by a rural hukou status is an important source of low access to social insurance opportunities [6–9]. However, it is inaccurate to attribute all the reasons for the exclusion of the migrant population from the urban social security system to policy discrimination and urban-rural differences; as early as the 2000s, Beijing, Shanghai, and Guangdong (popular destinations for the immigrants) already allowed the migrant population to participate in all five social insurance schemes, including pension, health, work-related injury, unemployment, and maternity insurance. Particularly, in 2016, the Chinese government issued relevant policies to break the original localized management barriers of medical insurance, so that the immigrants can enjoy the same medical insurance treatment as the residents in the destinations, and greatly reduce the cumbersome procedures of the migrant population in the process of insurance participation and reimbursement. Another part of the literature mainly analyzed the influencing factors of migrant population participation in social insurance, such as gender, age, education level, and other demographic characteristics, and analyzed the impact of occupation type, nature of the company, work income, and other occupational characteristics [10–13]. In the existing literature related to this study, metrics are usually measured using econometric models, and commonly used models are discrete choice models such as Logistic and Probit. The above methods are more applicable to the study of individual factors and do not reflect the spatial heterogeneity of the study area and the spillover effects between regions.

However, if the acquisition of social insurance is regarded as an "optional commodity" rather than a legal

right, it is not enough to only pay attention to the characteristics of the "demand side," the migrant population. As the "supply side," the policy environment and inclusive culture provided by the destination cities also have an influence that cannot be ignored. Considering the political, economic, social, cultural, ecological, and other factors of the destination government, the business environment is undoubtedly more directly related to labor mobility. In recent years, regions that attach importance to the optimization and improvement of the business environment have gained more migrant population dividends—on the one hand, a good business environment can promote economic development, thereby producing a siphon effect on labor [14]. On the other hand, a high-quality business environment means better financing convenience, better intellectual property protection, more effective government services, and better preferential tax policies. It will mainly serve enterprises and can effectively help enterprises invest in production, thus creating more jobs for labor inflows.

This study expands the relevant literature on China's immigrants participating in medical insurance from the following aspects: the first contribution focuses on "regional differences in policy environment"—the impact of the business environment on migrants' participation in insurance because orderly mobility is an inevitable requirement to promote labor market integration, but migration decisions are largely affected by different regional environments and policies. Therefore, "inter-regional policy environment difference" is the unavoidable problem of labor mobility. But the topic has never received more attention. The second contribution is to examine the temporal and spatial differentiation characteristics of the insurance participation rate from the perspective of economic geography. The distribution of the migrant population is based on regions, and there is spatial distribution heterogeneity that affects each other between regions. The insurance participation data of the migrant population can more objectively show the insurance participation rate. Therefore, this study uses the microdata of the China Migrants Dynamic Monitoring Survey (CMDMS) to conduct an exploratory spatial analysis. The third contribution lies in the use of the Geographically and Temporally Weighted Regression Model for Panel Data (PGTWR). Labor mobility and insurance participation in different cities is a spatial phenomenon. The business environment characteristics of city A not only affect the migrant population of itself but also affect the migrant population of neighboring cities and the decision to participate in insurance. The impact will vary with distance, culture, and policy, manifesting as spatial heterogeneity. However, the traditional linear regression model can only estimate the parameters "average" or "global" and cannot take into account the spatial location information contained in the data, while the commonly used Geographical Weighted Regression (GWR) is simply a large cross-sectional treatment of panel data and does not consider the transfer and conduction of spatial spillover effects in time.

The rest of the article is presented below. Section 2 will introduce the data from the China Migrants Dynamic Survey (CMDMS) and the PGTWR model. Then, an

exploratory spatial analysis of the health insurance participation rate in the destination cities of China's migrant population is conducted. In Section 4, the impact of the business environment on the participation rate is estimated based on the PGTWR model. The last section summarizes the main findings and related policy recommendations.

2. Data Sources and Research Methods

2.1. Data Description and Business Environment. The microdata used in this study are derived from the Migrant Population Dynamics Monitoring Survey conducted in China from 2011 to 2018. The survey uses the 2010–2017 migrant population in 31 provinces of China as the basic sampling frame and adopts a stratified, multistage, size-proportional PPS method with a total sample size of 1.648 million people. The respondents were the male and female floating population aged 15 to 59 years old who had lived locally for a month or more, with nonlocal hukou. The tourists and students at stations, docks, and other places were excluded. We define five types of conditions, in which the working population participating in the new rural cooperative medical insurance, cooperative medical insurance for urban and rural residents, medical insurance for urban residents, medical insurance for urban workers, and public medical care in the destination cities as “participating in the medical insurance.” After removing missing values and outliers from the data, 1222217 valid samples were obtained.

The definition of the business environment in this study is derived from the World Bank, i.e., the external environmental conditions faced by business activities from the start-up to the end of the process. At the microlevel, the business environment significantly affects the migration and integration intentions of the migrant population in terms of macroeconomic development, government policy competition, and infrastructure construction [15]. Given the availability of data and the homogeneity of the business environment at the provincial level, we constructed a business environment evaluation index system at the provincial level including three primary indicators of the macroeconomic, policy environment, and infrastructure as well as 11 secondary indicators, after that we used the entropy evaluation method to determine the indicator weights, and then measured the business environment of 31 provinces from 2010 to 2017. The data are obtained from the National Bureau of Statistics of China and the China Statistical Yearbook, and the index system and weights are listed in Table 1.

2.2. Geographically and Temporally Weighted Regression Model for Panel Data. The Geographically and Temporally Weighted Regression Model for panel data is a specific form of a geographically weighted regression model based on panel data, which includes cross-sectional data of different regions in different time dimensions. The model is based on the “peer effect” in economics, which emphasizes that the individual's behavior is influenced by the behavior of surrounding individuals, which can be found regularly in a

certain number of peer behaviors. The model form of the PGTWR based on the peer effect is shown in the following equation:

$$STW_{\{e\}} y_{\{e\}} = STW_{\{e\}} X_{\{e\}} \beta l + \varepsilon_{\{e\}}. \quad (1)$$

In equation (1), $\{e \in l\}$ denotes the set of sample areas in different periods included in the study based on certain rules when l is used as the target analysis area, i.e., in addition to the target area, other neighboring areas that have significant spatio-temporal spillover effects on the target analysis area should also be included in the sample area, and there are $Num_{\{e\}}$ elements in the $\{e \in l\}$. $STW_{\{e\}}$ is the spatio-temporal weight matrix of dimension $Num_{\{e\}} \times Num_{\{e\}}$. The y and X denote the matrix of explained variables and explanatory variables of the sample area with dimensions $Num_{\{e\}} \times 1$ and $Num_{\{e\}} \times (k + 1)$, respectively, and k is the number of explanatory variables. At this point, y and X contain not only the data information of the target analysis area but also the new information formed by the mapping of the “peers” to the sample area. In this case, the spatio-temporal weight matrix also needs to cover all the information mapped from the sample area to the target analysis area, and its elements are determined as shown in the following equation:

$$\begin{aligned} \Gamma &= STW'_{\{e \in l\}} STW_{\{e\}}, \\ STW_{\{e\}} &= STW_{l,direct} + [STW_{l,spillover} \text{diag}(STW_{l,direct})] \\ &\quad * I_{Num_{\{e\}}}. \end{aligned} \quad (2)$$

In equation (4), Γ denotes the weighted weight matrix used for parameter estimation of the panel spatio-temporal geographic weighted regression model. $STW_{\{e\}}$ denotes the spatio-temporal weight matrix used in mapping the information of the sample area to the target analysis area, where only the main diagonal has elements and the nonmain diagonal elements are all zero. $STW_{\{e\}}$ is the sum of two spatial effect values, one from the spatial effect of the direct mapping of the sample area to the target analysis area and the other from the spatial effect of the indirect mapping of the sample area to the target analysis area. $STW_{l,direct}$ refers to the spatio-temporal weight matrix from the direct spatio-temporal effect of the sample area $\{e \in l\}$ to the target analysis area l ; $STW_{l,spillover}$ refers to the spatio-temporal weight matrix of the spatio-temporal spillover effects between the sample area $\{e \in l\}$. $I_{Num_{\{e\}}}$ is a $Num_{\{e\}}$ order identity matrix, the symbol $*$ indicates the dot product between matrices, which takes the elements of the matrix $STW_{l,spillover} \text{diag}(STW_{l,direct})$ and puts them into the main diagonal elements of $I_{Num_{\{e\}}}$ to form a new matrix. The spatio-temporal weight matrix $STW_{l,spillover}$ of the spatio-temporal spillover effect between the sample area $\{e \in l\}$ can be referred to Fan and Hudson (2018) [16].

To ensure that the obtained spatial effect values are comparable, the adaptive bandwidths hd and hl need to be adjusted when determining the elements of the spatial weight matrix, i.e., $h = \text{Max}(hd, hl)$ is used to replace the initial values of the adaptive bandwidths hd and hl , thus ensuring that the total number of sample areas included in

TABLE 1: Business environment evaluation index system and weights.

Primary indicators	Secondary indicators	Explanation of indicators	Direction	Weight
Macroeconomics	GDP per capita	GDP per capita	Positive	0.2902
	Average wage level	Average wage of employees	Positive	0.2534
	Consumption rate	Final consumption expenditure/GDP	Positive	0.0973
	Fixed asset investment per capita	Fixed assets/resident population	Positive	0.3438
	GDP growth rate	GDP growth rate	Positive	0.0153
Policy environment	Government intervention	Local fiscal expenditure/GDP	Positive	0.0178
	Corporate tax burden	Taxes and surcharges on main business/total profit	Negative	0.9822
Infrastructure	Urban road area per capita	Urban road area/resident population	Positive	0.1323
	Number of beds in health institutions	Number of beds in health institutions	Positive	0.2576
	Power supply capacity	Electricity consumption of the whole society	Positive	0.3177
	Freight capacity	Total cargo volume	Positive	0.2824

the analysis framework is the same for each target area. For the specific programming, h will be calculated based on the following steps: first, based on the threshold of the number of sample areas included in the analysis, to determine the number of sample areas that should be included in the analysis for each target area, and the number of neighboring areas that should be included in each sample area. Second, all distances from the sample areas to the target analysis areas $d_{n_{\{e\ell\}} \rightarrow l}$, and all distances $d_{n_o \rightarrow n_d}$ from each sample area to its immediate neighbors included in the analysis, were calculated. Finally, h can be obtained by the following equation:

$$h = \text{Max} \frac{(d_{\{e\ell\} \rightarrow l}, d_{n_o \rightarrow n_d})}{\sqrt{-(1/\eta) \ln(\text{sevc})}}. \quad (3)$$

Among them, η is the empirical constant in the Gaussian kernel function, which takes the value of 0.5 in this study. sevc is the critical value of tolerable spatial effect on the spatial influence boundary, considering the definition domain of spatial effect (0,1) and the way the critical value of significance level is designed, this study sets $\text{sevc} = 0.05$, which means the spatial spillover effect does not exist when that between regions is less than 0.05.

Under the given spatial bandwidth and temporal bandwidth, the nearest neighboring local points incorporated in the analysis of a single local point will form a new panel, which is a subset of the initial panel containing all spatial points and all periods. At this time, all parameters and statistical properties of a single local point can be determined based on the traditional modeling logic of panel data in econometrics. At the same time, since the calculation of local point parameters and statistical properties depends on the determination of adaptive spatial bandwidth and temporal bandwidth, different adaptive bandwidths will imply different optimal models, so the problem of adaptive bandwidth preference and model selection can be determined based on the overall statistical properties of the model.

2.2.1. Parameter Estimation and Significance Assessment. The parameters of the PGTWR model and their variance estimates are $\tilde{\beta}_l = \tilde{S}_{y_{\{e\ell\}}}$ and $\text{Var}(\tilde{\beta}_l) = \text{Diag}_l[\tilde{\Omega}(\tilde{\beta}_l)]$, where $\tilde{S} = (X_{\{e\ell\}}' \Gamma X_{\{e\ell\}})^{-1} X_{\{e\ell\}}' \Gamma$, $\tilde{\Omega}(\tilde{\beta}) = \tilde{S} \Gamma^{-1} \tilde{S}' \tilde{\sigma}_1^2$; the random

disturbance term variance estimates are calculated by the following equation:

$$\tilde{\sigma}_1^2 = (H_{\{e\ell\}} - \tilde{H}_{\{e\ell\}})' \frac{(H_{\{e\ell\}} - \bar{H}_{\{e\ell\}})}{(\tilde{v}_{0,l} - 2\tilde{v}_{1,l} + \tilde{v}_{2,l})}, \quad (4)$$

$$\tilde{\sigma}^2 = (H - \tilde{H})' \frac{(H - \tilde{H})}{(\tilde{V}_0 - 2\tilde{V}_1 + \tilde{V}_2)}.$$

$\tilde{\sigma}_1^2$ is the variance estimate of the random perturbation term for the local point l , $l = 1, 2, \dots, NT$, $H_{\{e\ell\}} = \text{STW}_{\{e\ell\}} y_{\{e\ell\}}$, $\tilde{H}_{\{e\ell\}} = \tilde{h}_l y_{\{e\ell\}}$, $\tilde{h}_l = \text{STW}_{\{e\ell\}} X_{l,\{e\ell\}} S$; $\tilde{v}_{0,l} = \text{tr}(\text{STW}_{\{e\ell\}})$, $\tilde{v}_{1,l} = \text{tr}(\tilde{h}_l)$, $\tilde{v}_{2,l} = \text{tr}(\tilde{h}_l' \tilde{h}_l)$. $\tilde{\sigma}^2$ is the estimate of the variance of the random perturbation term for the model as a whole; $H = [H_1, H_2, \dots, H_l, \dots, H_{NT}]$, $H_l = y_l$; $\tilde{H} = [\tilde{H}_1, \tilde{H}_2, \dots, \tilde{H}_l, \dots, \tilde{H}_{NT}]$, $\tilde{H}_l = A \tilde{H}_{\{e\ell\}}$; A are the shares of spatial effects of all local points in the local point l analysis that have an effective effect on the local point l , $A = \text{tr}^{-1}\{\text{STW}_{\{e\ell\}}\} \text{Diag}\{\text{STW}_{\{e\ell\}}\}$; $\tilde{V}_i = \sum_l \tilde{v}_{i,l}/NT$, $i = 0, 1, 2$.

On the basis of determining the variance estimates of the random disturbance terms, it is easy to determine the statistics of T and its distribution for each local point parameter estimation, where $T_{l,k} = \tilde{\beta}_{l,k}/\text{Se}(\tilde{\beta}_{l,k}) \sim T(\tilde{v}_{0,l} - 2\tilde{v}_{1,l} + \tilde{v}_{2,l})$ and $\tilde{\beta}_{l,k}$ is the k th element of the vector of $\tilde{\beta}_l$. At this point, because the local point parameter estimation process is still in accordance with the traditional panel data econometric method, the probability value and probability critical value still need to be calculated according to the traditional algorithm, and the same for the determination of the relevant statistical property indicators (including the goodness of fit, AICc criterion value, F distribution value, and the probability value of F distribution). As the parameters of individual explanatory variables become insignificant in the overall analysis of the model, it is no longer necessary to make a separate analysis of the parameters of the explanatory variables and the hypothesis testing process of the overall model.

2.2.2. Overall Statistical Properties and Model Selection. In the PGTWR model, the target analysis region behavior will be explained or predicted by the product of the sample region behavior and its share in the total level of spatio-temporal

spillover effects from all regions to the target analysis region. The inferred or predicted accuracy of the target analysis region behavior, based on the sample region behavior, will be able to determine the most appropriate model and, consequently, the optimal spatial bandwidth [17].

The optimal bandwidth selection for the PGTWR model can be done according to the traditional CV criterion, GCV criterion, and AICc criterion, but the calculation formula needs to be adjusted slightly, as shown in the following equation:

$$\begin{aligned} CV &= (\tilde{y}_L - y_L)' (\tilde{y}_L - y_L), \\ GCV &= \frac{CV}{(NT - k - 1)^2}, \\ AICc &= \tilde{V}_0 \left[\ln(\tilde{\sigma}^2) + \ln(2\pi) + \frac{(\tilde{V}_0 + \tilde{V}_1)}{(\tilde{V}_0 - 2 - \tilde{V}_1)} \right]. \end{aligned} \quad (5)$$

Then, the optimal adaptive spatial and temporal bandwidths are determined according to the CV, GCV, and AICc criteria for taking the minimum values. When the values of the different criteria point to a different optimal bandwidth, the overall statistical properties of the model under different spatial and temporal bandwidths can be preliminarily calculated. The selection results of the most suitable bandwidth can be determined based on the optimal results of the statistical properties of the model. The overall merits and disadvantages of the model can be judged by the relevant statistical indicators, as shown in the following equation:

$$\begin{aligned} \tilde{R}^2 &= 1 - \frac{(\tilde{y}_L - y_L)' (\tilde{y}_L - y_L) / (\tilde{V}_0 - 2\tilde{V}_1 + \tilde{V}_2)}{(y_L - \bar{y}_L)' (y_L - \bar{y}_L) / (\tilde{V}_0 - 1)}, \\ F &= \frac{(\tilde{y}_L - \bar{y}_L)' (\tilde{y}_L - \bar{y}_L) / (2\tilde{V}_1 - \tilde{V}_2)}{(\tilde{y}_L - y_L)' (\tilde{y}_L - y_L) / (\tilde{V}_0 - 2\tilde{V}_1 + \tilde{V}_2)}, \\ \tilde{\alpha} &= \alpha \frac{(k+1)}{(2\tilde{V}_1 - \tilde{V}_2)}, \\ \ln L &= -\frac{\tilde{V}_0}{2} [\ln(\tilde{\sigma}^2) + \ln(2\pi) + 1]. \end{aligned} \quad (6)$$

\tilde{R}^2 is the modified goodness-of-fit value in the overall model; F is the F statistic of the overall model significance, whose distribution is of the form $F(2\tilde{V}_1 - \tilde{V}_2, \tilde{V}_0 - 2\tilde{V}_1 + \tilde{V}_2)$, from which the value of the F statistic and its corresponding probability level can be calculated. The probability threshold $\tilde{\alpha}$ of the overall model must be recalculated based on the predetermined significance level α ; $\ln L$ is the log-likelihood value of the overall model. \tilde{y}_L is the estimated value of the explained variable, \bar{y}_L is the mean value of the explained variable, \tilde{V}_i is the estimated value of the variable, and $\tilde{\sigma}^2$ is the estimated value of the variance of the random disturbance term. In general, the larger the proportion of significant parameter estimates at all local points in the overall model, the larger the value of \tilde{R}^2 , the more F passes the hypothesis test, and the corresponding model is likely to be the optimal model.

3. Spatial Distribution Characteristics of Health Insurance Coverage Rate of Migrant Population in the Destination

3.1. Analysis of Spatial Pattern. We take the city as the basic unit and divide the number of people participating in medical insurance by the number of surveyed people to measure the insurance participation rate and analyze the spatial distribution pattern of medical insurance participation in China's migrant population based on the natural fracture method. The results are shown in Figure 1. On the whole, the pattern of participation rates in Chinese cities is obvious: the high-value areas are mainly concentrated in the middle reaches of Yangtze River, Yangtze River Delta, Pearl River Delta, core cities in Shandong and Xinjiang, and northeast border cities of China; the rest of the high-value areas are scattered in and around economically strong cities. The participation rate of the migrant population in the above-mentioned areas is above 95%, which is consistent with the overall national medical insurance participation rate. The low-value areas are widely scattered in central, western, southwestern, and localized areas in Inner Mongolia and northeast China, which objectively reflects the reality that the overall level of urban integration willingness of the migrant population is low. No matter in the high-value areas or the low-value areas, the north is relatively concentrated, and the south is relatively scattered, reflecting the overall concentration and partial dispersion of the insurance participation rate in the inflow areas. Further, comparing the changes in the insurance participation rate from 2010 to 2017, it can be found that the willingness of the migrant population to participate in insurance has been increasing, especially in 2016 and 2017, which is closely related to the Chinese government's policy of establishing a unified basic medical insurance system for urban and rural residents introduced in 2016. In 2016, The State Council issued the Opinions on Integrating the Basic Medical Insurance System for Urban and Rural Residents. This policy allows the immigrants to enjoy the same medical insurance treatment as local residents in the destination cities and reduces the cumbersome procedures for the migrant population to enroll in insurance in other places and to return to their hometowns for reimbursement, which substantially reduces the worries of the migrant population to seek medical treatment in the inflow area. Among them, the areas with rapid growth in the participation rate are mainly concentrated in the Yangtze River basin and the more economically developed cities in the Yangtze River Delta, Pearl River Delta, and Shandong Province, indicating a high correlation between the willingness of the migrant population to blend into the city and the level of economic development in the destination area.

3.2. Spatial Association Features. We use spatial autocorrelation to study the spatial agglomeration characteristics of participation in the inflow areas of the migrant population. The calculation results for the global Moran's I are reported in Table 2. It can be seen that Moran's I is positive and highly

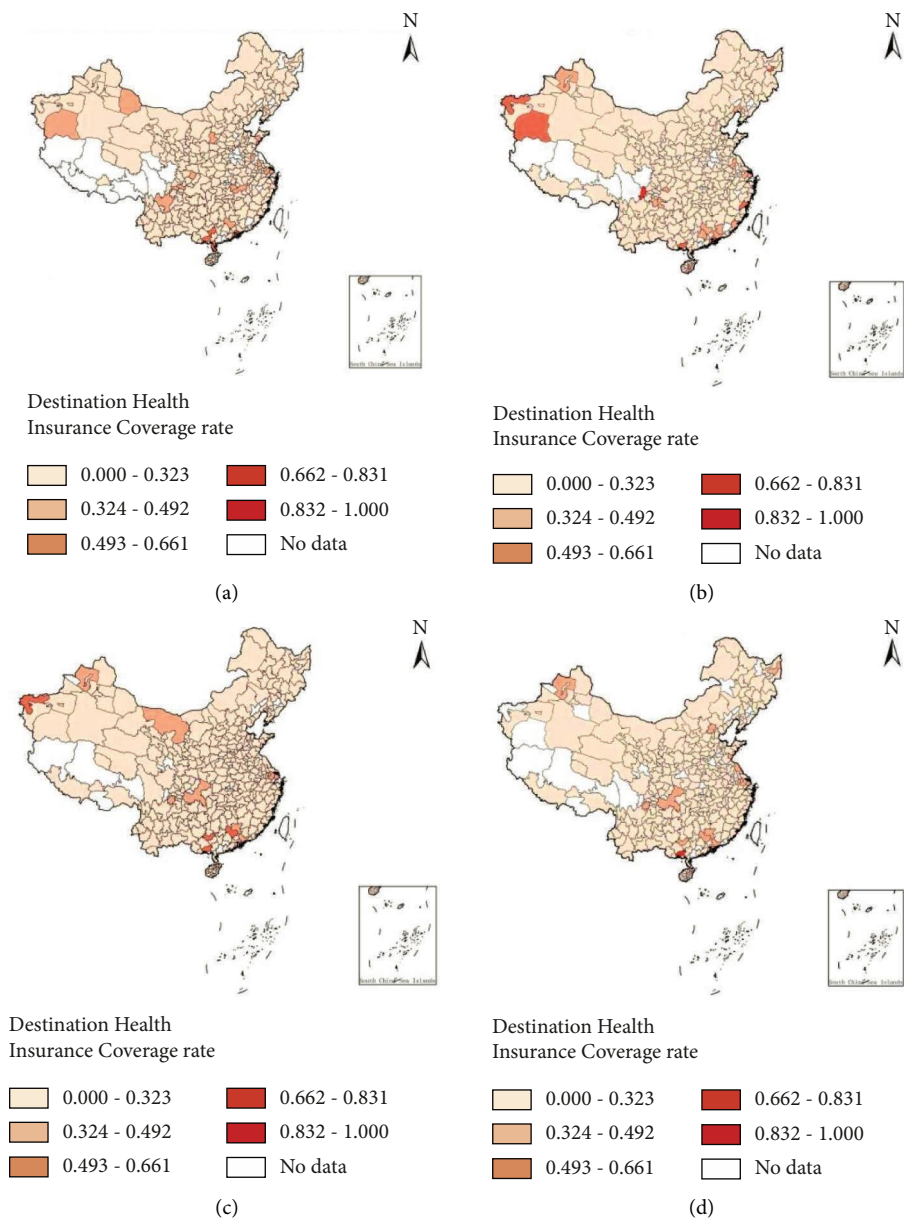


FIGURE 1: Continued.

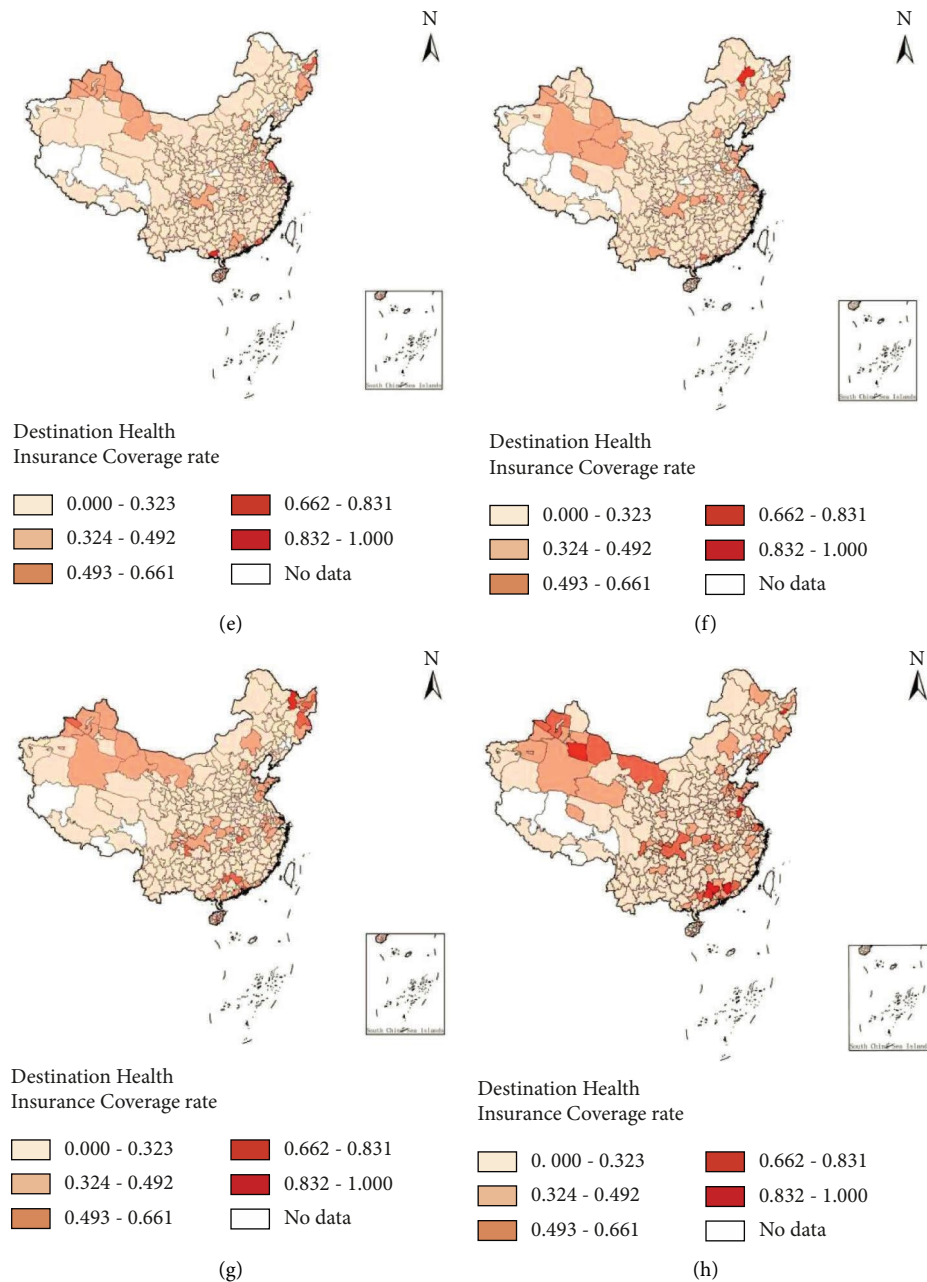


FIGURE 1: Spatial pattern of insurance participation rates 2010–2017. (a) Distribution map of destination health insurance coverage rate of floating population in 2010. (b) Distribution map of destination health insurance coverage rate for urban employees of floating population in 2011. (c) Distribution map of destination health insurance coverage rate of floating population in 2012. (d) Distribution map of destination health insurance coverage rate of floating population in 2013. (e) Distribution map of destination health insurance coverage rate of floating population in 2014. (f) Distribution map of destination health insurance coverage rate of floating population in 2015. (g) Distribution map of destination health insurance coverage rate of floating population in 2016. (h) Distribution map of destination health insurance coverage rate of floating population in 2017.

significant in all years, indicating that there is a significant spatial autocorrelation characteristic of the participation rate of migrant population inflow places among Chinese cities, and the areas with high participation rate have a positive impact on the increase of the participation rate in neighboring areas, thus making them neighboring. Further, it can be found that Moran's I increased from 0.090 in 2010 to 0.138 in 2017, indicating that the spatial concentration trend

of regions with similar levels of insurance participation rates is gradually increasing, and the development of insurance participation rates among cities tends to be agglomerated, showing two trends of high-speed development and low-speed development, which makes the difference in the local participation rate show a trend of magnified.

From the local spatial *LISA* agglomeration map in Figure 2, it can be seen that the spatial agglomeration characteristics of

the local area of the participation rate of the migrant population inflow are more obvious, mainly high-high agglomeration and low-low agglomeration, compared with the 2010, the cities with a high-high agglomeration of the participation rate increased significantly in 2017, and mainly concentrated in the Yangtze River Delta, Pearl River Delta, Shandong Province, and other regions, due to their high level of economic development, driving the development of surrounding cities and forming “rapid growth zone,” showing new high-high agglomeration characteristics. Low-low agglomeration mainly appears along the Longhai Railway from Shangqiu to Lanzhou and along with the border cities in Tibet, forming a “lagging agglomeration zone.” It can be seen that the participation rate has a more obvious spatial correlation, by this we can further analyze the spatial clustering law of the participation rate.

3.3. Spatial Clustering Characteristics. The spatial agglomeration distribution characteristics of the participation rate are identified using *Getis – Ord G^** , as shown in Figure 3. It can be seen that the hotspot areas of the participation rate become scattered, while the coldspot areas become clustered: compared with 2010, the hotspot areas are more widely distributed in the Pearl River Delta, Circum-Bohai-sea Region, Circum-Yellow-Sea Region, and most of Shandong and Xinjiang. In addition, the number of extremely hot spot cities has increased significantly. The hotspot and subhotspot areas are distributed at the outer edge of the hotspot area, such as southern Hunan, southern Fujian, Anhui, and western Jiangsu. As for the cold spot area, its scope spreads westward along the Longhai Railway, including Shaanxi, Henan, Ningxia, southeastern Gansu, northeastern Qinghai, and other regions, and new cold spot areas appear in southern Tibet and Yunnan in southwest China. The cold spot area originally in the central northeast gradually disappeared.

In general, the participation rate shows a clear spatial distribution pattern, showing differences between the eastern and western regions, i.e., the participation rate in the eastern cities and coastal regions is higher, while the participation rate in the vast central and western regions and the northeastern region is lower, and this pattern maintains a high level of evolutionary stability.

4. Business Environment and Migrant Population in Insurance at the Destination—Estimates Based on PGTWR

To examine the spatial and temporal differences in the business environment affecting the participation rate, we use the PGTWR model to conduct the analysis. Traditional OLS estimation tends to ignore the spatial spillover effects, which leads to biased estimation results. Therefore, an embedded spatial econometric model is needed to ensure that the estimation process can scientifically resolve the spatial spillover effects of the business environment and labor mobility. However, the spatial econometric global model needs to incorporate data from all regions for all periods to obtain the regularity of spatial dependence, which will ignore the heterogeneity of spatial dependence among factors

related to the business environment at an individual local point. Given this, this study combines the Geographically and Temporally Weighted Regression Model for Panel Data (PGTWR) with a self-coded program of MATLAB R2019a to estimate the problem of our concern.

Model selection is an important part of the analysis using PGTWR. The optimal spatial and temporal bandwidths are 31 and 4 for both the GCV-based and RSS-based criteria, and 30 and 8 for the AICc-based criterion. Since the optimal bandwidth selection results based on the GCV and CV criteria are equivalent, the optimal spatial or temporal bandwidths based on the CV criterion will not be considered in this study. Given the fact that the GCV criterion, RSS criterion, and AICc criterion point to different optimal spatial bandwidths and temporal bandwidths, we will report the overall statistical properties of the Geographically and Temporally Weighted Regression Model for Panel Data under the two optimal spatial and temporal bandwidths respectively, as listed in Table 3. Because the effective nearest neighbor local points incorporated under different bandwidth dimensions constitute the new panel data, this study also tries to calculate the overall statistical properties of the mixed effects, individual fixed effects, period fixed effects, and individual-period double fixed-effects PGTWR under the two optimal bandwidth dimensions, respectively. Since this study considers the Chinese provincial-level problem, in fact, all 31 spatial units are included and no further estimation of stochastic effect is required.

Comparing the overall statistical properties of the various possible models in Table 3, it can be found that the individual-period double fixed-effects PGTWR with an optimal spatial bandwidth of 31 and an optimal temporal bandwidth of 4 reflects relatively better statistical properties, where the significance ratio of the estimated values of the local coefficients reaches 77.85%, the modified goodness of fit reaches 0.9994, and the F-statistic can pass the hypothesis test with a significance level of 0.01. Meanwhile, the individual-period double fixed effects PGTWR with an optimal spatial bandwidth of 30 and an optimal temporal bandwidth of 8 also exhibits better overall statistical properties than the other three. In comparison, the model with an optimal spatial bandwidth of 30 and an optimal temporal bandwidth of 8 has smaller variance estimates of the stochastic disturbance term, and smaller values of the CV criterion, GCV criterion, and AICc criterion, reflecting better overall statistical properties. Therefore, in this study, the optimal spatial bandwidth and temporal bandwidth of 30 and 8, respectively, will be selected for the interpretation of the impact of the business environment on the health insurance participation rate in the destination of the migrant population.

After the optimal spatial and temporal bandwidths are selected, the relevant parameters and their statistical properties can be estimated for all local points, and the validity of the local point parameters can be diagnosed, as shown in Figure 4. Compared to the analysis based on the spatial metric global model, PGTWR gives each local point a separate analysis and incorporates only the near-neighboring local points that have an effective effect on the local point in the respective analysis process, thus making the estimation more accurate.

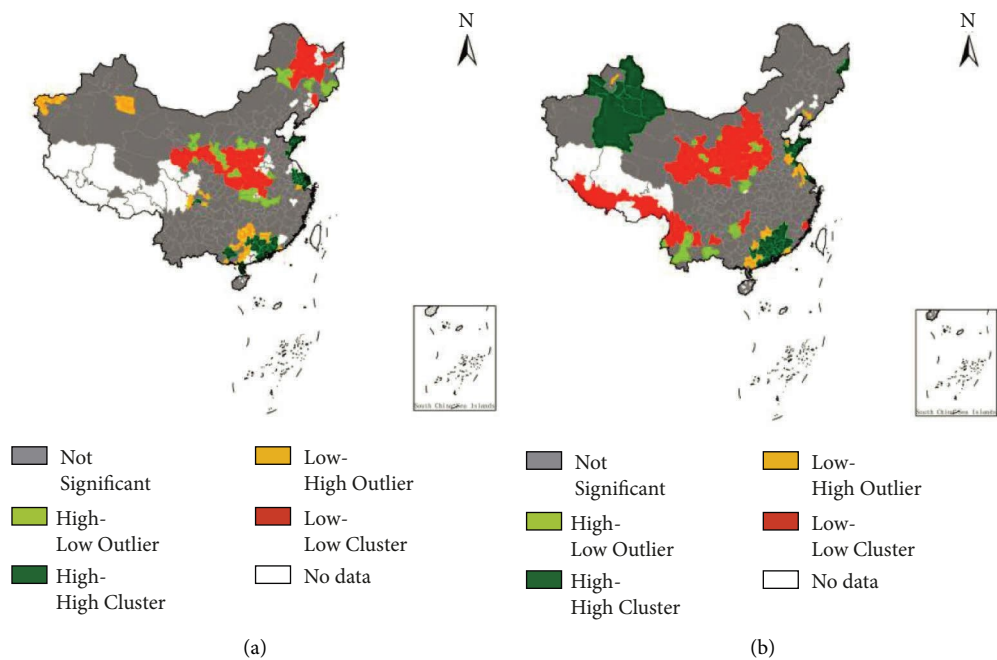


FIGURE 2: LISA agglomeration map. (a) LISA agglomeration map in 2010. (b) LISA agglomeration map in 2017.

TABLE 2: Moran’s I estimated value.

Year	2010	2011	2012	2013	2014	2015	2016	2017
Moran’s I	0.090	0.106	0.226	0.253	0.175	0.129	0.135	0.138
Z value	7.150	7.731	16.739	18.538	13.259	10.057	9.583	10.567
P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

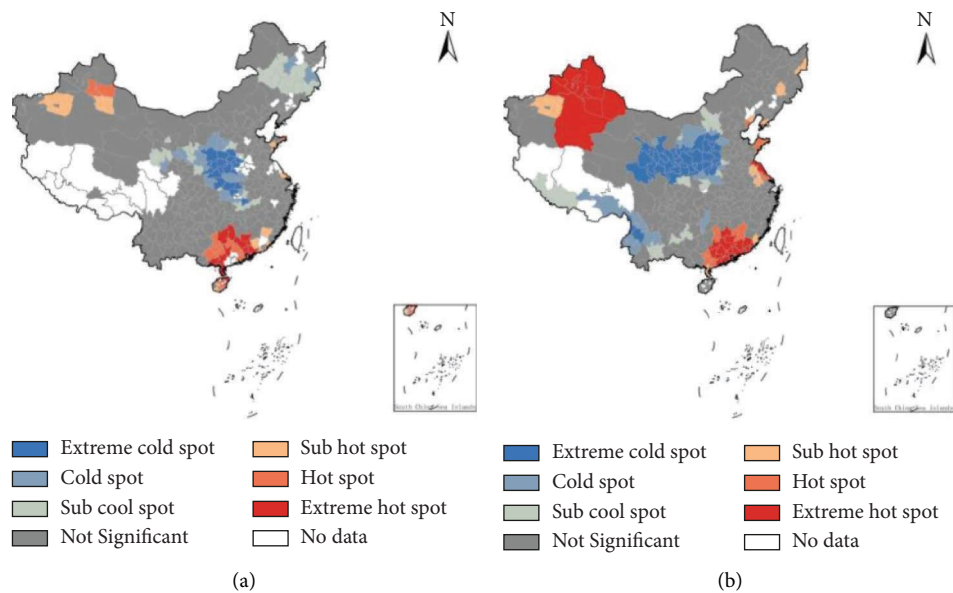


FIGURE 3: Distribution of hot and cold regions. (a) Distribution of hot and cold regions in 2010. (b) Distribution of hot and cold regions in 2017.

The parameter estimation process at local points still follows the traditional econometric approach for panel data, but the individual explanatory variable parameters become

insignificant in the overall analysis of the model, and we will no longer need to make a separate analysis of the explanatory variable parameters and hypothesis testing process for the

TABLE 3: Overall statistical properties of the model.

	GCV/RSS criterion (Optimal spatial bandwidth = 31; optimal temporal bandwidth = 4)				AICc criterion (Optimal spatial bandwidth = 30; optimal temporal bandwidth = 8)			
	Mixing effect	Individual fixed effects	Period fixed effects	Individual-period fixed effects	Mixing effect	Individual fixed effects	Period fixed effects	Individual-period fixed effects
Proportion of significance of local coefficient estimates	45.2%	55.78%	57.3%	77.85%	45.7%	77.02%	55.1%	78.66%
Sample size	248	248	248	248	248	248	248	248
Degree of freedom	86	95	87	95	116	119	116	120
Estimates of the variance of the random disturbance term	0.0345	0.0048	0.0269	0.0166	0.0280	0.0059	0.0203	0.0129
CV guidelines	2.9701	0.4531	2.3417	1.5783	3.2496	0.6975	2.3490	1.5526
GCV guidelines	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AICc guidelines	-118.58	-611.97	-183.00	-302.25	-170.19	-560.37	-253.31	-364.02
Modified goodness of fit	0.9845	0.6789	-0.2482	0.9994	0.9697	-0.1195	-2.3029	0.9994
F-statistic	7551.0	518.6	92.90	27845.0	16805.0	186.8	687.2	29235.0
Probability of the F-statistic	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***
Modified probability threshold	0.019	0.024	0.026	0.028	0.083	0.023	0.157	0.027
($\alpha = 0.01, 0.05, 0.1$)	0.095	0.121	0.128	0.141	0.416	0.113	0.787	0.136
	0.190	0.242	0.256	0.282	0.833	0.226	1.574	0.273
Log-likelihood value	65.46	310.96	96.37	156.19	91.41	285.38	131.65	187.20

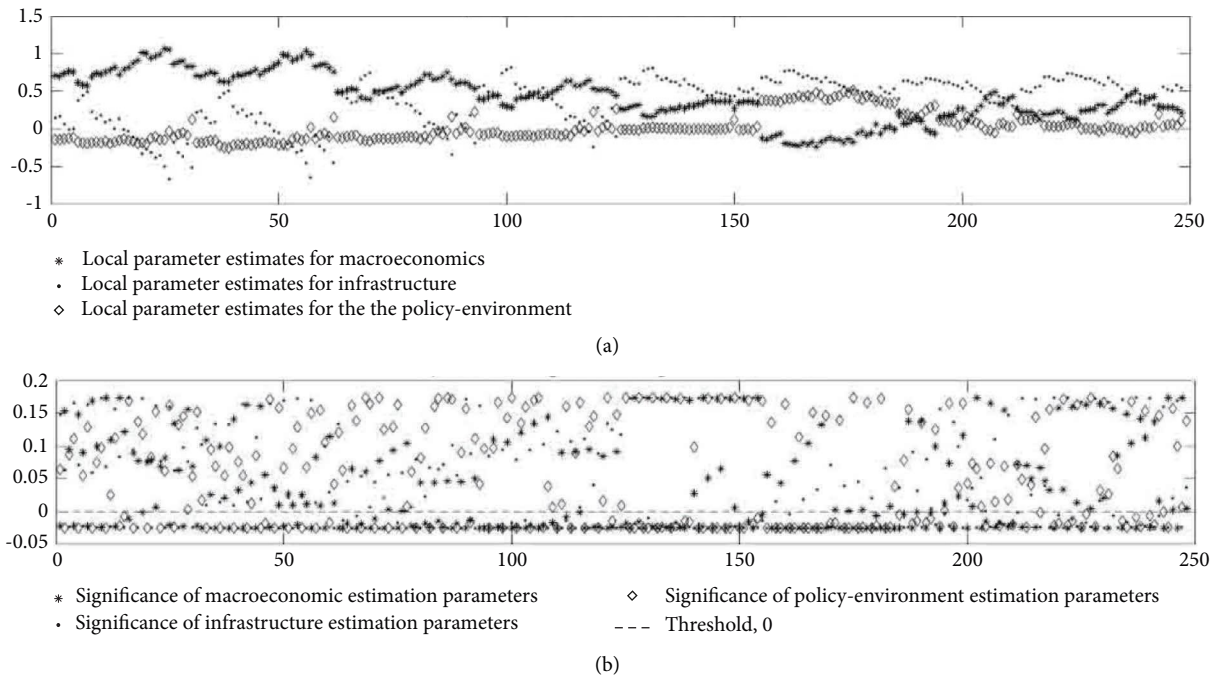


FIGURE 4: Parameter estimation results and validity diagnosis, (a) PGTWR parameter estimation results, (b) parameter significance diagnosis of the PGTWR.

overall model. To better explore the impact of the business environment on the participation rate, Table 4 reports the statistical characteristics of the regression coefficients of the PGTWR model and compares them with the global OLS

estimation results. From the global linear regression results, the macro environment and facility environment have a positive impact on the increase of the participation rate in the inflow of migrant population, while the policy

TABLE 4: Estimated results.

Variables	OLS estimation	Average value	Minimum value	Distribution of PGTWR estimation results				
				1/4 quartile	Median	3/4 quartile	Maximum value	Standard deviation
Macro environment	0.618 *** (0.052)	0.4170	−0.2319	0.2279	0.4022	0.6556	1.0674	0.3111
Policy environment	0.064 * (0.069)	0.0169	−0.2563	−0.1139	−0.0106	0.0762	0.5065	0.1820
Facility environment	−0.282 *** (0.037)	0.3530	−0.6677	0.1498	0.4585	0.5999	0.8144	0.3238
Adj. R^2	0.4385	0.9994						

environment has a negative impact, which may be related to the presence of the secondary indicator of the corporate tax burden. But of course, the linear estimation results are only the overall “average” and do not reflect the spatial and temporal variability of the impact of the business environment. The R^2 of this model is 0.4385, indicating that the model only explains less than half of the information, and its explanatory power needs to be further enhanced by embedding a spatial econometric model.

By comparing the adjusted R^2 it can be found that PGTWR has better explanatory power compared to OLS. First, the effect of macroeconomic indicators has a positive effect on the participation of the migrant population in the destination cities in the vast majority of provinces and autonomous regions in most years, except for a part of negative values in 2015. This situation accounted for 87.5% of the study period. On average, every 1% increase in the macroeconomic indicator increases the insurance participation rate by about 0.42%. Compared to the other two first-level indicators, the macroeconomic environment has a stronger positive impact, reflecting the important role of local economic development on the integration and willingness of the migrant population to participate in insurance. From a national perspective, for Jiangxi, Hubei, and Hunan in the central region; Guangxi, Chongqing, Sichuan, Guizhou, and Yunnan in the southwestern region; and Shaanxi, Gansu, Qinghai, Xinjiang, Tibet and other provinces in the western region, the average value of the estimated coefficients is higher than the national average (the national average is 0.4170). It indicates that in relatively backward regions, the marginal impact of macroeconomic development on the attractiveness of the floating population is stronger. In terms of time horizon, the estimated coefficients are *U*-shaped in all provinces, with the lowest value appearing in 2014 or 2015, which may be related to the implementation of the “National Insurance Registration Program” by the Chinese government in 2014 to integrate urban and rural social insurance information.

Second, the effect of the policy environment on the participation rate of the migrant population is relatively weak, with each 1% increase in this indicator during the research period increasing the participation rate in the destination city by about 0.017%, mainly because the policy environment for doing business is mainly expressed as the degree of “friendly” to enterprises. In the secondary indicators we selected, the weight of the corporate tax burden by the entropy method is 98%. Therefore, the tax burden of enterprises is the main component explaining the insurance participation rate. Nationally, the provinces with a negative

mean estimated coefficients include Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi, and Hainan in the coastal region and Anhui, Jiangxi, Hubei, and Hunan in the central region, which is also the main regions for undertaking manufacturing and processing industries in China, and a high enterprise tax burden will reduce the incentive of enterprises to invest and produce, which in turn affects the inflow of migrant population. The provinces with a positive mean estimated coefficients and higher than the national average of 0.016 are concentrated in western China, including Chongqing, Sichuan, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang, which indicates that enterprises in the western region still have a high potential in absorbing the migrant population.

Third, the infrastructure environment has a positive effect on the participation rate for the vast majority of the sample, with a share of 85.08% over the research period. On average, a 1% increase in infrastructure environment indicators will increase the migrants’ insurance participation rate by 0.35%, indicating that public services such as education, health care, and infrastructure development have a significant impact on the mobility decisions of the migrant population in the current market-oriented labor mobility process in China. The estimated coefficients are higher than the national average of 0.3530 for provinces in Northeast China, North China, East China, and Shaanxi, Anhui, Fujian, and Jiangxi in the central region. The sample with negative effects is small and has a spatial and temporal concentration trend, with only four provinces having negative effects for more than three years, namely Sichuan (2010–2012), Yunnan (2010–2013), Tibet (2010–2013), and Xinjiang (2010–2013).

5. Conclusion

The issue of medical insurance coverage for migrants is important in the urbanization process of China. This study systematically examines the spatial distribution and evolutionary characteristics of medical insurance coverage in the destination areas of the migrants using dynamic monitoring data of China’s migrant population and business environment data of 31 provinces from 2011 to 2018 and analyzes the impact of regional business environment on health insurance coverage rates in the inflow areas of the mobile population using the Geographically and Temporally Weighted Regression Model for Panel Data. The results are as follows: first, the spatial pattern of health insurance coverage in the inflow areas of the migrants in China presents a pattern of high in the east and low in the west, and the areas with high coverage rates are mainly distributed in the three major economic zones of China or provinces such as Shandong and Xinjiang. Second,

there is a significant spatial autocorrelation in the participation rate, which is manifested by the formation of clusters in cities with high and low participation rates each form agglomeration areas in the geographical space; the hotspot areas of the participation rate become dispersed, while the coldspot areas become clustered. Third, the use of panel spatio-temporal geographically weighted regression models examined not only the peer effects in the spatial neighbors but also the transfer and conduction effects of the spatial spillover effects in the sample regions, which better fits the reality of population mobility. The estimation results show that macroeconomic and infrastructure indicators in the business environment have a greater impact on the participation rate, while policy environment indicators are relatively weak, but overall the improvement of the business environment can significantly increase the probability of the migrants participating in health insurance in the destination area.

This study has important policy implications as follows: first, for a long time, the huge floating population is not only an important force for economic growth but also the main body to promote “100 million people to settle in cities and towns.” The spatial distribution and evolution characteristics of the medical insurance participation rate can reflect the medical insurance policy of the floating population in China. The regional characteristics of the implementation are to provide a reference for the rational allocation of regional health service resources and the formulation of regionally differentiated medical insurance policies. Second, the medical security system plays an important role in alleviating the migration worries of the floating population and enhancing the urban identity. After clarifying the role of the business environment in promoting the medical insurance participation of the floating population, it can guide the local government to improve the business environment as an important measure to promote the urban integration of the migrant population. At the same time, it can also continuously remove the management barriers to the social security of the floating population and improved and expanded the medical insurance participation rate and coverage of the migrants.

Data Availability

The data used to support the findings of this study may be released upon application to the China Migrants Dynamic Survey, who can be contacted at National Health Commission P.R.China.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Retraction

Retracted: Fuzzy Neural Network for the Online Course Quality Assessment System

Mathematical Problems in Engineering

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

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

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

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

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

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

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- [1] X. Bai and Y. Bai, "Fuzzy Neural Network for the Online Course Quality Assessment System," *Mathematical Problems in Engineering*, vol. 2022, Article ID 4865027, 10 pages, 2022.

Research Article

Fuzzy Neural Network for the Online Course Quality Assessment System

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Under the influence of COVID-19, online office and online education has ushered in a golden period of development. The teaching quality of online education has been a controversial issue. Our study takes online course teaching quality assessment as the starting point, explores the influencing factors of online course quality assessment with online courses as the research object, and analyzes the latest research proposal for an online course quality index. To make the online course quality assessment more intelligent, we propose an online course quality assessment method based on a fuzzy neural network. The method uses fuzzy rules as the baseline and adds a TSK perception mechanism to expand the perception domain of the fuzzy neural network and improve the course quality index prediction accuracy. At the input side of the fuzzy neural network, we preclassify the online course data into four parts, and each part of the data represents a different assessment domain. Due to the large data cost, we expanded the collective amount of data using data augmentation methods. In addition, we parse the structure of the fuzzy neural network hierarchy and introduce the construction and role of the TSK perception mechanism in the fuzzy rules. An optimal learning strategy is proposed in the fuzzy neural network training. Finally, in the experimental session, we verify the effectiveness of data augmentation and explore the distribution of course quality assessment weights. In the comparison of the model prediction results with the actual assessment results, our method achieves an excellent matching rate, which proves the high efficiency of our method in the online course quality assessment system.

1. Introduction

Affected by COVID-19, economies around the world have been affected to varying degrees, and most industries have begun to change their office methods to online to minimize losses. For the education industry, online teaching has become the most ideal way due to the impact of the national-level antiepidemic policy. Although the teaching effect is not as good as offline teaching, online teaching also has advantages that cannot be matched by offline teaching [1–3]. The online teaching approach adds many features, is clearer in the presentation of teaching purposes, and is equally capable of face-to-face interactive teaching with the aid of visual sensors [4]. The construction of an online teaching environment can be personalized according to the teaching

purpose, and compared with the traditional offline teaching mode, online teaching can obtain a better teaching presentation with the help of teaching environment construction. The advantage of online teaching is that it can be done with simple electronic devices for both students and teachers, which can greatly save the cost and time for teachers and students to move around [5–7].

Online teaching and learning, aided by computer vision and human-computer interaction technologies, has greatly improved the effectiveness of teaching and learning and also further motivated teachers and students to attend classes. Several researchers have also done several studies to enhance the effectiveness of online teaching and have worked to upgrade the online teaching model to that of face-to-face instruction [8]. The online teaching of the course is tailored

according to the differences like the course, and the student's interests and the teacher's teaching habits are simulated to learn through neural network algorithms, and different elements are inserted in the content, process, and structure of the online course teaching to enhance the experience and communication of the online course teaching. For the teaching materials involved in the course, some researchers build their online teaching database and crawl the Internet resources into the dataset synchronously so that students and teachers can get rich teaching resources in time during the online teaching process. Compared with traditional face-to-face teaching, the access rate and sharing rate of teaching materials have been greatly improved [9, 10]. Since the online teaching system has been put into use, the acceptance of online teaching mode by teachers and students varies. Many factors influence the evaluation of the teaching quality of online courses.

Many researchers have gradually shifted their research focus to the assessment of teaching quality, and some researchers have tried to rate classroom performance in teaching environments. Some researchers have tried to develop assisted adaptive apps to test the effectiveness of teaching. Other studies have attempted to add testing units to the teaching system to obtain evaluation results between teachers and students in both directions [11–13]. Some studies have also proposed to integrate parameters such as students' postclass grades, teachers' performance in class, and student's classroom performance into neural networks students to obtain trend lines of teaching effectiveness factors as an evaluation criterion. Researchers in the literature [14] on the development of online teaching systems point out that the quality assessment of online courses is a comprehensive evaluation system that requires researchers to reasonably control the course efficiency indicators from an objective perspective, and the evaluation system needs to fully take into account the student side and the teacher side of the course patterns and preferences and cannot be generalized with a uniform specification [15–18]. Different courses should also set up independent evaluation systems, establish independent human-machine models, and learn two-way evaluation indicators between teachers and students. Given that both teachers and students of each course have the right to choose in both directions, we should extend the course evaluation system to another human level to obtain better evaluation results while meeting the evaluation conditions of online courses [19].

Synthesizing previous studies in the literature, we decided to adopt a deep learning approach to explore the influencing factors of online course quality assessment by taking online course teaching quality assessment as the starting point. We propose a fuzzy neural network-based online course quality assessment method. The method uses fuzzy rules as the baseline and adds TSK perceptual agencies to expand the perceptual domain of fuzzy neural networks. In addition, we will explore the factors influencing the educational quality of online courses and develop a weight percentage assessment of them. Finally, we verify the effectiveness of our method through experiments.

The other studies in this paper are distributed as follows. Section 2 presents the latest research progress related to the field of online course evaluation. Section 3 details the principle and implementation process of the online course quality assessment method based on an improved fuzzy deep neural network. Section 4 presents the experimental results of the online course quality assessment effectiveness test and the analysis of the data enhancement test. Finally, Section 5 reviews our study and reveals its shortcomings of the study.

2. Related Work

Considering that course quality assessment is a highly comprehensive project, if we want to automate course quality assessment, we need to cover the course process comprehensively with course assessment factors, for example, course curriculum, course purpose, course scheduling, course participant survey, course instructor effectiveness assessment, and course practice effectiveness testing. In a study exploring advanced course quality assessment, researchers in the literature [20] noted that the quality assessment results of a course can only be described if course participant satisfaction, self-efficacy, and course comprehension are considered in combination with the factors and weighted results are given. The authors applied a hybrid quality assessment approach in their study to efficiently complete the collection and analysis of course quality assessment data. The study in the literature [21] is oriented towards a comprehensive assessment of different disciplines, and the researchers proposed a linear regression learning-oriented model of transferable course assessment, which takes the guided learning framework [22] and the availability principle as a baseline, or presents student perceptions, teacher perceptions, classroom effects, and postclass tests related to the course from different dimensions of coordination complexity, and reduces the course assessment through a perceptual machine. The process of course assessment is recreated by a perceptual machine. Finally, the authors demonstrated the effectiveness of the method through experimental validation. The study in the literature [23] is an exploration of the validity of online education, and the authors first stated the need for online education in the context of COVID-19. To investigate the validity of online education, the authors proposed a visual strategy instructional assessment method, which analyzed the feasibility of online education from the perspective of online education participants and designed single- and mixed-group experiments to verify the reliability of course assessment. The experimental results demonstrate that the method provides a valid measure of the pedagogical direction and purpose of online courses. The researcher in the literature [24] added an online course quality assessment system to the online course archiving system. The study was based on rich course data and aimed to improve students' online course experience, and the authors proposed a metacognitive reflection-based course quality assessment method. The method gives students and instructors great freedom in course feedback efforts, fully satisfies the needs and suggestions of individual online course participants, and forms a closed-loop dual

institutional system for online education feedback and assessment.

Online course quality assessment is a comprehensive system, and a large number of researchers have presented research results on it. The assessment system of online courses is more specifically divided, and the research of each system represents the weight ability of online assessment factors. Neural network models can greatly improve the efficiency and accuracy of online course assessment, and there is a large amount of research that has been conducted to prove this. In different online course assessment applications, the applicability of neural network models needs to be considered, and the development of specialized deep neural network structures based on specific assessment needs can effectively improve the robustness and generalization of online course assessment systems. In a study in the literature [25], the researcher used the facial expressions of online course participants as the focal point to transform classroom teacher-student interaction expressions into course quality assessment weights. By experimenting with different combinations of neural networks and Bayesian optimization structures, the facial expressions were defined as “understanding,” “not understanding,” and “doubtful” to determine that the online system can automatically analyze the performance of students and teachers. The system automatically analyzes the complex facial expressions of students and teachers and converts the expression learning and fusion analysis into course evaluation metrics to improve the generalization performance of the course evaluation system. The researchers in the literature [26] provide a new research idea for online course quality assessment, where the authors will use deep neural networks to capture the effects of efficiency in online course testing. The study uses data from three online courses as the basis of the research and tries to collect the effect of online course tests from the student side and then matches the test results with the course quality feedback results. Finally, the online course test evaluation weights are learned through deep neural networks, and the experimental results prove that the method can effectively improve the testing efficiency of the online course posttesting system and provide a local reference standard for course evaluation.

Several researchers agree that the most reflective factor of course quality and efficiency in online courses is the interaction between the instructor and students, and to quantify this interaction in a visual form as a factor for course quality assessment, many researchers have shown rich results in this study. The study in the literature [27] focused on the study of student and teacher engagement in online courses, learning about the interaction between teachers and students in online courses through a large dataset to predict course efficiency and quality assessment of online courses. The authors used Bayesian networks as the basic structure in processing the teacher-student interaction data, and then the student behavior learning process can determine whether the students enter the learning state in the online course, and then mapping correlation with the postclass test results can obtain the course learning efficiency of students. In this way, the authors transformed the quality assessment of online courses into visual behavioral analysis

and achieved excellent accuracy in the experiment. The researcher of the literature [28] considered the issue of student learning efficiency in online courses as the most critical factor in the quality assessment of online courses. To quantify the learning efficiency of students in online courses, the authors proposed a two-layer framework based on convolutional neural networks and memory unit networks that can unify the parameters of multiple dimensions such as students’ course scores, posttest scores, teacher averages, student feedback, and classroom performance into one assessment dimension. To reduce the model’s false negatives, the authors also performed a sensitive optimization of the loss function to balance the anisotropy problem of various parameters in the model. The experimental results show that the model can provide direct assessment weights for online course evaluation with an accuracy of 87%.

3. Method

3.1. Online Course Quality Assessment System Process. In this section, we detail the fusion of fuzzy rules with perceptual neural network structures and compare the distribution of network layers in the same dimension. Before considering the fusion of fuzzy rules, we compared a large number of perceptual neural networks and found in the experimental validation that the structural design of the feedforward neural network is more compatible with our research needs. Therefore, based on the structure of feedforward neural networks, we designed dedicated fuzzy rules and proposed an online course quality assessment method based on perceptual fuzzy feedforward neural networks. We also designed the online course quality assessment system, and the overall composition of the system is shown in Figure 1.

As can be seen from Figure 1, we divided the online course index assessment into four parts. The first part is the online classroom assessment, which contains the classroom interaction rate, question and answer rate, classroom participation, and other factors composition. The second part is the course arrangement assessment, which contains the rationality, scientificity, and overall control of the teaching schedule of the online course arrangement by the school’s academic affairs office. The third part is the course test evaluation, which includes factors such as the completion of postclass assignments, the passing rate of postclass tests, and the overall assessment of the course completion. The fourth part is the course feedback, which includes students’ opinions on the course, students’ ratings of the teacher’s teaching tasks, the school’s ratings of the course, and the teacher’s teaching tasks. The above four parts represent different influencing factors of online courses, and these four influencing factors are input as online course quality assessment parameters into TSK fuzzy neural network to fuse and learn the course quality weights and finally output the course quality assessment results.

3.2. Fuzzy Neural Network Structure. Considering that online course quality assessment involves different dimensions of assessment metrics, we reconstructed each

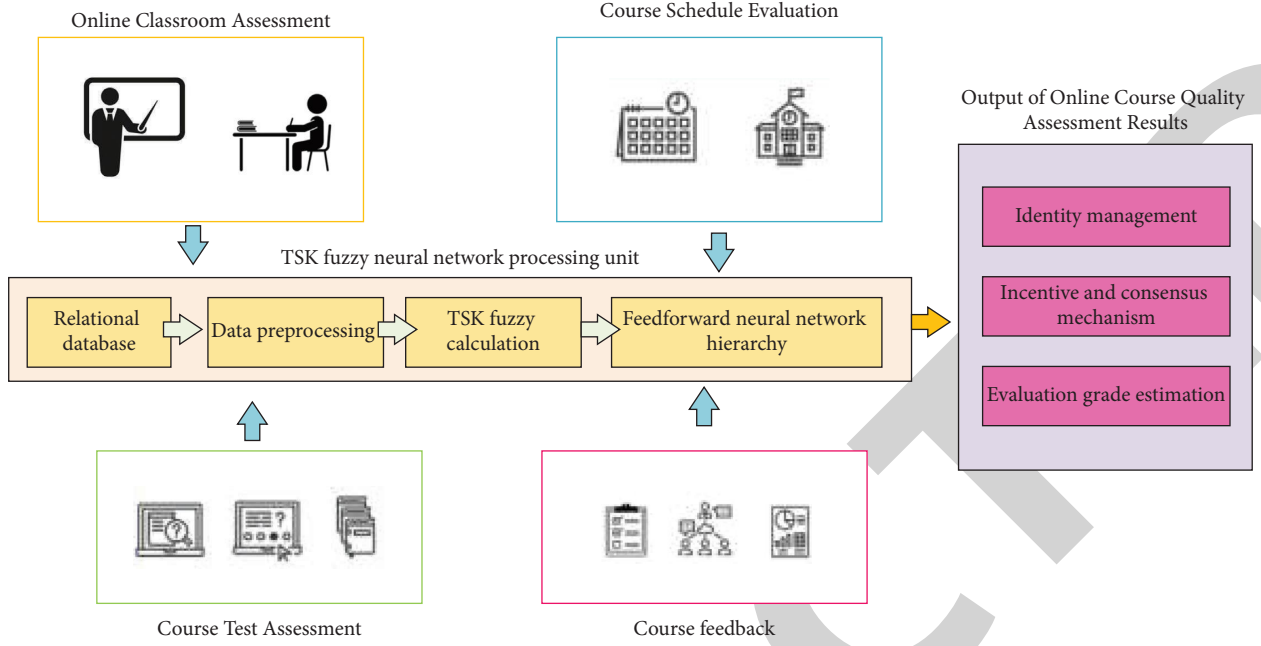


FIGURE 1: Online course quality assessment system process.

independent layer in the process of designing the deep neural network structure and gave each independent layer similarity to the data fit according to TSK fuzzy rules. In the network layers we designed, the main network structure consists of seven layers. It is shown in Figure 2.

After the data is input to the deep neural network, the neuron processing nodes in the input layer convert the input variables into a set of identifiable sequences with labels, which are assumed to be X . The mathematical equations are expressed as follows:

$$X = [x_1, x_2, \dots, x_n]^T. \quad (1)$$

The transformation layer is located after the input layer, and in the design of the transformation layer, we fully consider the interactions between the factors of evaluation variables of different dimensions. The neurons in the network produce a reversal linear transformation of the variables to map the interaction links between the variables to a higher-level feature transformation layer [29]. For the initial mapping of interactions between variables, the following mathematical equation is satisfied.

$$Z_i = \Gamma_i^T (X - M_i), \quad (2)$$

where M_i denotes the center of the i -th fuzzy calculation rule definition and can be given as

$$M_i = [m_{i,1}, m_{i,2}, \dots, m_{i,n}], \quad (3)$$

where Γ_i^T denotes the i -th transpose matrix generated by the fuzzy calculation to represent the variable mapping trajectory in the noninteraction space as follows:

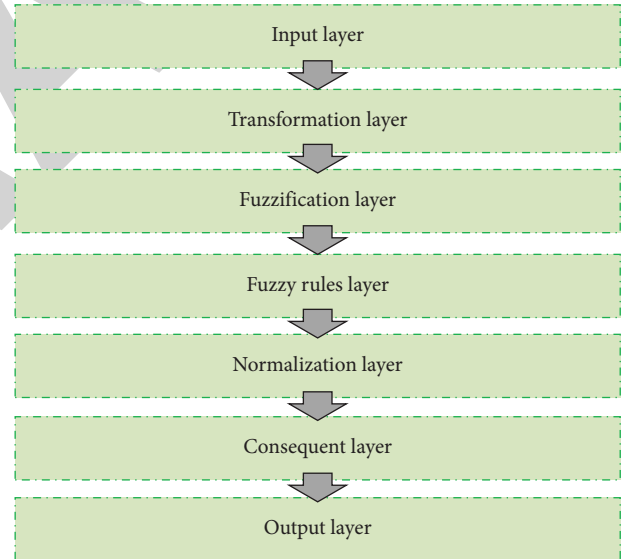


FIGURE 2: Network hierarchy distribution.

$$\Gamma_i = \begin{bmatrix} \gamma_{1,1,i} & \gamma_{1,2,i} & \cdots & \gamma_{1,j,i} & \cdots & \gamma_{1,n,i} \\ \gamma_{2,1,i} & \gamma_{2,2,i} & \cdots & \gamma_{2,j,i} & \cdots & \gamma_{2,n,i} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \gamma_{l,1,i} & \gamma_{l,2,i} & \cdots & \gamma_{l,j,i} & \cdots & \gamma_{l,n,i} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \gamma_{n,1,i} & \gamma_{n,2,i} & \cdots & \gamma_{n,j,i} & \cdots & \gamma_{n,n,i} \end{bmatrix}, \quad (4)$$

where $\gamma_{l,j,i}$ denotes the trajectory mapping matrix of the l -th row and j -th column of the Γ_i matrix.

The fuzzification layer can make full use of each neuron to calculate the affiliation in the noninteractive mapping results of the variable data. According to the definition of fuzzy rule for introducing power bi, the random mapping relationship of different variables needs to match the affiliation of the j -th mapping value, and its calculation equation is given as

$$\mu_{ij} = A(z_{ji}, \beta_i) = e^{-1/2((z_{ji})^2)^{\beta_i}}, \quad (5)$$

where z_{ji} denotes the j -th characteristic dimensional variable of the matrix computed at the i -th fuzzy rule.

The fuzzy rules layer unites local neuron nodes to achieve mapping links for different interaction space variables. For variables of different dimensions, we additionally add T-Norm operators to enhance the computational accuracy of the fuzzy rules. The mathematical equation expressions are given as

$$\mu_i = \prod_{j=1}^n \mu_{ij}, \quad (6)$$

The normalization layer regularizes the fuzzy matrix affiliation features extracted from the previous layer and coordinates the feature strengths of different variables by normalization. For instance, regarding variable response input, different types of fuzzy rules need to be selected to trigger the affiliation strength. The mathematical equation is given as

$$\phi_i(X) = \frac{\mu_i(X)}{\sum_{l=1}^R \mu_l(X)}, \quad (7)$$

The consequent layer involves the vector constraint problem of linear functions, where the output of all variables will be in the fuzzy rule matrix as the normative range, and the feature intensity weighting of the data will also be affected by the linear functions in the process of predicting vector associations. According to the calculation principle of fuzzy rule and linear function, the mathematical equation of the prediction of the feature vector is

$$y_i = a_{i0} + \sum_{j=1}^n a_{ij} x_j, \quad (8)$$

where a_{ij} denotes the correlation coefficient of the i -th fuzzy rule matrix with the j -th eigenvector. Finally, the output layer performs individual neuron reorganization based on the number of feedbacks between each neuron to obtain the prediction trend between feature vectors and then converts the prediction results into indicator results output.

3.3. Learning Strategy. In the network model training experiments, we found that vector features with different evaluation metrics could not complete the traversal task in an orderly manner, for the layer-to-layer specificity led to the variability of feature sharing. Therefore, we replanned the model training strategy. For feature learning fixed fuzzy vectors of the same stratum, we fixed the formal parameters

of each stratum and then adjusted the output values of each stratum by adjusting them until the desired range of values was reached. On the data input side, we quantified the prerequisite parameters as error expectations to balance the different values of input and output between different layers. For the case where the feature learning fuzzy vector values are in random variation, we scale down all parameters equally, but none of them exceeds the minimum value range of each parameter. Then the preserial hierarchy parameters are set to constant values, and while keeping the input-output error range consistent between the upper and lower hierarchy levels, we vary the mapping correlation of the fuzzy vectors to accommodate the trend pattern of the output prediction. The detailed flow chart of the model learning strategy is shown in Figure 3.

In addition, we employ the TSK perception mechanism to improve the correlation between networks and to improve the fusion and wholeness of the fuzzy vector features. The TSK perception mechanism takes the output value of the feedforward neural network as a starting point to expand the feature mapping range of each layer under the restriction of minimizing parameters. Although such a means generates a large amount of extremely invalid mapping data, a sizable amount of data can be filtered by simply setting a fixed threshold. If the minimum range of parameters cannot be adjusted for some layers, the fuzzy rule parameters can also be changed so that the fuzzy rule weight parameters of the next layer can be adaptively adjusted according to the difference between the output of the previous layer and the expected value, avoiding the feature rotation between each layer resulting in large feature deviation values. In the parameter adjustment of subsequent layers, the TSK perception mechanism will focus on adjusting the parameter differences of different network layers and improving the output pattern of fuzzy variables in an orderly manner under the premise of coordinating the expected values of the layers so that the output of each layer will share different course indicator features independently. To reasonably optimize the parameter tuning of each network layer, we calculate the expectation value L of the layer parameters in the ideal state, and the expectation value is calculated as .

$$L = \frac{1}{2} \sum_{k=1}^N \sum_{i=1}^R (\phi_{i,k} - \varphi_{i,k})^2 + \sum_{k=1}^N \lambda_k \left(\sum_{i=1}^R \varphi_{i,k} (y_i - y_k^*) \right), \quad (9)$$

where λ_k denotes the k th Lagrange constraint coefficient.

3.4. TSK Fuzzy Neural Network Online Course Quality Indication. To ensure the matching of online course quality indexes with a fuzzy neural networks, we add a TSK perception mechanism on top of the fuzzy neural network. The TSK perception mechanism can effectively handle the black-box nonlinear feature vectors of the integrated correlation degree. The echo state network of the fuzzy neural network also belongs to the computational scope of the TSK perception mechanism. We perform fuzzy clustering of the echo state network and then supplement the feature variable values generated by each neuron node with singular value

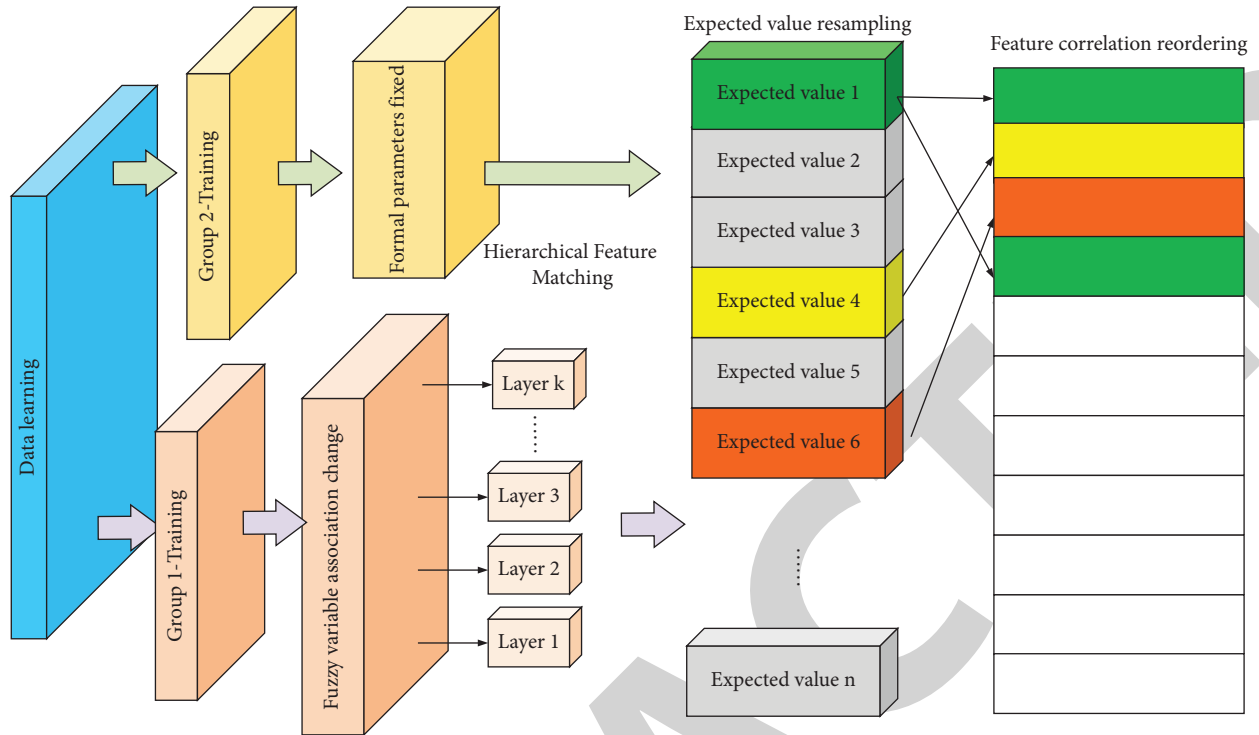


FIGURE 3: Model learning strategy flow chart.

decomposition so that the randomized mapping association of feature vectors can be realized. According to the fuzzy inference rules, the TSK sensing mechanism can add fuzzy vector simulation value, which is positively correlated with the expected value, under the premise of fuzzy inference. The simulated value is used as the final evaluation result screening threshold, which can effectively improve the prediction accuracy of the fuzzy neural network.

With the assistance of the TSK perception mechanism, the fuzzy neural network can effectively decompose the online course evaluation indexes and extract the feature vectors of different indexes, which can balance all the online course index features through the interaction mapping association between neurons and the calculation of fuzzy rules. The structure of our proposed TSK fuzzy neural network online course feature extraction network is shown in Figure 4. The data on the input side contains four components: online classroom assessment, course schedule evaluation, course test assessment, and course feedback. The data of each part are preprocessed in advance to avoid the problem that the fuzzy rule-based network data cannot be identified. Then the course quality index features calculated by the initial fuzzy rules are input to the fuzzifier layer in turn, then to the TSK perceptual structure layer to enhance the perceptual domain of the fuzzy neural network, and then to the fuzzified layer to defuzzify all the feature vectors, and finally to output the predicted values of the course quality assessment indexes.

4. Experiment

4.1. Data Preprocessing. Online course quality assessment involves different types of data, and as mentioned in the previous sections, there are four categories of input data for

our online course assessment metrics. The online classroom assessment part of the data includes teacher-student interaction and student participation in the course, which are often collected in the form of images or videos. In the process of data preprocessing, this part of data will be prioritized for image preprocessing and image recognition operations. Finally, the extracted features are fed into the fuzzy neural network. The course schedule evaluation part of the data contains the rationality and scientificity of the online course schedule by the university's academic affairs office. The preprocessing of this data is based on the logistic regression optimal solution algorithm, which predicts the reasonableness and scientificity of the course and gives weight labels. Finally, the extracted features are fed into the fuzzy neural network.

The course test assessment part of the data contains the posttest results of the course, which is more representative of the course quality in terms of species level. This part of the data is mainly based on big data processing analysis to predict the efficiency of the course in each teaching period. Finally, the extracted features are input into the fuzzy neural network. The course feedback is that part of the data which contains students' opinions about the course, students' ratings of the teacher, the school's ratings of the teacher's teaching performance, and the teacher's opinions about the improvement of the classroom, etc. This part of data preprocessing mainly involves text processing. Finally, the extracted feature data are then input into the fuzzy neural network. The detailed data preprocessing process is shown in Figure 5.

4.2. Dataset Distribution. For the quality assessment of online courses, there is no publicly available dataset for online course quality assessment, even though many

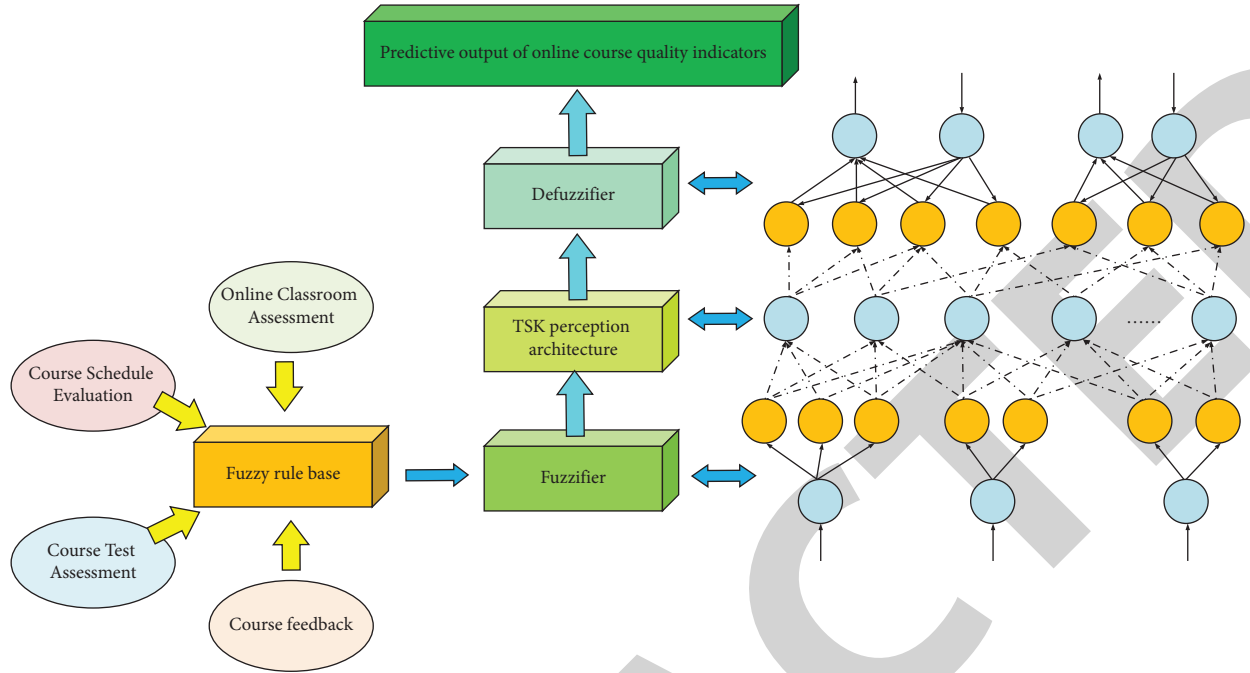


FIGURE 4: TSK fuzzy neural network online course feature extraction network structure.

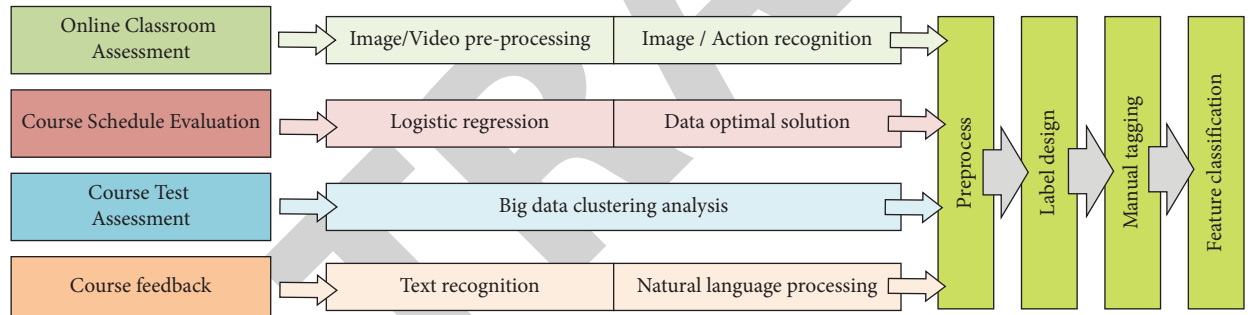


FIGURE 5: The detailed data preprocessing process.

researchers have presented new results and ideas. To verify the validity of our approach, we collaborated with universities after applying for a research license. Based on the four components involved in online course assessment, we produced four types of datasets. The details of the dataset distribution are shown in Table 1. In the production of the datasets, due to the large labor cost, we used data augmentation processing the datasets, which not only expands the collective amount of data but also enhances the fuzzy neural network's control of global features. In the experimental analysis section, we still use precision, F1 score, and recall to test the performance of our method. In the subsequent analysis, we will refine the dataset and verify the substantial effect of data enhancement.

4.3. Results and Analysis. In the work of dataset production, we used data augmentation to expand the experimental data and enhance the data domain of the model. To verify the effectiveness of data augmentation, we compared the augmented data and the augmented data fused with the original data using

the original data as the reference standard. To reflect the efficiency of data augmentation, we used affinity and diversity as validation metrics. Affinity indicates how well the augmented data fit the original data in the model training. Diversity indicates the complexity of the augmented data in the model training. The experimental results are shown in Table 2.

From the experimental results in the above table, it can be seen that the data enhancement results fit more closely with the original data affinity, the diversity differences are small, and the accuracy is maintained above 90%. It proves that data augmentation can effectively expand the dataset and enhance the global data coverage of the model. In addition, the variability of online course quality assessment metrics is obvious, and data type specificity cannot be avoided. To have a basis for weighing the role of each indicator in the quality assessment of courses, we explored the issue of course quality assessment weights. To examine the impact of different data on course quality, we validated four aspects of course efficiency (CE), course pass rate (CPR), course practice satisfaction (CPS), and course retake rate (CRR). The results of the experiment are shown in Table 3.

TABLE 1: The details of the dataset distribution.

	Dataset			
	Online classroom assessment	Course schedule evaluation	Course test assessment	Course feedback
Group 1 training	1241	1032	1520	1102
Data augmentation	2482	2064	3040	2204
Group 2 training	964	987	1003	992
Data augmentation	1928	1974	2006	1984
Test	231	204	289	274
Total	6846	6261	7858	6556

TABLE 2: Comparison of data enhancement effects.

	Affinity	Diversity	Accuracy (%)
Group1	1	0.6	100
Augmentation 1	4	0.4	95
Group1 + Augmentation 1	3	0.3	94
Group2	1	0.6	100
Augmentation 2	4	0.5	96
Group2 + Augmentation 2	5	0.3	91

TABLE 3: Comparison of weighting percentages for quality assessment of course indicators.

	CE (%)	CPR (%)	CPS (%)	CRR (%)	Weight
Online classroom assessment	80	79	75	78	0.3
Course schedule evaluation	43	50	41	40	0.1
Course test assessment	93	90	94	91	0.4
Course feedback	66	60	65	67	0.2

From the experimental results in the above table, it can be seen that course test assessment has the largest proportion of all indicators in the course quality evaluation, followed by online classroom assessment. The total proportion of course schedule evaluation and course feedback is only 0.3. Based on the experimental results of the weighting ratios, we will adjust the model data category parameters to ensure that the datasets with higher quality weighting ratios also maintain the same vector feature ratios in the model training. After the experiments with tuning the parameters for improvement, we test the efficiency of our method in an online course quality assessment. Four indicators such as precision (P), F1 score ($F1$), recall (R), and course quality assessment matching rate (MR) were assessed in the experimental validation. The detailed experimental results are shown in Table 4.

From the experimental results in Table 4, it is clear that our proposed methods all maintain above 90% in terms of accuracy. The large difference in F1 scores is due to the specificity between different categories of datasets, but considering the diversity of online course assessment metrics, the F1 scores have little effect on the quality assessment grade. The matching rate shows that our method matches

TABLE 4: The efficiency of online course quality assessment.

	Online classroom assessment	Course schedule evaluation	Course test assessment	Course feedback
Precision	91%	92%	90%	95%
F1 score	0.87	0.81	0.79	0.83
Recall	0.93	0.89	0.91	0.92
Matching rate	95.4%	96.6%	97.1%	95.2%

the results of online course quality assessment with the actual assessment results by more than 95%, which proves the excellent applicability of our method in this field of study.

5. Conclusion

This paper explores the factors influencing the quality assessment of online courses and analyzes the current research proposal of online course quality indexes with online courses as the research object. To make the online course quality assessment more intelligent, we propose an online course quality assessment method based on a fuzzy neural network.

The method uses fuzzy rules as the baseline and adds a TSK perception mechanism to expand the perception domain of fuzzy neural network and improve the course quality index prediction accuracy. At the input side of the fuzzy neural network, we preclassify the online course data into four parts, and each part of the data represents a different assessment domain. Due to the large data cost, we expanded the collective amount of data using data augmentation methods. In addition, we parse the structure of the fuzzy neural network hierarchy and introduce the construction and role of the TSK perception mechanism in the fuzzy rules. An optimal learning strategy is proposed in the fuzzy neural network training. Finally, in the experimental session, we verify the effectiveness of data augmentation and explore the distribution of course quality assessment weights. In the experimental validation of accuracy testing, our method maintains accuracy of over 90% in online course quality assessment and achieves a 95% matching rate with actual assessment over, which proves that our method has excellent applicability in practice.

Although our study has achieved high matching rate and accuracy in practical applications, there is still a gap in the specificity of our method between different disciplines. In our future work, we will use a transfer learning approach to find shared parameters in course evaluation between different disciplines and enhance the disciplinary generalization of our method.

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 there are no conflicts of interest.

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Research Article

Intelligent Optimization Method of the Higher Vocational Education System for Labor Market Demand in Guangdong-Hong Kong-Macao Greater Bay Area

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The current educational development in the Guangdong-Hong Kong-Macao Greater Bay Area is not enough to support the construction of a world-class bay area, so the education reform and innovation in the Greater Bay Area face many challenges. This study systematically sorts out the challenges faced by education in the Guangdong-Hong Kong-Macao Greater Bay Area, starting from the interpretation of the talent training standards in the new era, and proposes that the education innovation in the Guangdong-Hong Kong-Macao Greater Bay Area should re-understand and implement the national education right of the SAR, improve the standards and raising quality of talents, and strengthen innovation-driven development, and an education system with the characteristics of the Greater Bay Area should be built to give full play to the role of education in regional economic development and to cultivate talents in the new era.

1. Introduction

In 2012, the Central Talent Work Coordination Group approved the Guangzhou Nansha-Shenzhen Qianhai-Zhuhai Hengqin Guangdong-Hong Kong-Macao Talent Cooperation Demonstration Zone as a National Talent Management Reform Pilot Zone [1]. The service industry is a pillar industry in the Greater Bay Area which requires a large number of high-quality labor input. In the future development orientation of the Guangdong-Hong Kong-Macao Greater Bay Area, the development of emerging industries and advanced manufacturing also requires the support of a large number of high-level talents. It has built a global high-tech innovation highland and an important source of emerging industries, which puts forward higher requirements for education in the Guangdong-Hong Kong-Macao Greater Bay Area [2].

At present, the entire Guangdong-Hong Kong-Macao Greater Bay Area is facing enormous pressure from industrial upgrading, and the existing industrial structure is

facing low-end dilemma and unbalanced dilemma. The so-called low-end dilemma refers to the development of traditional manufacturing industries to high-end manufacturing and innovative industries faced by the Greater Bay Area. According to the Report on Influence of the Four Great Bay Areas (2018) released by the Institute of Financial and Economic Strategy of the Chinese Academy of Social Sciences and the Sun Yat-sen Research Institute, the Guangdong-Hong Kong-Macao Greater Bay Area's innovation basic indicators and innovation capability indicators are ranked at the bottom of the four major bay areas. The overall development quality and innovation level of the Hong Kong-Macao Greater Bay Area still has a certain gap compared with that of developed countries. The so-called unbalanced dilemma refers to the problem of unbalanced or unbalanced development in Guangdong, Hong Kong, and Macau. There is a large gap in development within the Greater Bay Area where synergy and inclusiveness need to be strengthened, and there is still homogeneity in some regions and fields. The mismatch between competition and

resources has led to the lack of sustained and stable support for Hong Kong's economic growth. Macao's economic structure is relatively single, and its development resources are limited. The market economic system of nine cities in the Pearl River Delta needs to be improved. Facing the dilemma of economic development in the Guangdong-Hong Kong-Macao Greater Bay Area, on the one hand, we must focus on improving the quality of education in the Guangdong-Hong Kong-Macao Greater Bay Area and cultivate more high-level talents; on the other hand, we must integrate the educational resources in the Guangdong-Hong Kong-Macao Greater Bay Area to avoid mutual the increasing alienation and bad competition between them, realize the collaborative innovation of education, and create a first-class education in the Bay Area [3].

There are two systems in the Guangdong-Hong Kong-Macao Greater Bay Area, including three customs areas and four core cities, involving nine cities and one urban agglomeration. Facing the complex background of multiple systems in one district, we must face up to the weak links in the past institutional design to meet the requirements of governance capability and modernization of governance system [4]. Under the basic national policy of one country, two systems, Hong Kong and Macao enjoy great regional autonomy including the right to education after their return, which has largely led to the lack of national education in the special administrative region. Especially in Hong Kong, the problem of youth ideological education is particularly prominent. From the Occupy Central illegal assembly in Hong Kong in previous years to the demonstrations and riots that broke out in Hong Kong after the revision of the Fugitive Offenders Ordinance in 2019, there were a large number of Hong Kong youths who blocked traffic in the name of fighting for freedom carrying out illegal acts of violence such as beating citizens, arson, occupation of universities, and refusing to recognize their Chinese identity. Behind the Hong Kong Independence ideology and violent behavior is the problem of education in Hong Kong [5]. Hong Kong and Macao governments lead the formulation of education policies in the Special Administrative Region, and from the perspective of Hong Kong's educational practice, the implementation of national education in Hong Kong has been greatly hindered. In 2010, the Hong Kong Special Administrative Region Government proposed to add national education and moral education courses as compulsory courses in primary and secondary schools, but it was shelved indefinitely due to the accusation of political brainwashing by the opposition [5]. In the sense of pragmatism and desinicization left by the colonial era in Hong Kong, the anti-Communist consciousness left by the Cold War system in Hong Kong, and the anti-mainland nation consciousness of new nativism, now we urgently need to strengthen the awareness of National ethnic identity and cultural identity education for young people in the Special Economic Zone. The return of Hong Kong and Macau to the motherland is only a return in terms of legal principles, but to realize the return of people's hearts and to truly unite the people of the three places on both sides of the strait and seek common development, we must pay attention to the role of education.

The system design in the past did not pay enough attention to the education of the special administrative region, which is a weak link that needs to be paid attention to in the future education reform and innovation of the Guangdong-Hong Kong-Macao Greater Bay Area [6].

Throughout the world, the center of economic development is often the center of education. To achieve the strategic goal of building a dynamic and internationally competitive first-class bay area and world-class city cluster, it is necessary to focus on building an education center in the Guangdong-Hong Kong-Macao Greater Bay Area to realize cooperative development, shared development, and integrated development of the three places. At present, the integration and complementarity of the education systems of Guangdong, Hong Kong, and Macao still face great challenges. In terms of the educational model, Hong Kong follows the British and American educational models while Macau follows the Portuguese and European educational models. In terms of the management system, the cooperation in running schools in the Guangdong-Hong Kong-Macao Greater Bay Area needs to be governed by the Regulations on Sino-foreign Cooperative Education, and the barriers to joint training and the flow of teachers and students in the three places need to be further broken down. In terms of educational development level, educational resources and higher education strength between cities are uneven [7]. High-level research universities are concentrated in Hong Kong and Guangzhou. The gap in school-running strength has hindered the integration of the education systems of the three places to a certain extent. At the level of cooperation, student exchanges and scientific research cooperation in the Guangdong-Hong Kong-Macao Greater Bay Area are mostly spontaneous interactions between schools, lacking top-level design and in-depth exchanges [8]. Expanding cooperation models, establishing cooperation platforms, realizing resource sharing and complementary advantages, and forming an educational community will be important measures for the development of education in the Guangdong-Hong Kong-Macao Greater Bay Area.

To build a talented highland in Guangdong, Hong Kong, and Macao, it is also necessary to remove several obstacles in the flow of talents and coordinated development. Firstly, the social and legal systems of Guangdong, Hong Kong, and Macao are different, and they belong to different tariff areas. Secondly, the level of market connectivity needs to be improved. The low degree of connection between social and public services such as medical care has brought certain obstacles to the cross-regional work and life of residents in the three places. Thirdly, the current construction of carrier platforms such as large-scale scientific installation platforms, innovation and entrepreneurship bases, and incubators in the Guangdong-Hong Kong-Macao Greater Bay Area finds it difficult to meet the need of coordinated development of talents. Lastly, the survey shows that Hong Kong has a low degree of recognition of the overall development concept of the Guangdong-Hong Kong-Macao Greater Bay Area, and there is less flow of talents from Hong Kong and Macao to the mainland. If the specific obstacles in these practices cannot be removed, it will be difficult to form a talent flow

and coordinated development system in the entire Guangdong-Hong Kong-Macao Greater Bay Area [9]. Figure 1 shows research technology roadmap.

2. Research Methods

This study mainly adopts literature research method, comparative research method, field investigation method, and interview method for research. The specific research ideas are as follows.

2.1. Literature Research. Literature research is mainly carried out in two forms online and in the field. In terms of network, it is mainly conducted through CNKI, Google Scholar, and Taiwan Huayi Literature Database; in terms of field, it is mainly conducted with the help of Guangzhou Library, Taiwan Yishou University Library, Taiwan Kaohsiung Municipal Library, Hong Kong Central Library, etc., understanding the research progress, rationalizing the research background, and finding problems through the way of studying, consulting, collating, and analyzing the literature at home and abroad and related data, so as to provide the literature support for the thesis research.

2.2. Comparative Research Method. By comparing the training systems of vocational exhibition professionals in Guangdong, Hong Kong, Macao and Taiwan and combining the current situation and development trend, the research puts forward reform measures. This study follows the expression and connotation of Guangdong in the Guangdong-Hong Kong-Macao Greater Bay Area Development Plan; that is, Guangdong refers to nine cities in Guangdong Province, which are referred to as Guangdong nine cities in the study [10].

2.3. Fieldwork

2.3.1. Survey Conditions. The researcher has been engaged in vocational education in Guangzhou for many years and participated in many exhibitions in Guangdong, Hong Kong, Macao, and Taiwan. He has studied in Hong Kong for two semesters and in Taiwan for one semester. Through the observation, reflection, and summary of his own work, study, and field research, he further explores the research content of this study.

2.3.2. Investigation Stage. The specific field investigation work is divided into three stages: preliminary preparation, on-site investigation, and sorting and analysis.

2.3.3. Survey Outline. The field investigation method mainly focuses on the exhibition industry and exhibition vocational education. The specific content of the survey outline is as follows.

First, participate in and experience local exhibition activities, intuitively feel and understand the development of the local exhibition industry, especially pay attention to

comparing the development of similar exhibition activities in Guangdong, Hong Kong, Macao, and Taiwan, and communicate with industry personnel.

Second, inspect local vocational education-related institutions, go as far as possible into the classroom, collect relevant public information on the spot, and interact with relevant personnel.

2.4. Interview Method

2.4.1. Semistructured Interview. The semistructured interview method used in this study is mainly based on the following considerations.

Compared with the questionnaire survey, the interview method can better judge the authenticity of the respondent's views and answers through the details of gestures, expressions, and language during the interview process. The semistructured interview method is more flexible which can timely raise more questions and conduct in-depth interviews that can obtain more useful information according to the answers of the interviewees. In addition to general interviews, key person interviews are also used to obtain professional information more efficiently. For example, the researchers made in-depth interviews with the pioneers of Taiwan's exhibition industry and interviewed the general manager of Taiwan's first professional large-scale exhibition company, the outstanding new generation and young representatives of Taiwan's convention, and exhibition industry through appointment interviews. Taiwan's exhibition industry at the food exhibition was held at the Kaohsiung Exhibition Center in Taiwan through interview reservations.

2.4.2. Reliability and Validity. The first is reliability. In order to improve the validity of the interview, after the interview, the researcher will search the relevant materials of the interviewed experts and scholars from literature, collections of papers, industry journals, news reports, etc., and sort out and analyze whether their opinions are consistent with the interviews. The reliability of the interview results was insufficient, and the interview was canceled.

The second is validity. In this study, an interview outline was drawn up, and the interview process was based on standard questions, which was more effective than unstructured interviews. In addition, through the study and practice of interview skills before the interview, the researcher tries to ask questions accurately and objectively, so as to avoid guiding the interviewee's answer and improve the validity of the interview.

2.4.3. Preparing for the Interview. Adequate preparation can improve the efficiency and quality of interviews, help establish a good interview relationship, and ensure the smooth progress of the interview process. The pre-interview preparations in this study include the following: clarifying the purpose and content of the interview, designing the interview outline, screening and determining the scope and object of the interview, establishing the interview

Professional degrees and academic degrees are postgraduate education at the same level with different training requirements, and together they form the current postgraduate education structure in my country [11]. By sorting out the full-time master's degree in Guangdong, Hong Kong, and Macao universities, first of all, the master's degree in colleges and universities is divided according to the way of study. Guangdong can be divided into full-time and part-time, and Hong Kong and Macao can be divided into full-time and part-time. Since the part-time university master's degree in Hong Kong and Macao is limited to the residents of Hong Kong and Macao, this paper studies the master's degree in full-time universities. Secondly, due to the differences in educational systems and cultural backgrounds between Hong Kong and Macao and Guangdong, the taught degree in Hong Kong and the development-oriented degree in Macao correspond to the professional master's degree in universities in Guangdong. Finally, the master's degree in mainland colleges and universities is also divided into four professional directions: college teaching, sports training, social college guidance, and competition organization. At present, the four colleges and universities in Guangdong have no admissions for master's degrees except for the direction of competition organization. South China Normal University, Guangzhou University College, and Guangzhou University are involved in the other three directions. South China University of Technology currently only has one direction of college teaching. Compared with the Guangdong region, the professional direction setting of the master's degree in the universities in Hong Kong and Macao is relatively simple. In addition to the Chinese University of Hong Kong's professional setting for master's degrees, the other four universities in Hong Kong and Macao have only one professional setting for master's degrees [12].

3.2. Professional Degree Postgraduate Training Mode.

Professional degree postgraduate training model refers to the process of postgraduate training in order to meet the needs of the society for high-level, compound, and applied professionals under the guidance of the educational ideals and educational concepts of classified training and to achieve the training goals of professional degree postgraduates [13].

The current academic circles hold different viewpoints on the constituent elements of the professional degree postgraduate training model, mainly including the three-element theory, four-element theory, five-element theory, six-element theory, and multielement theory. By inquiring about relevant literature and meeting the needs of this research, the main components of the training mode of professional degree graduate students in this study are divided into three aspects: training objective, training process, and quality evaluation.

3.2.1. Training Objectives. The training goal of professional degree postgraduates is to enable the training objects to achieve the required requirements and standards in knowledge, ability, and quality structure through training

activities in a certain way and within a certain period of time. The training goal defines the training direction and is the guiding element of the training model. Clarifying the training objectives is the premise of professional degree graduate education, which answers the question of what kind of graduate students to train, and is also the starting point and destination of professional degree graduate students in the entire training activities.

3.2.2. Cultivation Process. The training process of professional degree postgraduates is the core of the professional degree graduate training model. It mainly answers the question of how to train people. It includes admissions system, admission requirements, training years, professional settings, teacher characteristics, professional practice, graduation thesis and requirements, related facilities conditions, and many other aspects.

3.2.3. Quality Evaluation. The quality evaluation of professional degree postgraduates is to objectively consider and judge the quality and benefits of personnel training according to the corresponding standards, to test and monitor the training objectives and processes, to understand the current situation and problems of training quality in a timely manner, and to accumulate experience and draw lessons and make timely feedback and adjustments. The evaluation of the training quality of professional degree postgraduates generally starts from the perspective of internal and external quality. The internal quality concept refers to the evaluation of the quality of professional degree postgraduate training by the postgraduate training unit itself. The evaluation methods generally adopt three methods, assessment system, practical learning, and thesis quality assessment, to ensure the quality of professional degree graduate training. External quality view means that the quality of postgraduates will be evaluated by organizations, societies, and individuals outside the postgraduate training unit. Quality evaluation will run through the whole process of professional degree postgraduate training, and it is the backbone guarantee for whether professional degree postgraduate education can achieve its goals [14].

Among the elements of the entire professional degree postgraduate training model, the three elements are interconnected, influenced, and promoted each other, which are the more important and indispensable elements among the many elements of the professional degree graduate training model. The cultural and social background and the products under the actual situation have distinct characteristics of the times and will be adjusted with the changes of the needs of the times, and they will vary according to different majors. Therefore, we should adjust the training accordingly according to the specific situation in the practice model. Figure 2 shows the logical relationship diagram of the professional degree postgraduate training model.

Our observation of the system of professional degree graduate training mode corresponds to at least the following three subsystems: training objectives, training process, and quality evaluation. Taking the postgraduate training model

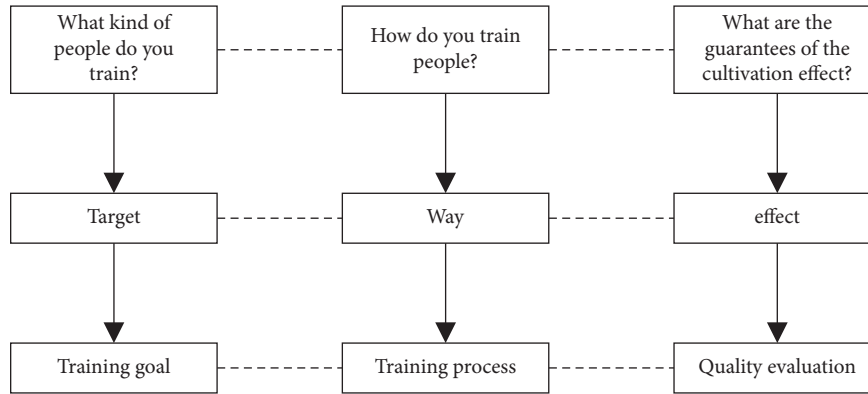


FIGURE 2: The logical relationship diagram of the professional degree postgraduate training model.

for master's degree as a system, the explanations of the relevant elements are as follows:

- (1) Training objectives: the training objectives of post-graduates with professional degrees in higher vocational education belong to the decisive elements, and the decisive elements define the overall development direction of personnel training, play a leading role among many elements, and are the premise of constructing the training system, training process, facility conditions, and quality evaluation and basis.
- (2) Cultivation process: the training process of professional degree graduate students in higher vocational education, as the core part of sports talent training, is a normative element in the entire training system. The main connection is how to achieve the training goal and whether the training activities of professional degree graduate students in higher vocational education can be carried out smoothly important guarantee. Generally, it includes the student system, admission requirements, training years, professional settings, teacher characteristics, curriculum settings, practical links, graduation thesis and requirements, and related facilities conditions.
- (3) Quality evaluation: the quality evaluation of professional degree postgraduates in higher vocational education has typical feedback characteristics, and the feedback of training quality information runs through the entire training model and belongs to the controlling element. The quality of talent training is scientifically measured by adopting certain evaluation standards for various situations in the training process. Quality evaluation generally includes course assessment, student source quality, tutor status, employment status, collaboration platform, and international cooperation.

Among the elements of the training mode for post-graduates of professional degree in higher vocational education, the three elements interrelate, interact, and promote each other. The products under certain cultural and social backgrounds and actual situations have distinct characteristics of the times. Therefore, in practice, we should adjust

the training mode accordingly according to the specific situation. Figure 3 shows the implementation approach of higher vocational students' ability training.

4. Positioning of the World Regional Higher Education Center

4.1. An Integrated Framework for the Positioning of Higher Education in the Guangdong-Hong Kong-Macao Greater Bay Area. Higher education in the Guangdong-Hong Kong-Macao Greater Bay Area plays an important supporting role in the construction of the Greater Bay Area urban agglomeration, the construction of an international technology innovation center, and the realization of national regional development strategies. Under the historical opportunity of the construction and development of the Guangdong-Hong Kong-Macao Greater Bay Area, the positioning and development of higher education have long-term strategic significance [15].

In Figure 4, the social development of the Guangdong-Hong Kong-Macao Greater Bay Area is a system as a whole, and higher education, as a subsystem, intersects with other subsystems such as politics, technology, politics, and culture [16]. Throughout the world's development experience, economic centers, technology centers, and higher education centers are often accompanied by and complement each other.

From the perspectives of the realistic demands of the economic and social development of the Guangdong-Hong Kong-Macao Greater Bay Area for higher education, the current situation of higher education in the three regions, and the development experience of higher education in the three major bay areas in the world, the construction of the Guangdong-Hong Kong-Macao Greater Bay Area has an impact on higher education [17]. According to the needs of development, combined with the actual situation of higher education, it is inferred that there should be a leading strategic goal for the cooperation and development of higher education in the Guangdong-Hong Kong-Macao Greater Bay Area [18]. Specifically, the first is the three levels of innovation, talents and cooperative development proposed by the industrial system, technology, and political and cultural development of the Guangdong-Hong Kong-Macao

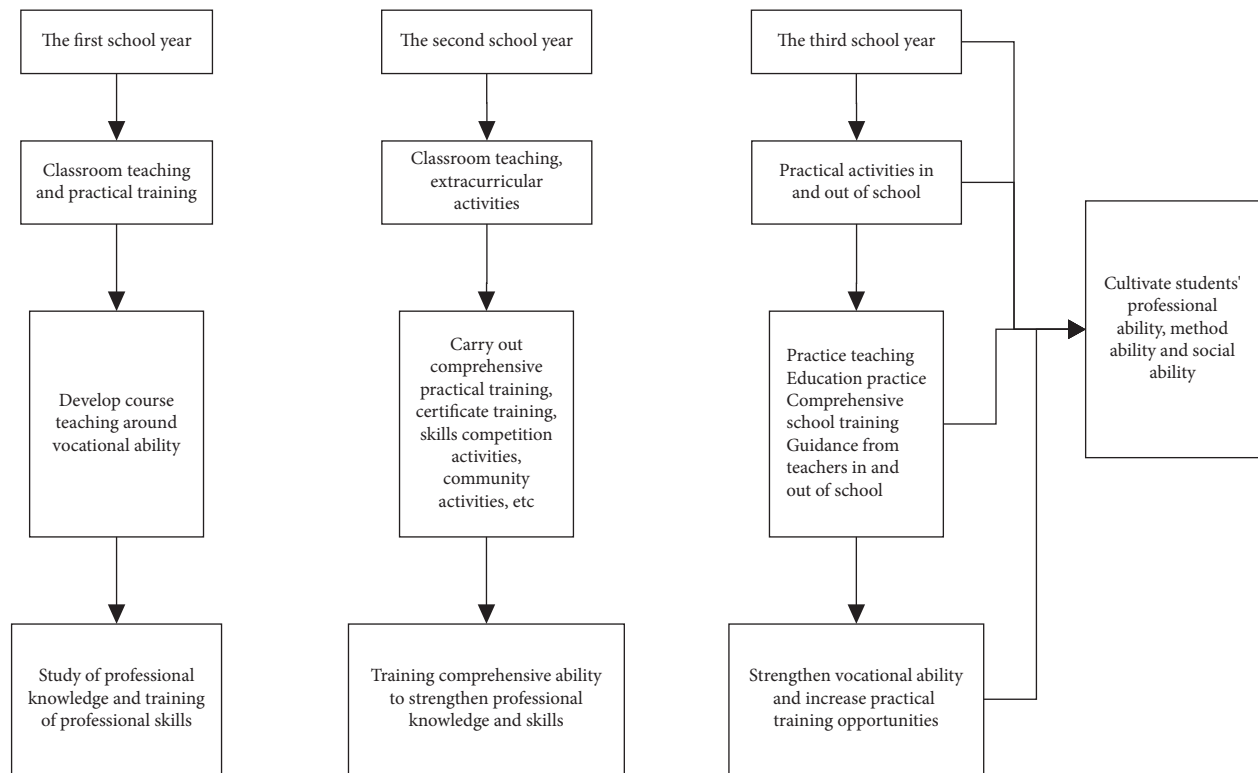


FIGURE 3: The implementation ways of higher vocational students' ability cultivation.

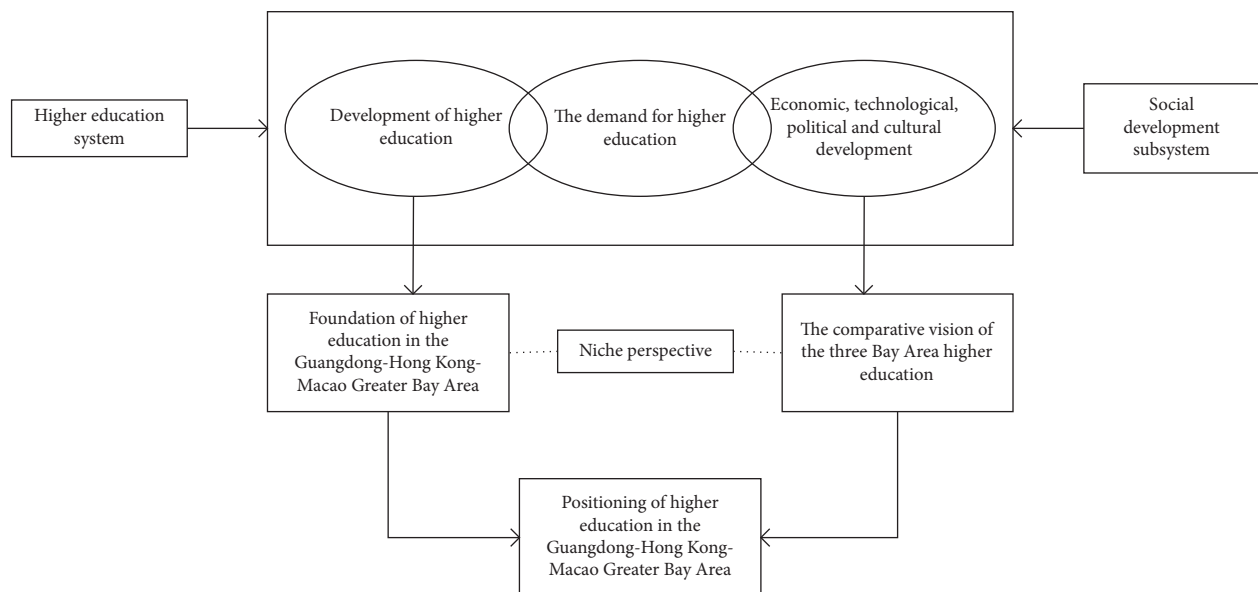


FIGURE 4: An integrated framework for the positioning of higher education in the Guangdong-Hong Kong-Macao Greater Bay area.

Greater Bay Area for higher education; the second is the interactive experience of the cooperation model on the regional economy and society; thirdly, the development of higher education in Guangdong, Hong Kong, and Macao has its own constraints and is highly complementary. This

strategic goal not only needs to play the supporting role of higher education in cultivating high-quality talents but also to lead the cooperative development of higher education in the three places, to provide cutting-edge technology and innovative collaborative development.

4.2. The positioning of higher education in the Guangdong-Hong Kong-Macao Greater Bay Area. Therefore, the development of higher education in the Guangdong-Hong Kong-Macao Greater Bay Area should have a specific and implementable target orientation [20]. Based on the locality and forward-looking nature of higher education positioning goals, the Guangdong-Hong Kong-Macao Greater Bay Area higher education positioning goals should not only focus on the existing higher education foundations in the Greater Bay Area, focus on the discussion and attribution of problems, but also recognize that Guangdong, Hong Kong and Macao Higher education in the Greater Bay Area is in a strategic position beyond the regional or national level, and finally proposes the goal of positioning higher education in the Guangdong-Hong Kong-Macao Greater Bay Area [21]. To this end, taking the construction and development of the Guangdong-Hong Kong-Macao Greater Bay Area as an opportunity, with a longer-term strategic vision, a broader international vision and a more advanced planning layout, to support the higher education in the Guangdong-Hong Kong-Macao Greater Bay Area to be at the forefront of the world.

4.3. The Development of Higher Education in Guangdong, Hong Kong, and Macao from the Perspective of Ecological Niche

- (1) There are few internationally renowned universities, and the level of internationalization needs to be improved (the following data are from the official website and published in 2019)

In the ranking of American News World Universities in 2019, a total of 14 universities in Guangdong ranked on the list. Among the 14 universities, Sun Yat-sen University and South China University of Technology ranked the top 500, ranking 208 and 336, respectively. In the QS World Ranking in 2019, there are 7 universities in Guangdong. Among the 7 universities, only Sun Yat-sen University has entered the top 500, ranking 295 in the world. In the World University Ranking in 2020, a total of 8 universities in Guangdong were listed, of which only Sun Yat-sen University and Southern University of Science and Technology ranked in the top 500. The world rankings are 251–300 and 301–350, respectively. In the ARWU World Ranking in 2019, a total of 11 universities in Guangdong were selected, of which 5 were ranked among the top 500 in the world, including Sun Yat-sen University (101–150), South China University of Technology (201–300), Shenzhen University (301–400), Jinan University (401–500), and South University of Technology (401–500). It can be seen that although there are many colleges and universities in Guangdong Province, not many universities enjoy international reputation. According to the world university rankings released by US News, QS, and the ARWU, only Sun Yat-sen University can enter the top 500 of

the mainstream world university rankings, but the ranking is not very high. In Hong Kong, there are five top 100 universities in the world, including the University of Hong Kong, the Hong Kong University of Science and Technology, the Chinese University of Hong Kong, and the City University of Hong Kong. It can be seen that there are still relatively few internationally renowned universities in Guangdong Province. It is necessary to strengthen the construction of first-class universities and first-class disciplines, expand the international reputation and influence of Guangdong education, and better promote the development of the internationalization of higher education in Guangdong [19].

- (2) The level of cooperative education is lower and there are fewer majors

Guangdong Province has 9 Sino-foreign (mainland and Hong Kong, Macao, and Taiwan) cooperative educational institutions and 52 Sino-foreign (mainland, Hong Kong, Macao, and Taiwan) cooperative educational projects, including doctoral education, foreign bachelor's degree education, foreign master's degree education, foreign doctoral degree education, and other categories, but mainly at the tertiary level and undergraduate level, such as Sino-foreign cooperative projects (see Figure 5) accounting for 55.8% of the academic level and categories of institutions of higher learning, and 19.2% belong to the level and category of undergraduate education. The level of master's and doctoral education is relatively small, and the level of cooperative education is relatively low. The cooperative training of high-level talents needs to be further strengthened.

Among the cooperative educational institutions and projects, there are relatively few majors, and only a few majors are offered by Sino-foreign cooperative educational institutions without legal personality. For example, the Sun Yat-Sen University-Carnegie Mellon University Joint School of Engineering only offers electronic and computer engineering majors; the Sino-French School of Nuclear Engineering and Technology of Sun Yat-sen University only offers nuclear engineering and nuclear technology majors for undergraduate education, and nuclear energy and nuclear technology engineering majors only for postgraduate education. Sino-foreign (mainland, Hong Kong, and Macao) cooperative education programs mainly focus on economic management and business management is the main category, and other majors in science and engineering are relatively few, and it is necessary to further develop a variety of majors and courses [22].

In addition, the number of cooperative education institutions and projects in Guangdong Province is still relatively small, and there are not many local colleges and universities participating in cooperative education which needs to be further widen.

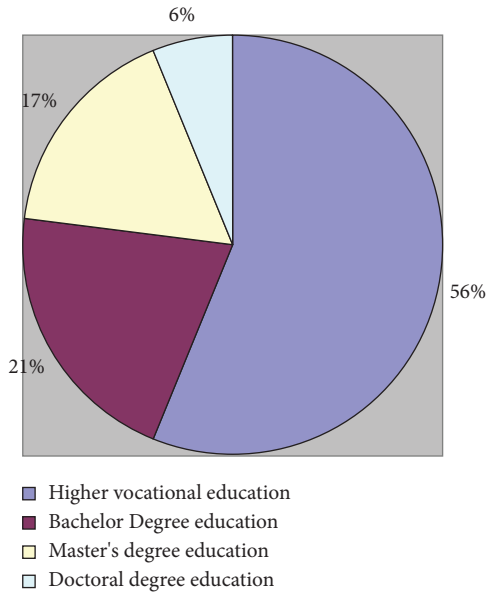


FIGURE 5: Scale chart of sino-foreign cooperation projects in Guangdong Province.

- (3) The school-running system is not flexible enough, and market forces are not involved enough

Professor Lu Xiaozhong believes that since the reform and opening up, Guangdong's education internationalization has achieved certain achievements, but Guangdong's level of education internationalization is much lower than its level of economic internationalization. Educational decision-making is not open enough, and the school operation system is not flexible enough. The system is not yet perfect lacking social participation and marketization. At present, Guangdong colleges and universities still mainly rely on the government to run schools. School-running system is not flexible enough, and the market forces are not involved enough. Relying solely on government funding, it is difficult to meet the needs of Guangdong to build a double first-class university. The outline puts forward clear strategic positioning and development goals, such as building an international scientific and technological innovation center, building a modern industrial system with international competitiveness, etc. To promote the internationalization of higher education in the context of the new era, Guangdong Province must first respond to the strategic positioning and goals of the Hong Kong-Macao Greater Bay Area, clarifying the strategic goal of developing the internationalization of higher education in Guangdong in the context of the new era, further promoting the depth of multiparty cooperation, establishing and improving the multiparty cooperation mechanism, and actively promoting international scientific research cooperation, Sino-foreign cooperation in running schools, and other internationalization Educational activities to serve the

construction and development of the Guangdong-Hong Kong-Macao Greater Bay Area [23]. Secondly, Guangdong Province should try to create a school-running system that is dominated by the government, integrated into the market, and participated in by the society. The main body is diverse, the forms are diverse, and the school-running system is full of vigor and vitality.

- (4) Insufficient attention to international assessment and lack of quality assurance system

Quality assurance is an important aspect in the process of education internationalization. To promote the internationalization of higher education, there must be corresponding supporting management systems and operating mechanisms as guarantees, such as quality evaluation systems, so as to comprehensively promote the internationalization of higher education and provide international. The exchange and cooperation activities provide sufficient management support. In 2010, the Guangdong Provincial Department of Education launched the first pilot work of external evaluation of education internationalization in 8 colleges and universities in the province, which is an important attempt to establish and improve the quality assurance system of higher education internationalization in Guangdong. However, at present, Guangdong has not yet formed a set of higher education internationalization evaluation system and quality assurance system to guide and guarantee the development of higher education internationalization of various institutions of higher education. Some colleges and universities may unilaterally pursue a certain aspect of education internationalization in the process of developing higher education internationalization, such as blindly focusing on expanding Sino-foreign or overseas cooperation projects and ignoring other internationalization indicators, making the development of higher education internationalization not comprehensive and sufficient [24]. Some institutional documents, such as the Regulations of the People's Republic of China on Sino-Foreign Cooperative Education, though they have put forward access conditions and school-running procedures for Sino-foreign cooperative education, there may be unclear points in the implementation process and a lack of effective supervision mechanisms. Therefore, it is necessary to formulate a scientific and reasonable internationalization evaluation system to comprehensively evaluate the development of internationalization of higher education, find and solve problems in a timely manner, effectively promote the process of internationalization of higher education, ensure the quality of internationalization development, and connect the strategic needs of Guangdong-Hong Kong-Macao

Greater Bay Area. At the same time, it is necessary to establish an effective supervision mechanism to ensure that the internationalization of education develops better on a reasonable and legal path and to promote the internationalization of higher education in Guangdong to open up a new situation in the new era.

5. Conclusion

There are various types of higher education in the Guangdong-Hong Kong-Macao Greater Bay Area, each with its own characteristics and complementarity. Focusing on the positioning of higher education in the Guangdong-Hong Kong-Macao Greater Bay Area, the demand for higher education in the economic, technological, political, and cultural development of the Guangdong-Hong Kong-Macao Greater Bay Area is summarized from the three dimensions of talent cultivation, collaborative innovation, and cooperative development. The division of these three dimensions is not the existence of mutual separation, but the interconnected organic unity, which constitutes the realistic demands of the construction of the Guangdong-Hong Kong-Macao Greater Bay Area for higher education [20, 21].

Data Availability

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

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Evolutionary Game Analysis of Green Building Development Dynamic System under Government Regulation: From the Perspective of the Contractor

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To speed up the development of green buildings (GB) and meet the requirements of low energy consumption, low carbon dioxide emissions, and green sustainable development, the key is to build a high-efficient green building dynamic system (GBDS). The government, the developer, and the contractor are the main power of GB promotion, and they are the main participants of GBDS. This paper aims to study how to improve the motivation of contractors' investment and participation in GB under the government regulation measures, to make up for the gap of research on the contractor's dynamic mechanism in the GBDS. In the research, evolutionary game theory was applied to build a dynamic model of the evolutionary game among the government, the developer, and the contractor, and the evolutionary laws and stability strategies of their game behaviors were analyzed. The research results show that the contractor's motivation of building GBs depends on the sum of receipts after the mix of income from construction and government rewards and penalties. The higher the sum of receipts is, the more stable the contractor's decision to participate in GBs is. When the government gives better incentive measures to the contractor, it is easier for the government, the developer, and the contractor to form an unanimous decision on the GB strategy, so the development dynamic system of GB is more stable.

1. Introduction

The direct impact of GBs on reducing energy consumption and carbon dioxide emissions has been widely recognized [1]. As a strategy to promote green, energy-saving, and the sustainable development of the construction industry [2], GB is not only recognized by academics engaged in theoretical research, but also welcomed and respected by the governments around the world. GB emphasizes the use of sustainable building technologies, materials, and equipment [3]. Compared with traditional buildings, GBs can be constructed through more technical improvements, such as the use of clean energy, material substitution, design iterations, energy efficiency modeling, and complex simulations, so as to achieve sustainability goals [4]. For the technical improvement and application of GB, not only the input and efforts of the contractor, but also the support of the developers and the cooperation of the designer are

needed to break the technical barriers [5]. This means that the successful implementation of GB is the result of the efforts of all stakeholders. Through the discussion of failure cases, the differences of stakeholders' values and their complex interactions will lead to obstacles in the implementation of GB [6, 7]. The interests of different stakeholders are heterogeneous, and they are interdependent with competition and cooperation [8]. Therefore, it is worth studying to build the dynamic system of GB development, balance the economic relationship between stakeholders, and promote the sustainable and healthy development of GB.

Historical experience has proved that the external force is an important agent to cause or accelerate industrial change, just as severe environmental pressure leads to the proposal of GB [9]. Government compulsion and economic incentive are considered to be the most important external motivation of GB promotion [10–12]. The government's

compulsion is reflected in the green building certification and evaluation standards issued in succession [13, 14]. Economic incentives are also implemented by the government, including laws and regulations, policy, and green building certification, and it is mainly for developers [15, 16]. The contractor participates in the developer's GB plan and plays an irreplaceable role in the promotion of GB, but from the perspective of government economic incentives, the additional work required by the GB plan has almost no economic return [17]. The reason why the incentives for the contractor have not yet been discussed is that the contractor is still regarded as a passive party in GB construction, ignoring the value and significance of the contractor in promoting GBs [18]. Neglecting the value and role of contractors among stakeholders is not conducive to achieving the sustainability expectation of GB through professional and technical innovation [19], but also hinders the improvement of the performance level and functional quality of GB [20–23]. Therefore, the contractor is an indispensable part of the GBDS.

In this paper, the government, the developer, and the contractor of engineering projects are the main power of GB promotion, and they are the main participants of GBDS. Different from previous studies, this paper aims to study how to improve the motivation of contractors' investment and participation in GB under the government regulation measures, to make up for the gap of research on the contractor's dynamic mechanism in the GBDS. The research results will help to mobilize the enthusiasm and initiative of contractors to participate in the GB development plan and improve the incentive and restraint mechanism for the government to promote the green building development strategy. In the research, the evolutionary game theory was adopted to build a tripartite evolutionary game model among the government, the developer, and the contractor, and the behavioral strategy evolution of the participating actors in the GBDS was studied. This study is not only a reference to existing results, but also an extension and application of related theories such as evolutionary game theory, government regulation theory, and green building theory.

2. Literature Review

2.1. Government Regulation Measures of GB. Although GB has been widely valued, there are still many obstacles in its implementation. In the previous research, the factors affecting the implementation of GB such as high costs, lack of knowledge, and awareness of sustainable construction were listed [24]. The main obstacle to these factors is higher costs. Besides, many studies confirmed that the costs of GBs are much higher than those of traditional buildings. Kim et al. conducted a comprehensive cost comparison analysis of residential engineering projects [25]. The results of their research showed that, compared with traditional buildings, the GB systems with more energy-saving appliances and equipment have increased the construction cost of the project by 10.77%. Bartlett and Howard study showed that project construction costs of energy-saving and

environment-friendly buildings were 5% to 15% higher than those of ordinary buildings [26]. The research data of Lapinski et al. showed that the installation of sustainable building equipment such as photovoltaics in GBs increased the delivery cost of GB projects [27]. In the course of promoting the development of GBs, whether or not more economic benefits can be obtained is the focus of many enterprises. All behaviors and decisions of enterprises are centered around the increase of benefits or income. Economic benefits can be regarded as the main driving factor for the promotion of GBs. Under the circumstances of fierce competition in the global property market, the initial high costs of GBs cause the developer to pause and ponder in the development and investment of GBs [28, 29]. Therefore, under the current situation, multiple incentive sources are needed to accelerate the development of GBs. Among those sources, government incentives and rewards have proved to be a good way to promote GBs [30, 31]. Meanwhile, some other scholars suggested that the government can force the developer and the contractor to construct GBs by setting standards, supervision, and enforcement [32, 33]. These views are consistent in understanding the necessity of using external incentive and constraint mechanism to promote the development of GB and are defined as the regulatory mechanism of governments.

The government regulation measures to promote GB summarized in the current research include law enforcement, economic incentives, and green certification promotion. Law and regulation drive means that the government promotes the investment and development of GBs by formulating and enacting laws and regulations related to mandatory GBs [34]. Economic incentive drive refers to the government's use of various financial incentives [12, 35], such as direct appropriations, tax incentives, financial subsidies, rebates, and discount development administrative charges, so as to encourage the developer to actively invest and develop GBs. GB certification drive means that the government or related industry associations design and develop a scientific and comprehensive evaluation index system and a sound evaluation mechanism, which plays a guiding and standardizing role in the evaluation, construction, and implementation of GBs [36]. It also can attract the consumer's attention to certified GBs and enhance the influence and status of GBs in the market [37, 38].

2.2. Green Building Dynamic System. The definition of GB has a wide range of connotations, including design and construction, energy and resource utilization, and environment and operation management [16]. Society, government, developers, designers, contractors, material and equipment manufacturers and suppliers, as well as home buyers can promote or hinder the promotion of GB [39]. However, the relationship between the above parties is too complex to be studied in an independent system [40]. In the research of GB's driving forces, it is mainly static research from a one-sided or multi-party perspective; while dynamic research is usually conducted from the perspective of

bilateral cooperation, there is no dynamic research from the perspective of multi-party cooperation. Static research refers to the research based on questionnaire survey and interview [16, 39, 40], and it shows that high costs of the developer are the most serious obstacle to the promotion of GB [29, 41], and effective government supervision is the most effective measure to promote the popularization of GB [39]. Eliminating the factors restricting the application of green construction technology [42], such as the ability of project manager, coordination between the designer and the contractor, and designer support [43], can reduce the initial cost of GBs. The application of green construction technology can not only reduce the waste of nonrenewable resources [44], but also help to realize the best GB and increase its added value [45]. However, static research lacks analysis of behavior choice and strategic decision in the process of stakeholder cooperation.

The dynamic research in this paper is based on the dynamic theory, which studies the behavior choice and strategy decision-making of the participants over time. The dynamic research on the driving force of GB is mainly based on the evolutionary game method from two aspects. For example, Fan and Hui studied the interrelationship between the government and the developer through the evolutionary game method and proposed that the price premium, the degree of government incentives for green buildings, and the cost bearing capacity of developers are the critical factors for the decision-making of main participants [46]. Zhu et al. studied the evolutionary game problems of green construction behavior between the main contractor and the subcontractor in large-scale projects and proposed that there is an optimal subsidy allocation coefficient between the main contractor and the subcontractor, which can minimize the total probability of opportunistic behavior of the participants [1]. The dynamic research from the perspective of any two parties cannot cover all the main stakeholders.

The complexity of GB project delivery process needs to be realized through the joint efforts and sincere coordination of developers, designers, contractors, and other stakeholders [2]. According to the conclusion of static research, under the premise that the design is the contractor's responsibility, this paper takes the government, the developer, and the contractor as the main stakeholders to build the GBDS. The GBDS is the system composed of the main stakeholders involved in the project that affect the promotion of GB, and it is the dynamic source to promote the development of GBs. In the system, the behavior choice of each member is influenced and restricted by other members.

2.3. Evolutionary Game Theory. Evolutionary game is a decision-making method based on dynamic theory, which is suitable for the study of cooperative behavior with conflict of interest. It uses mathematical models to analyze and judge the behavior choices and decisions of participants over time [46]. Evolutionary game theory is increasingly used in the research of government incentive and constraint mechanism and enterprise strategic management. For example, Zhao et al. used the evolutionary game model to study the

potential reaction of main body to the implementation of incentive policies with regard to carbon emission reduction labeling plan, indicating that both direct subsidies and tax preferences have a positive impact on the implementation of carbon emission reduction labeling plan [47]. Fan et al. studied the optimal implementation strategy of government low-carbon subsidy measures, as well as the efficiency and stability of regulation [48]. Miao et al. analyzed optimal combination decision of manufacturer's production output and product pricing under the carbon tax policy as well as quota and trading plan [49]. The results showed that carbon emission regulations issued by the government can reduce the demand for new products and promote the sales of remanufactured products. Cohen et al. analyzed the impediment to the development and rapidly spreading of GBs in Israel by using the method of game theory and proposed measures to overcome the obstacles [50]. The above research results show that evolutionary game theory can be applied to study the effect of government action on corporate behavior choice. Therefore, GBDS, as a complex system of corporate behavior selection under government regulation measures, can use evolutionary game theory to analyze its stability. Based on stakeholder theory, the relationship between project stakeholders is competition and cooperation [51–53]. The developer is reluctant to develop GBs because of its high costs, and the contractor is also reluctant to choose green construction strategies because of high costs and low benefits [29, 41]. Therefore, the government must actively guide the behavior of the developer and the contractor through positive incentive measures or negative restrictive measures [12, 35]. Influenced by government intervention and guidance, there is a conflict of interest between the government, developers, and contractors. Moreover, the evolution of the system is affected by government regulation measures and participant strategies. Evolutionary game theory can reduce the assumption of rational person and provide a good theoretical tool for the study of GBDS.

3. Research Hypotheses and the Model

The complete life cycle of GB project starts from investment decision, through engineering project design, then the construction process, and finally into project operation. As shown in Figure 1, the government is the maker and guide of GB development strategies or development plans, and it affects the decisions of the developer and the contractor through incentives and penalties. From the perspective of the developer, its decision-making and behavior are, respectively, affected by internal and external factors of the green building market. The internal factors include the economic benefits of the company, and the external factors mainly come from the constraints of policies and regulations issued by the government and the pressure of competition in the free market. For contractors in the system, it is affected by the internal factors, like its own economic benefits, as well as the external factors, like the government's regulatory restrictions and incentive measures, and the competitive pressure of other enterprises in the market. Among the main

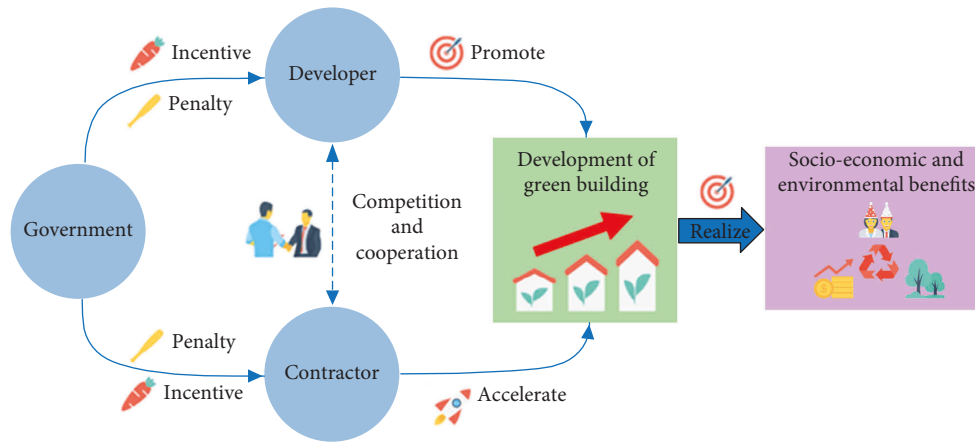


FIGURE 1: Mechanism of the GBDS.

stakeholders of GB development and construction, the developer is responsible for the decision and investment, but GBs, as a construction product, are the result of the developer commissioning the contractor to design and construct. Therefore, from the perspective of investment, development, and construction of GBs, the government, the developer, and the contractor are all major stakeholders. The interdependence and cooperation between stakeholders involved in the project are very important for the promotion of GBs and are an important guarantee for the realization of energy-saving effects of GBs [1].

In order to build an effective GBDS and promote the development of GBs, the evolutionary trajectory of the behavioral strategies of the government, the developer, and the contractor in the GBDS was studied without loss of generality. The following hypotheses were made:

Hypothesis 1. The government, the developer, and the contractor are three game players in the market. Based on stakeholder theory, government's incentive, and supervision, the developers' investment and the contractors' technology realization constitute the dynamic system of promoting and realizing GBs [2, 6, 7]. For the three parties, driven by interests and threatened by opportunism [8, 54], they have bounded rationality in the process of deregulation and realization of building.

Hypothesis 2. The government may adopt different strategies due to the influence of its own financial capacity and governance costs, as well as the pressure of different energy conservation and environmental protection supervision indicators [55, 56]. According to the two different measures of positive guidance and negative restriction, the government regulation can be divided into positive and negative behaviors [30–33]. So, its strategy set is {positive action, negative action} = {subsidy/penalty, no subsidy/no penalty}. The government's positive actions include giving subsidies, and monitoring and evaluating the construction effect of the subsidized projects. If the project fails to meet the standard requirements, penalty will be given, with the probability of z , while the probability of taking negative actions is $1 - z$ and

$z \in [0, 1]$. Negative action means that no subsidy incentive measures have been taken, but the implementation of project energy-saving standards is still evaluated, and punitive measures are taken if the evaluation fails. The government supervision or third-party supervision entails supervision costs, which are recorded as c . When the government takes positive actions, additional benefits can be obtained from GBs, including local environment improvement, energy consumption reduction, citizen satisfaction improvement, and high-efficient local government administration [57, 58], which are recorded as m ; when the government is inactive, the extra benefits from GBs are less than that under positive actions, which are recorded as n .

Hypothesis 3. Driven by economic benefits, developers' GB investment and development strategies are influenced by whether the cost of GB can bear [25, 28] and consumers' purchase intention [59]. So, its strategy set is {developing green buildings, developing ordinary buildings}. The probability of the developer developing GBs is y ; its probability of developing ordinary buildings is $1 - y$ and $y \in [0, 1]$. In the context of the government's positive actions, the government subsidy that the developer can get for developing GBs is H . If the subsidy has been obtained, but in the government's supervision and evaluation, the developer does not meet the corresponding GB evaluation index, the government will give the developer the penalty of F , and $F > H$.

Based on stakeholder theory, when the objectives and cooperation strategies of project stakeholders are consistent, it is conducive to the realization of common interests and individual interests [51–53]. On the contrary, it is difficult to guarantee the common interests and individual interests. Under the premise that the contractor implements a green construction strategy, when the developer chooses to develop a GB development strategy, its return is σ_1 ; when the developer chooses to develop an ordinary building strategy, its return is σ'_1 , and $\sigma_1 > \sigma'_1$. In the context of the contractor implementing a traditional construction strategy, when the developer chooses to develop a GB strategy, its return is σ_2 ; when the developer chooses to develop an ordinary building

TABLE 1: A three-party game return matrix.

	The government takes positive actions (z)		The government takes negative actions (1 - z)	
	Develop green buildings (y)	Develop ordinary buildings (1 - y)	Develop green building (y)	Develop ordinary buildings (1 - y)
Green construction (x)	$m - c - H - h$ $\sigma_1 + H$ $\pi_1 + h$	$n - c + F - h$ $\sigma_2' - F$ $\pi_2 + h$	$m - c$ σ_1 π_1	$n - c + F$ $\sigma_2' - F$ π_2
Traditional construction (1 - x)	$-c - H + f$ $\sigma_2 + H$ $\pi_1' - f$	$-c + F + f$ $\sigma_2' - F$ $\pi_2' - f$	$-c + f$ σ_2 $\pi_1' - f$	$-c + F + f$ $\sigma_2' - F$ $\pi_2' - f$

strategy, its return is σ_2' , and $\sigma_2' > \sigma_2$. Among them, $\sigma_1 > \sigma_1' > \sigma_2 > \sigma_2' > \sigma_2 > \sigma_2$.

Hypothesis 4. The contractor is affected by its own GB design technology, construction technology, and cost, so its selectable strategy set is {green construction, traditional construction} [24, 44]. The probability of the contractor choosing green construction is x , while the probability of choosing traditional construction is $1 - x$ and $x \in [0, 1]$. In the context of the government's positive actions, if the contractor chooses green construction, the government subsidy it can obtain is h ; if the subsidy has been obtained, but in the government's supervision and evaluation, the contractor does not meet the corresponding green building evaluation index, the government will give the contractor the penalty of f , and $f > h$.

Similarly, based on stakeholder theory, the following assumptions can be made [51–53]. In the case where the developer chooses to develop green buildings, when the contractor's decision is a green construction strategy, its return is π_1 ; when the contractor's decision is a traditional construction strategy, its return is π_1' , and $\pi_1 > \pi_1'$. In the case where the developer chooses to develop ordinary buildings, when the contractor's decision is a green construction strategy, its return is π_2 ; when the contractor's decision is a traditional construction strategy, its return is π_2' , and $\pi_2 > \pi_2'$. Among them, $\pi_1 > \pi_1' > \pi_2 > \pi_2'$.

3.1. Evolutionary Game Model of GBDS. In view of the above hypotheses, a three-party game return matrix for the government, the developer, and the contractor in the green building dynamic system is constructed, as shown in Table 1.

When positive actions are taken, the government's expected returns are

$$f_{G1} = -C + F + f - (my - ny + n - h - f)x - (F + H)y. \quad (1)$$

When negative actions are taken, the government's expected returns are

$$f_{G2} = -C + F + f - (my - ny + n - f)x - Fy. \quad (2)$$

The government's replicated dynamic equation is

$$U(Z) = z(1 - z)[hx - Hy]. \quad (3)$$

The developer's expected returns for developing green buildings are

$$f_{D1} = zH + \sigma_2 + x(\sigma_1 - \sigma_2). \quad (4)$$

The developer's expected returns for developing ordinary buildings are

$$f_{D2} = \sigma_2' - F + x(\sigma_2' - \sigma_2'). \quad (5)$$

The developer's replicated dynamic equation is

$$U(Y) = y(1 - y)[zH + \sigma_2 + x(\sigma_1 - \sigma_2) - \sigma_2' + F - x(\sigma_2' - \sigma_2')]. \quad (6)$$

The contractor's expected returns from green construction are

$$f_{C1} = zh + \pi_2 + y(\pi_1 - \pi_2). \quad (7)$$

The contractor's expected returns from traditional construction are

$$f_{C2} = y(\pi_1' - \pi_2') + \pi_2' - f. \quad (8)$$

The contractor's replicated dynamic equation is

$$UX = x(1 - x)[zh + \pi_2 + y(\pi_1 - \pi_2) - y(\pi_1' - \pi_2') - \pi_2' + f]. \quad (9)$$

3.2. Evolutionary Game Analysis of GBDS. Through establishing a simultaneous replicated dynamic equation of the government, the developer, and the contractor, we obtained a replicated dynamic system of the green building ecosystem, as shown in

$$\begin{cases} UX = x(1 - x)[zh + \pi_2 + y(\pi_1 - \pi_2) - y(\pi_1' - \pi_2') - \pi_2' + f], \\ U(Y) = y(1 - y)[zH + \sigma_2 + x(\sigma_1 - \sigma_2) - \sigma_2' + F - x(\sigma_2' - \sigma_2')], \\ U(Z) = z(1 - z)[hx - Hy]. \end{cases} \quad (10)$$

Friedman pointed out that the evolutionary stable equilibrium solution of the replicated dynamic system can be obtained by the local stability analysis of Jacobi matrix of the system [60], so Jacobi matrix of green building replicated dynamic system is shown in equation (11). In the green building replicated dynamic system (equation (10)), if each replicated dynamic equation is set to zero, 9 stable equilibrium points of the GB replicated dynamic system can be obtained. According to the evolutionary game theory [61], the evolutionary stability sets (ESS) of the GB replicated dynamic system that obeys Jacobi matrix eigenvalues are all negative conditions. The eigenvalues of the Jacobi matrix are shown in Table 2.

TABLE 2: Jacobi matrix eigenvalues of the replicated dynamic system.

Equilibrium point	Eigenvalue λ_1	Eigenvalue λ_2	Eigenvalue λ_3
$E_1(0, 0, 0)$	$\pi_2 - \pi'_2 + f$	$\sigma_2 - \sigma'_2 + F$	0
$E_2(0, 0, 1)$	$h + \pi_2 - \pi'_2 + f$	$H + \sigma_2 - \sigma'_2 + F$	0
$E_3(0, 1, 1)$	$h + \pi_1 - \pi'_1 + f$	$-H - \sigma_2 + \sigma'_2 - F$	H
$E_4(0, 1, 0)$	$\pi_1 - \pi'_1 + f$	$-\sigma_2 + \sigma'_2 - F$	$-H$
$E_5(1, 0, 0)$	$-\pi_2 + \pi'_2 - f$	$\sigma_1 - \sigma'_1 + F$	h
$E_6(1, 0, 1)$	$-h - \pi_2 + \pi'_2 - f$	$-H - \sigma_1 + \sigma'_1 - F$	$-h$
$E_7(1, 1, 0)$	$-\pi_1 + \pi'_1 - f$	$-\sigma_1 + \sigma'_1 - F$	$h - H$
$E_8(1, 1, 1)$	$h - \pi_1 + \pi'_1 - f$	$-H - \sigma_1 + \sigma'_1 - F$	$-h + H$
$E_9(x^*, y^*, z^*)$	Saddle point		

TABLE 3: Stability of the replicated dynamic system.

Equilibrium point	Eigenvalue			Asymptotically stable condition	Stability
	λ_1	λ_2	λ_3		
$E_1(0, 0, 0)$	Uncertain	Uncertain	0	\	Unstable
$E_2(0, 0, 1)$	Uncertain	Uncertain	0	\	Unstable
$E_3(0, 1, 1)$	+	+	+	$H + \sigma_2 + F < \sigma'_2$	Saddle point
$E_4(0, 1, 0)$	+	-	Uncertain	$H + \sigma_2 + F > \sigma'_2$	Unstable
$E_5(1, 0, 0)$	+	+	+	\	Unstable
$E_6(1, 0, 1)$	-	+	+	$\pi_2 + f < \pi'_2$	Saddle point
$E_7(1, 1, 0)$	-	-	-	$\pi_2 + f > \pi'_2$	Unstable
$E_8(1, 1, 1)$	-	-	-	$h + \pi_2 + f < \pi'_2$	Unstable
				$h + \pi_2 + f > \pi'_2$	Stable
				$h < H$	Stable
				$h > H$	Unstable
				$h > H$	Stable
				$h < H$	Unstable

$$J = \begin{bmatrix} 1 - 2x[zh + \pi_2 + y(\pi_1 - \pi_2) - y(\pi'_1 - \pi'_2) - \pi'_2 + f] & x(1-x)(\pi_1 - \pi_2 - \pi'_1 + \pi'_2) & x(1-x)h \\ y(1-y)(\sigma_1 - \sigma_2 - \sigma'_1 + \sigma'_2) & (1-2y)[zH + \sigma_2 + x(\sigma_1 - \sigma_2) - \sigma'_2 + F - x(\sigma'_1 - \sigma'_1)] & y(1-y)H \\ z(1-z)h & -z(1-z)H & (1-2z)(hx - Hy) \end{bmatrix}. \quad (11)$$

As can be seen from Table 3, except $E_6(1, 0, 1)$, $E_7(1, 1, 0)$, and $E_8(1, 1, 1)$, the other points cannot meet the requirements of eigenvalues in Lyapunov's discriminant method (indirect method), so it cannot form evolutionary stability. For $E_6(1, 0, 1)$, $E_7(1, 1, 0)$, and $E_8(1, 1, 1)$, their evolutionary stability is significantly different according to their different external initial conditions, which is specifically divided into two cases.

Case 1. Without changing the external initial conditions, the stability of the three-party evolutionary game cannot be judged because whether some of its eigenvalues are positive cannot be determined.

Case 2. If the external initial conditions change, the following stable evolution strategy can be obtained:

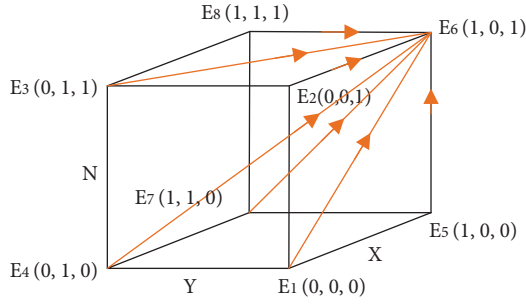
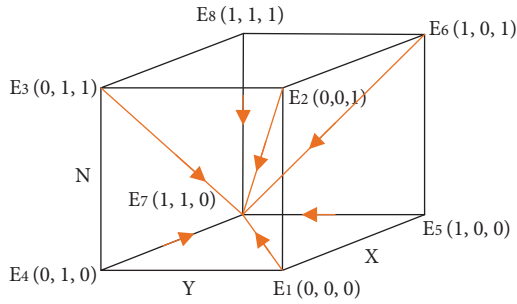
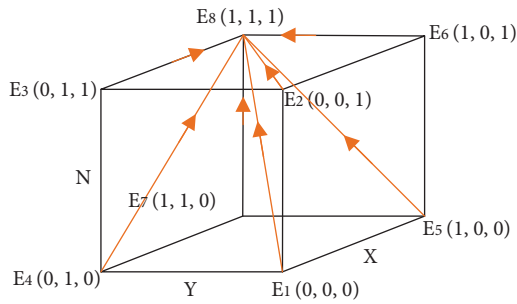
- (1) If $h + \pi_2 + f > \pi'_2$, then all the eigenvalues corresponding to the equilibrium point $E_6(1, 0, 1)$ are negative; that is, (green construction, developing

ordinary buildings, positive government action) is an evolutionary stability strategy.

- (2) If $h < H$, all the eigenvalues corresponding to the equilibrium point $E_7(1, 1, 0)$ are negative; that is, (green construction, developing green buildings, negative government action) is an evolutionary stability strategy.
- (3) If $h > H$, all the eigenvalues corresponding to the equilibrium point $E_8(1, 1, 1)$ are negative; that is, (green construction, developing green buildings, positive government action) is an evolutionary stability strategy.

The phase diagram of the model in Case 2 is shown in Figures 2–4.

3.3. GBDS Evolution Simulation. In order to intuitively depict the impact of the government's positive and negative regulatory measures on the strategy evolution of the

FIGURE 2: Phase diagram when $h + \pi_2 + f > \pi'_2$.FIGURE 3: Phase diagram when $h < H$.FIGURE 4: Phase diagram when $h > H$.

developer and the contractor in the GBDS, the paper uses ODE45 function of MATLAB software to simulate the evolution track of the behavior strategies of the three parties in the system.

Chinese residential projects have the characteristics of rapid and reproducible, and the data and analysis results are highly universal. Therefore, this paper takes the residential project of 20000 square meters which is common in China as the research object, and sets the parameter value of $\sigma_1, \sigma'_1, \sigma_2, \sigma'_2, \pi_1, \pi'_1, \pi_2$, and π'_2 , through the project investigation. According to the economic incentive and punishment measures of the Chinese government in promoting the development of GBs, based on the accounting method of government input and revenue from GBs determined by Liu et al.[41], the basic values of F, H, f, m, n , and c in the (10) are worked out as follows: $m = 2340$, $n = 2000$, $c = 3.5$, $F = 380$, $H = 200$, $f = 185$, $\sigma_1 = 1760$, $\sigma'_1 = 1530$, $\sigma_2 = 1300$, $\sigma'_2 = 1400$, $\pi_1 = 530$, $\pi'_1 = 495$, $\pi_2 = 450$, and $\pi'_2 = 473$.

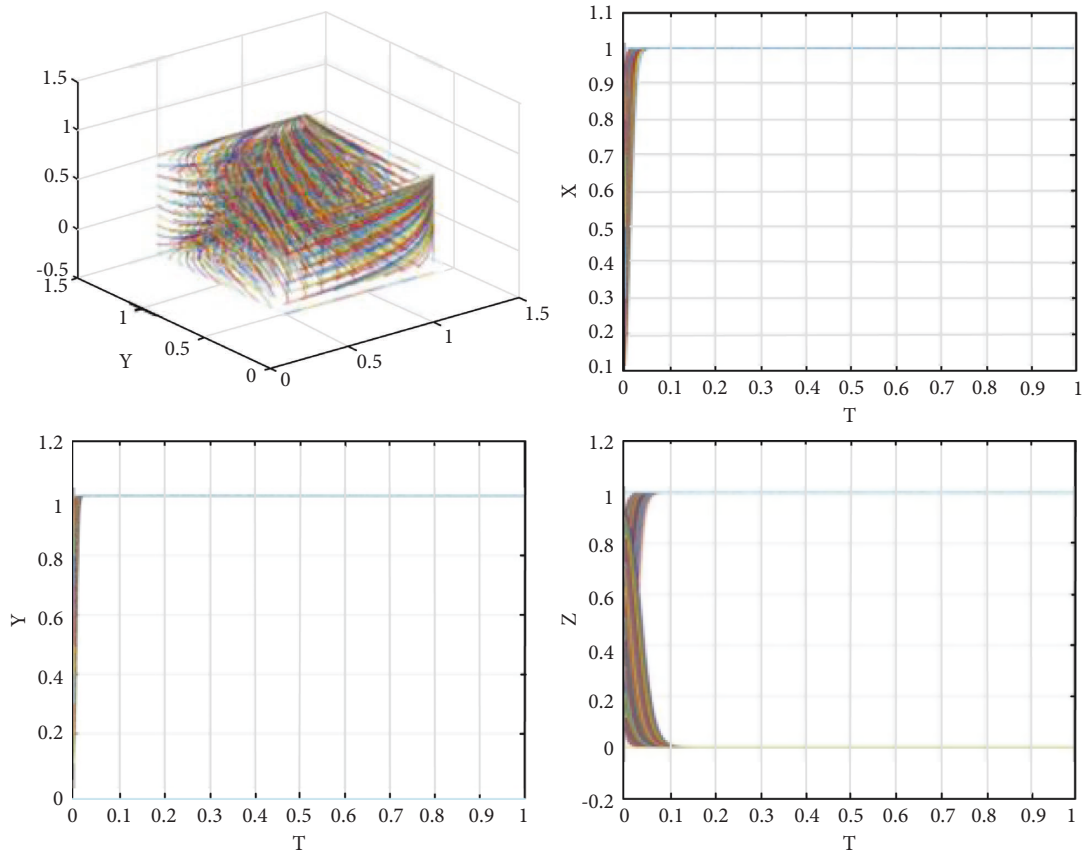
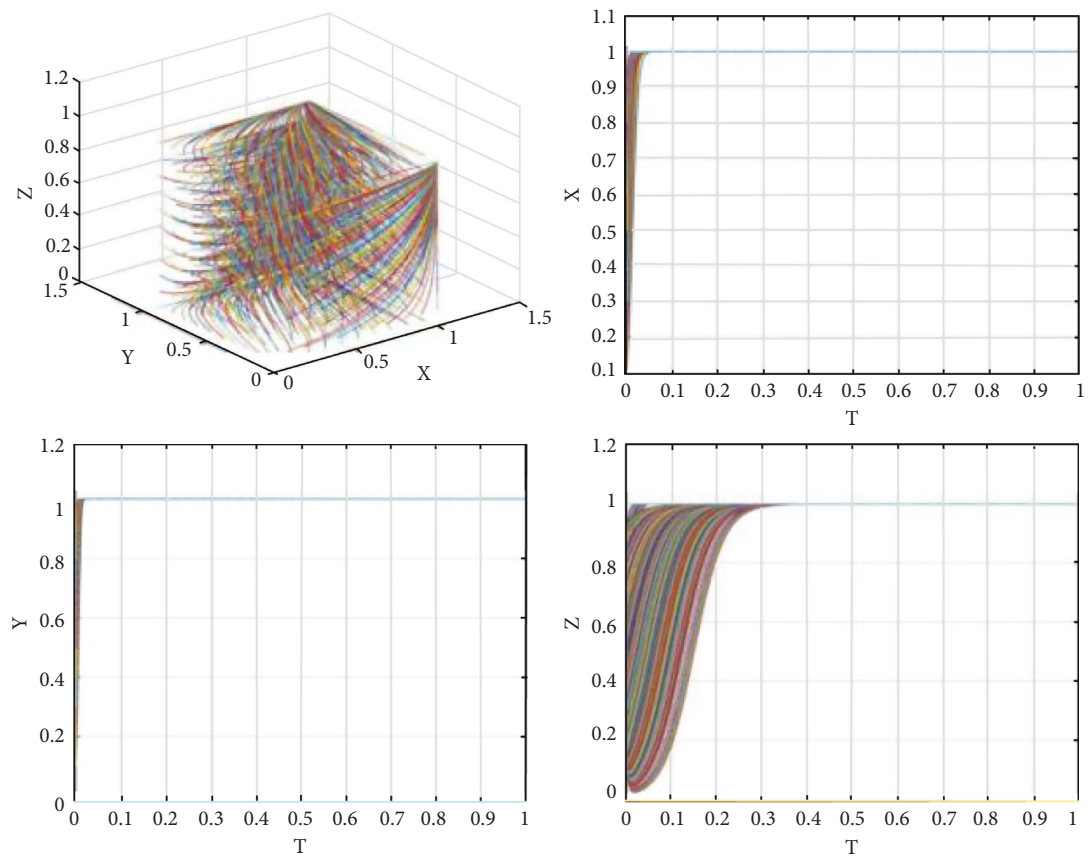
3.4. The Government Adopts Positive Regulation Measures. It is assumed that the government's economic subsidy for green construction of the contractor is 130, i.e., $h = 130$, which only satisfies the constraint condition of $h + \pi_2 + f > \pi'_2$. The behavior strategy evolution trajectory of the three parties in GBDS is shown in Figure 5.

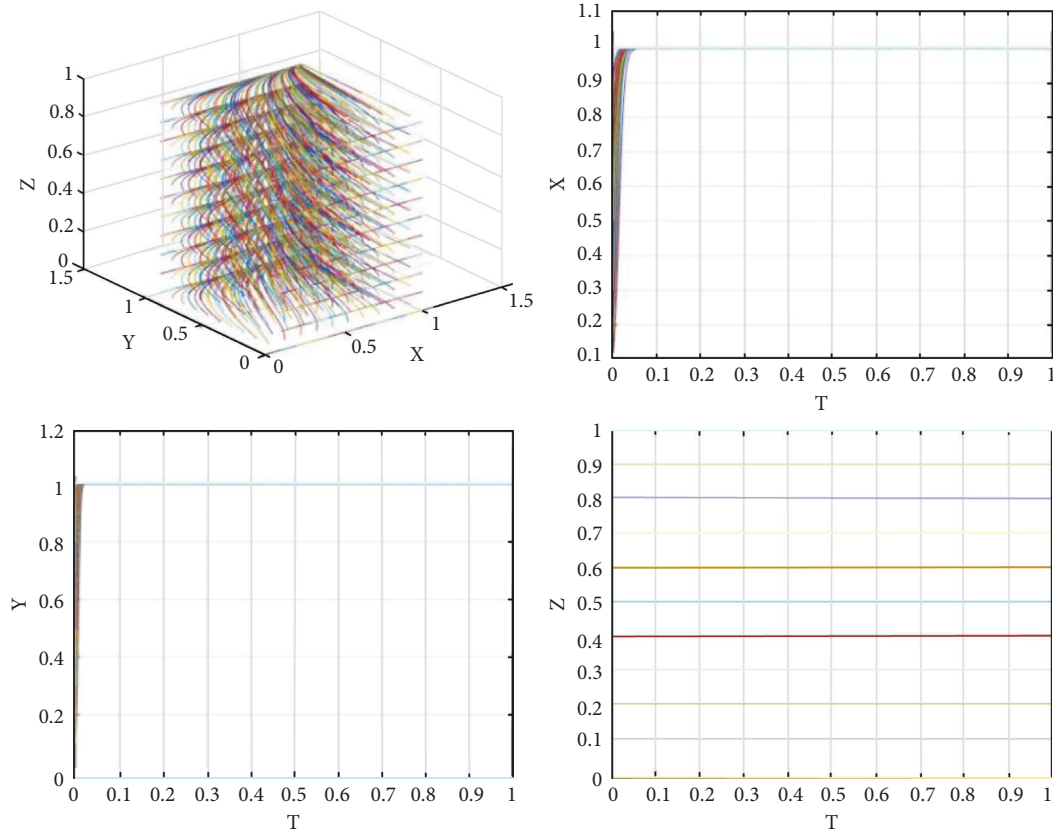
However, when the government's economic subsidy for green construction of the contractor is 230, i.e., $h = 230$, the constraint conditions of $h > H$ and $h + \pi_2 + f > \pi'_2$ are met at the same time. The behavior strategy evolution trajectory of the three parties in GBDS is shown in Figure 6.

When the government adopts positive regulation measures on the developer and the contractor at the same time, i.e., $H > 0$, $h > 0$, according to the tripartite evolutionary game stability process shown in Figures 5 and 6, it shows that in order to promote their efficiency in GB development and construction, the government takes positive actions such as motivating and punishing the developer and the contractor. If the sum of the contractor's green construction income π_2 and the government subsidy h is greater than the difference between the contractor's ordinary construction income π'_2 and the government penalty f , as time goes on, the contractor's choice of strategy is green construction. Figure 6 shows that when the government adopts positive actions, if the government's incentive h for the contractor's green construction behavior is greater than its incentive H for the developer's development of GB behavior, the evolutionary game among the three parties will stabilize at the point of $E_8(1,1,1)$; that is, (green construction, developing green buildings, positive government action) is an evolutionary stability strategy. The evolution of these two strategies is consistent with the theoretical analysis. If the incentive and punishment measures taken by the government to the contractor can only make the contractor not suffer economic loss due to the green construction strategy, it can make the contractor tend to choose the green construction strategy. However, it cannot make the developer choose green building strategy. Only when the government's incentive measures to the contractor can achieve the purpose of reducing the investment of the developer by reducing the cost of the contractor, can the green building strategy selection of the developer and the contractor be consistent.

3.5. The Government Adopts Negative Regulatory Measures. When the government only adopts negative regulation measures, let $H = 0$, $h = 0$, and only satisfy the evolution stability condition of E_7 . The behavior strategy evolution trajectory of the three parties in GBDS is shown in Figure 7.

When the government takes negative regulation measures on the developer and the contractor, according to the stable process of tripartite evolutionary game shown in Figure 7, we can see that when the government adopts negative actions, the value of the contractor's income from its traditional construction behavior π'_1 minus the government's penalty f for the traditional construction behavior is less than the contractor's income from its green construction behavior π_1 ; the developer's return from developing GBs σ_1 is greater than the developer's return on the development of

FIGURE 5: $h = 130$ stable process of tripartite evolutionary game.FIGURE 6: $h = 230$ stable process of tripartite evolutionary game.

FIGURE 7: $H=0$ $h=0$ stable process of tripartite evolutionary game.

ordinary buildings σ_1' minus the penalty F . As time goes on, the evolutionary game among the three parties will stabilize at the point of $E_7 (1,1,0)$; that is, (green construction, developing green buildings, negative government action) is an evolutionary stability strategy. The above data analysis shows that with a single punishment regulation measure, the developer and the contractor can also reach an agreement on green building strategy choice because of fear of economic losses caused by punishment.

It can be seen that for the contractor, there are two external sources of motivation for its green construction behavior. One is that the government encourages the green construction behavior of the contractor through positive actions, and that the government's incentives for the contractor are higher than those for the developer can promote the consistency of the developer and the contractor in their strategies of GBs and green construction. The second is that the government takes negative actions on the developer and the contractor's decisions in GBs and green construction, so the developer and the contractor can only reach an agreement on GB and green construction strategies through economic benefits.

4. Conclusions and Implication

In view of the dynamic system of GB development under the government regulation, this paper discusses the different GB strategy combinations of the developer and the contractor

under the government's positive incentives and negative actions through the evolutionary game analysis among the government, the developer, and the contractor from the perspective of the contractor. Compared with the incentive measures given to the developer, when the government makes better incentive measures for the contractor, it is easier for the three parties to reach an agreement on the GB strategy, and the GBDS is more stable. The government's positive incentive behavior for the developer and the contractor can achieve better results than those for the developer alone, which is more conducive to the development and promotion of GBs. It shows that the current government only aims at the incentive measures for the developer, which results in that the contractor cannot benefit from the incentive measures and provide a strong promoting force for the development of GB. Therefore, the government needs to directly encourage the contractor to maintain the stability of the GBDS.

Based on the purpose of better promoting the popularization of GBs and building an effective corresponding dynamic system, according to the research conclusions of this paper, the following implications can be obtained: (1) the government usually adopts financial subsidies, tax incentives, and other incentive measures. Keeping the total incentive amount unchanged, when the incentive for the contractor is stronger than that for the developer, it will be more conducive for them to reach an agreement on promoting GB development strategy. The short-term effect of

direct incentive is that the contractor chooses green environment-friendly and energy-saving materials and equipment in the project, and the contractor's costs can be partly shared due to the government's incentive measures. As a result, the contractor's profit in the project remains unchanged. If the contractor guarantees the project profit through government incentive, the contract price of the project will not be increased, and the pressure of increasing investment caused by GB can be relieved. The long-term effect is that the government's direct incentive to the contractor can stimulate and support the latter to make GB technology innovation, which can accelerate the maturity of GB technology and reduce the costs of GB technology. The cost reduction of GB technology can solve the problem of high costs of GB. In the long-term development process, the developer and the contractor can reach an agreement on GB development strategy. (2) When the government takes negative measures such as supervision and punishment, as long as the adverse consequences that the developer and the contractor need to bear are greater than the additional costs in the GB strategy, then the developer and the contractor will turn to the GB strategy. Therefore, it is necessary to strictly implement the national standards of GB through the third party and comprehensively carry out the green construction evaluation mechanism. At the same time, matching economic punishment measures should be implemented to force the developer to develop GBs and the contractor to conduct green construction. The action-forcing measures for contractors to save energy and reduce emissions can enable the EPC contractor to increase the R & D investment in green design, popularize the application of green construction technique, and promote the research and promotion of relevant energy-saving equipment and environmental protection materials. The introduction of third-party methods can reduce the increased expenditure required by the government's own supervision or expand the scope of management services and improve the efficiency of management services without increasing government expenditure. In the current market environment, if we want to improve the initiative of relevant enterprises to develop GBs and green construction, we must recognize that whether the enterprise has design capability, green construction capability is the basic condition for competition and survival in the long-term market. The government should guide the developer and the contractor to actively participate in the sustainable development of engineering construction through regulations, policies, and market regulation, and clearly convey to the market, enterprises, and consumers that GBs and green construction are a signal of long-term mechanism.

In the research, the evolutionary game model is applied to study all potential strategic combination of the government, the developer, and the contractor in the GBDS. Through the stability analysis of evolutionary game model, the corresponding research conclusions are obtained, which supplement the theory of government regulation and management of GBs. However, only three stakeholders are included in the GBDS. Therefore, the follow-up research is to add other stakeholders to the three parties of the existing

research and study the choice and decision-making of all stakeholders in GBDS.

Data Availability

The data used to support the findings of this study can be obtained from the author upon request.

Conflicts of Interest

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

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Retraction

Retracted: Landscape Design of Rural Characteristic Towns Based on Big Data Technology

Mathematical Problems in Engineering

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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. Zhang and Y. Sui, "Landscape Design of Rural Characteristic Towns Based on Big Data Technology," *Mathematical Problems in Engineering*, vol. 2022, Article ID 7356508, 13 pages, 2022.

Research Article

Landscape Design of Rural Characteristic Towns Based on Big Data Technology

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This study explores an effective method for constructing a landscape model of characteristic rural towns. In this study, the landscape pattern index of characteristic rural towns is obtained by calculating the total area, patch density, patch shape index, and average patch fractal dimension of the landscape area of characteristic rural towns. At the same time, this study calculates the minimum function of the three-dimensional rural characteristic town landscape cloud fusion transformation. At the same time, this study uses this function to calculate the 3D translation transformation, the rotation matrix of the 3D model, and the scaling factor transformation of the 3D model to construct the 3D model of the rural characteristic town landscape area. The simulation results show that the above method can reduce the error, reduce the registration time, improve the convergence, and reduce redundancy. This method can enhance the overall effect of constructing a three-dimensional model of a rural characteristic town landscape area.

1. Introduction

Under the background of Chinese urbanization development and transformation and new-type urbanization becoming a new bright spot for China's future growth, the solid industrial relevance and driving force of tourism make tourism urbanization a hot spot of widespread concern in the industry and an essential factor in new-type urbanization. In recent years, tourism characteristic towns have become typical representatives of characteristic towns and have become an important way of China's new urbanization. The booming of rural tourism in China in recent years has triggered massive industry changes and profound consumption transformation and dealt a feasible breakthrough direct for rural vitalization. Under the background that rural tourism is increasingly dominated by local tourism consumption, the economic ecology of characteristic towns formed by relying on the unique local natural and human resources has opened up a new path for the transformation and development of the domestic tourism industry. In recent

years, the landscape design of characteristic rural towns has gradually become a unique ecotourism resource, and its development and utilization have been paid more and more attention by people. When people plan and design the landscape area of characteristic rural towns, due to the influence of urbanization and ecological environment changes, the construction of the rural characteristic town landscape model has high model construction redundancy, the complexity of model construction increases, and the design effect is better. It is necessary to explore an effective method for constructing the landscape model of characteristic rural towns, which can improve the registration time of model construction, the convergence, and the efficiency of model construction. It has important practical significance in practical application [1].

The influence of tourism characteristic towns is embodied in the process of tourism urbanization. The researchers believe that tourism is an important industry to promote the development of the national economy, and tourism characteristic towns have become one of the

important ways to promote the economic development of traditional small towns. With the rapid development of rural tourism and the continuous increase in small-town construction, rural tourism's role in promoting the construction of small towns will become increasingly apparent, and the leading role of tourism-featured towns will be more significant. Some scholars have proposed that the development of tourism can increase the employment rate in urban areas and promote the improvement of local employment status, industrial structure, and infrastructure, thereby improving the quality of life of urban residents and enhancing their sense of belonging and happiness [2]. Researchers agree that tourism urbanization profoundly impacts urban and rural development, population and social structure, land use, and landscape environment. The urbanization of tourism has accelerated the development of cities, making the scale of cities continue to expand and making significant changes in the ideological concepts and attitudes of rural residents, such as life attitudes, educational concepts, and business concepts. Many rural residents show the characteristics of urban residents. Some rural residents have experienced the social role transition from farmers to operators and then to modern entrepreneurs. Many urbanized areas have improved infrastructure and the environment. These changes have triggered changes in education, transportation, and infrastructure in cities and towns. Tourism urbanization has changed the industrial structure of cities and the direction of urban and rural development, resulting in the continuous expansion of tourism land, the rapid expansion of nonagricultural populations, and the large number of women employed with far-reaching influence.

The researchers found that while tourism characteristic towns positively impacted local construction, they also brought many challenges. In addition to the urban waste disposal due to the short-term population surge brought about by tourism, in the process of tourism urbanization, with the influx of nonlocal population, the phenomenon of residents' laziness and population hollowing appear, and tourism characteristic towns exist. With solid population mobility and chaotic population management, resulting in contradictions in land use and even the problem of land occupation and waste to a certain extent, tourist towns also pose challenges to the ecological environment. Tourism urbanization has brought about the emergence of social class differentiation and isolation. In tourism, urbanization, rising prices, increasing social problems, floating population, and seasonal employment have difficulties in social management. Basile's research has found a strong correlation between the unscientific disposal of municipal solid waste, the decline in surface water quality, and the increase in the incidence of downstream waterborne diseases during the tourist season. Some scholars take Zhouzhuang, a historical water town, as a case point, revealing that tourism development will not only bring economic and environmental changes to the destination but also lead to the fragmentation of social relations and the loss of sense of place in the destination [3]. The researchers believe that the development of tourism characteristic towns must first take into account resources and location, look for distinct cultural themes, create core

attractions from both tangible and intangible levels, use the core business format of commercial street + accommodation to connect and enrich build the texture of the characteristic tourism town, and use the business management + operation method to continuously optimize and design the business model of the characteristic tourism town. In this study, a method for constructing a 3D model of a rural characteristic town landscape based on cloud point fusion is proposed and verified by simulation tests. This method can reduce registration time, reduce errors, and improve convergence.

2. Urgent Problems to Be Solved in the Planning and Development of Characteristic Towns

2.1. Embody the Characteristics. A characteristic town refers to a comprehensive development project with a clear industrial orientation, cultural connotation, tourism characteristics, and community functions that rely on a characteristic industry and distinguishing environmental factors (Figure 1). Since the introduction of relevant incentive policies, the construction of characteristic towns in various places has entered the fast lane. However, some places have become government departments' "performance projects," and the planning and construction of characteristic towns have turned into road building and tree planting, and extensive planning of cultural and tourism towns; some town planning and construction emphasize "form" over "soul." The construction of the spatial form of the town is too rigid, the local culture is not explored, and the basic rules for developing characteristic towns are not combined [4]. There is a lack of scientific planning for the consumption formats, cultural projects, and characteristic content of characteristic towns, which is difficult to stimulate the local economy.

2.2. Clarify the Planning Direction. Cultural and tourism characteristic towns are the product of the development of local social and economic development to a particular stage, the accumulation of local history and culture to a certain extent, and the development of characteristic local industries to a certain extent, combined with the unique local cultural and geographical environment. Under the boom in the construction of characteristic towns, many enterprises blindly follow the trend to seize resources and obtain policy support [5]. The construction of some cultural and tourism characteristic towns is "out of shape," and it is easy to make wrong judgments on critical links such as decision-making and investment, eagerness for quick success, lack of scientific decision-making and good planning, and lack of overall long-term planning so that resources are wasted in many places. Based on planning first, combined with local reality, the planning, construction, and development direction of characteristic towns are clarified.

2.3. Pay Attention to Cultural Connotation. In constructing the characteristic town landscape, it is necessary to consider how to protect and inherit the local culture. For example, there are ancestral clan halls in many rural areas in Guangdong, which are iconic buildings in characteristic

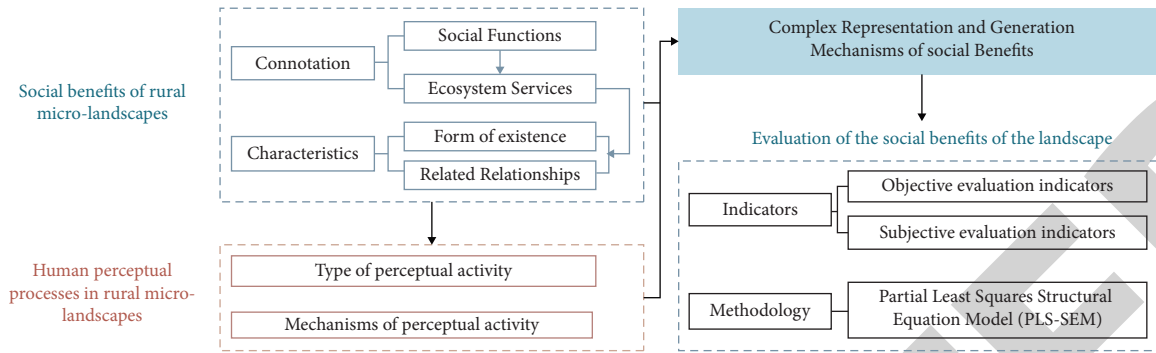


FIGURE 1: Connotation of characteristic towns.

towns, and many ancestral halls are damaged due to disrepair. In constructing the characteristic town landscape, effective measures should be taken to repair it and prevent it from being damaged. The design and construction projects should also be combined with the local conditions and architectural styles in the specific implementation. The design content should be integrated into the local culture, reflect the local characteristics, and create a foundation for the inheritance of culture. If the characteristic town is in the Chaoshan area, Chaoshan cultural elements are injected; if it is in the minority area, it must combine the minority culture to create the characteristic landscape of the minority culture.

2.4. Incorporating Local Customs. In the planning and construction of the “culture + agriculture” characteristic town, the local villagers’ customs, lifestyles, and regional economic conditions should also be investigated to ensure the rationality and operability of the landscape plan. For example, in the construction of areas that focus on planting, it is necessary to combine the economic development methods of local villagers to avoid the adverse impact of planning and construction on their lives and production. When building a “cultural + agricultural” characteristic town, local specialties and relevant elements of leading industries can be extracted and applied to the architectural firm. Scenes familiar to the villagers are also used to set up the characteristic town landscape, which can ensure its cultural identity. This is also a meaningful way to promote the inheritance of culture.

2.5. Focus on Holistic Planning. The planning and construction of “cultural + agricultural” characteristic towns should be comprehensively analyzed to ensure the coordination and unity of human, natural, and artificial landscapes. **Planning and Design:** before planning, it is necessary to dig deep into the local history and refine the symbols that reflect the regional culture. For example, you can select topics from historical events, famous sentences, etc., and integrate them into the planning and design. In terms of performance, based on determining the topic selection, it is necessary to adopt an appropriate form of expression, reflect the connotation of the region’s specific culture, and find an entry point in the planning and design. Regarding material

technology, it is necessary to select raw materials that reflect regional characteristics and the region’s unique natural or humanistic characteristics. Regarding craftsmanship, the core part of traditional craftsmanship is inherited from innovation.

3. Influencing Factors of Landscape Design of Characteristic Towns

“Although a building is substantial, what it can suggest or reveal includes the whole of life. Because it not only reflects the technical and scientific level of an era, the spirit of that era, and the aesthetic concepts at that time but also faithfully records the way of life and values of the people at that time.” Chinese buildings are people-oriented, the embodiment of human civilization, as are the environmental landscapes. Through the architectural forms and landscape features presented by these, you can appreciate the unique local customs of various places. Since the development of the times, the humanistic concern in the creative activities of the Chinese nation is more reflected in the humanized design [6]. The so-called humanized design is to take people as the main body of the design and comprehensively consider the needs of all aspects of people, and its core is still people-oriented. In the environmental landscape design of characteristic towns, the human factors can be grasped from the following aspects: to meet the crowd’s needs. First, it is necessary to understand the positioning of characteristic towns, whether industrial parks or tourist attractions. According to different types of towns, the town landscape is rationally planned to meet the needs of the main event groups for venue functions. For example, in the landscape planning of the community, more fitness places and resting places should be set up; more public service and tourist-oriented facilities should be set up in tourist attractions.

Demonstrate Humanistic Care. The first is the selection of materials. In slippery places, nonslip floor coverings should be selected; shading facilities should be appropriately set in areas with solid solar radiation; lighting equipment should be added in dark places. Secondly, we must pay attention to scale control and barrier-free design and reasonably design the length and height of steps, the height of handrails, and the planning of barrier-free passages, to

provide travel guarantees for the elderly and children, and the disabled.

Show the Humanistic Spirit. In the design of landscape modeling and landscape sketches, the local special cultural symbols are integrated, and they are used as elements in the landscape design of the town, which can show the unique humanistic outlook. For example, the Tea Horse Department in Ya'an, located in Changchun Village, Xindian Town, Mingshan County, Ya'an City, Sichuan Province, is an old site on the Ancient Tea Horse Road, and there is still a Yamen Institution that managed tea and horse trading in ancient times (Figure 2). While protecting this ancient site, the local people also built landscape sketches reflecting the ancient tea-horse road culture (Figure 3). These sketches reproduce the scene of caravan people carrying horses and camels in those days, highlighting the characteristics of caravan culture and showing the spirit of caravan merchants who are not afraid of hard work and hardships.

"Harmony between man and nature" advocates that people must follow nature's laws and coexist with nature. In the design, it is recommended to get inspiration from nature and carry out creation activities according to the principles of nature. This philosophical viewpoint is applied to all aspects of ancient creation activities, such as furniture architecture and garden landscapes, and still has an essential reference for today's design concepts. Landscape design techniques derived from this philosophical viewpoint are as follows.

3.1. Taking Advantage of the Situation. Borrowing scenery according to the situation is to use the original landscape features and cleverly borrow angles to enrich the sense of hierarchy of the landscape. The technique of borrowing scenery can be applied in two aspects, and one is the natural landscape. The land of China is vast and rich in terrain [7]. According to the local topography, different architectural structures and spatial layouts have been formed. In constructing characteristic towns, using topographical features to construct new buildings can maintain the overall landscape effect of the settlement to the greatest extent. In landscape planning, reasonable use of close-up and distant views can extend the landscape space and better integrate the scenery into nature.

3.2. Localized Design. Localized design is a creative activity that combines national characteristics with regional characteristics based on the national culture and current needs. Mr. Wu Liangpu once said, "To create a beautiful environment, we must achieve two kinds of integration. One is to integrate with nature, and the other is to integrate with history and culture, that is, to integrate with 'cultural context,' to inherit and develop historical heritage." After several years of inheritance and evolution, each ethnic group has formed its unique regional customs. Regional cultural characteristics need to be presented through traditional cultural symbols. An in-depth study of regional culture, extraction of traditional cultural symbols with the most local characteristics, and proper application of urban cultural



FIGURE 2: Ya'an Tea-Horse Division.



FIGURE 3: Sketch Sculpture of Ancient Tea Horse Road.

landscape design can give the design a sense of cultural identity.

3.3. Sustainable Design. With the shortage of resources and the gradual awakening of national consciousness, sustainable landscape design has become the focus of current designers. Sustainable landscape design emphasizes meeting people's needs and creating a comfortable and green landscape environment to ensure environmentally sustainable development. Adapting measures to local conditions is one of the fundamental principles of sustainable development. Building a small-town landscape following local conditions will not destroy the ecological balance and achieve ecological and green town landscape design.

4. Construction Principle of the 3D Model of Rural Characteristic Town Landscape Area

The construction principle of the three-dimensional model of the landscape area of the characteristic rural town is to calculate the spatial orientation coordinate system of the rural characteristic town landscape through the imaging principle of the visual camera and use the visual difference ranging method to obtain the image points of the rural

characteristic town landscape image corresponding to the three-dimensional coordinate system. After transforming the world coordinate system and the coordinate equipment system, the actual rural characteristic town landscape area model is constructed.

Suppose $Q_\varepsilon - Y_\varepsilon A_\varepsilon C_\varepsilon$ represents the three-dimensional coordinates of each pixel in the visual camera. C_ε corresponds to the corresponding depth orientation along the optical axis. A_ε represents the corresponding height orientation along the optical axis. The Y_ε table corresponds to the width orientation along the optical axis. $Q_j - Y_A$ represents the landscape spatial coordinate system of characteristic rural towns. $Q_k - V_X$ represents the device configuration coordinate system. H_ω represents the landscape image of the characteristic rural town in the camera, and the depth coordinate system of the point is calculated by the visual difference between the projection points H_1, H_2 of the landscape image plane through the H_ω point. The visual difference calculation formula is as follows:

$$\begin{cases} C_\varepsilon = \frac{xk}{1000q}, \\ q_\omega = \chi_1 - \chi_2. \end{cases} \quad (1)$$

In the formula, C_ε represents the depth coordinate of H_ω in the camera coordinate system. x represents the baseline spacing. k is the focal length of the camera. q_ω represents the visual difference corresponding to the depth coordinate system of the H_ω point. χ_1 represents the abscissa of the landscape image coordinate system corresponding to the projection point H_1 . χ_2 represents the abscissa of the landscape image coordinate system corresponding to the projection point H_2 .

The rural characteristic town landscape image is saved by the device coordinate system of the unit pixel selected in the image device. It is on the same plane as the rural characteristic town landscape image coordinate system and the same azimuth coordinate axis, and the origin position is changed. The point conversion relationship of the rural characteristic town landscape image coordinates is expressed as follows:

$$\begin{bmatrix} i \\ j \\ 1 \end{bmatrix} = \begin{bmatrix} \vartheta_i & 0 & -v_0\vartheta_i \\ 0 & \vartheta_j & -v_0\vartheta_j \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \nu \\ v \\ 1 \end{bmatrix} = N_2 \begin{bmatrix} \nu \\ v \\ 1 \end{bmatrix}. \quad (2)$$

In the formula, N_2 represents the coordinate transformation matrix of the landscape image of characteristic rural towns. (ν, v) means that the projection point of H_ω is the abscissa and ordinate on the device coordinate system. (v_0, v_o) represents the abscissa and ordinate of the origin coordinate system of the rural characteristic town landscape image on the device coordinate system. i represents the width, azimuth, and unit pixel size of the landscape image of rural characteristic towns. j represents the height and orientation unit pixel size of the landscape image of rural characteristic towns. Using the principle of linear

camera pinhole imaging, the pixel coordinates of the camera width and height orientation of point H_ω are expressed as follows:

$$\begin{cases} Y_\varepsilon = C_\omega \frac{i_1}{k}, \\ A_\varepsilon = C_\omega \frac{j_1}{k}. \end{cases} \quad (3)$$

In the formula, (i_1, j_2) represents the coordinates of the landscape image of the rural characteristic town at the camera projection point. If $Q_\omega - Y_\omega A_\omega C_\omega$ is the world coordinate system placed on the ground, C_ω represents the depth orientation corresponding to the rural characteristic town landscape. A_ω means that the landscape of rural characteristic towns corresponds to the front-facing vertically upwards. Y_ω represents the horizontal orientation along the landscape of rural characteristic towns. The formula for converting camera coordinates to the landscape of rural characteristic towns is as follows:

$$\begin{bmatrix} Y_\omega \\ A_\omega \\ C_\omega \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(\alpha) & -\sin(\alpha) & 0 \\ 0 & \sin(\alpha) & \cos(\alpha) & 0 \\ 0 & z & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} Y_\varepsilon \\ A_\varepsilon \\ C_\varepsilon \\ 1 \end{bmatrix} = \begin{bmatrix} Y_\varepsilon \\ A_\varepsilon \\ C_\varepsilon \\ 1 \end{bmatrix}. \quad (4)$$

According to formula (4), after the transformation of the world coordinate system and the equipment coordinate system, the actual rural characteristic town landscape model formula is constructed as follows:

$$T = \begin{bmatrix} Y_\omega \\ A_\omega \\ C_\omega \\ 1 \end{bmatrix} = N \begin{bmatrix} i_1 \\ j_2 \\ 1 \end{bmatrix}. \quad (5)$$

In summary, the construction principle of the three-dimensional model of the landscape area of the characteristic rural town has been completed, and the construction of the three-dimensional model of the rural characteristic town landscape area has been realized according to this principle.

5. The Construction Method of the Three-Dimensional Model of the Landscape Area of the Characteristic Rural Town

5.1. Obtaining the Landscape Pattern Index of Characteristic Towns in Rural Areas. The process of the landscape pattern index of characteristic rural towns is to obtain the landscape pattern index of characteristic rural towns by calculating the total area, patch density, patch shape index, and average patch fractal dimension of the landscape area of characteristic rural towns.

5.1.1. The Total Area of Landscape Area of Characteristic Rural Towns. It is assumed that the selected wetlands have n total of landscape area types. A type of rural characteristic

town landscape area is selected, which is represented by ι , the number of patches is represented by m , and b_{il} is an area in the number of patches. The calculation formula of the total area of the rural characteristic town landscape area is as follows:

$$B_{DA} = \sum_{l=1}^m b_{il} \left(\frac{1}{10000} \right). \quad (6)$$

5.1.2. Patch Density in Landscape Area of Characteristic Rural Towns. The patch density in the landscape area of the characteristic rural town can reflect the fragmentation of the landscape area and the spatial heterogeneity of the rural characteristic town landscape. The larger the landscape patch density value in characteristic rural towns, the greater the fragmentation and heterogeneity of the landscape area. The formula for calculating the landscape patch density in characteristic rural towns is as follows:

$$S_{EF} = \frac{m_{\iota}}{(B \times 10^6)}. \quad (7)$$

5.1.3. Patch Shape Index in Landscape Area of Characteristic Rural Towns. The shape of landscape patches of rural characteristic towns is used to show the patch specifications of landscape elements and the contours' complexity. The patch shape index is to select a particular type of patch in the rural characteristic town landscape and calculate its area. At the same time, a square of the same area is used as a reference, and the deviation degree of the two is used to determine the size and complexity of the landscape patch shape. The more complex the patch shape, the higher the shape index value. The landscape patch shape index of characteristic rural towns is as follows:

$$L_{XZC} = \frac{c_{\iota}}{2\sqrt{\pi B_{\iota}}}. \quad (8)$$

5.1.4. The Average Patch Fractal Dimension of the Rural Characteristic Town Landscape. Let P_{fd} represent the average patch fractal dimension of the rural characteristic town landscape, and the value is $1 \leq P_{fd} \leq 2$. When $P_{fd} \leq 1$, the shape of the rural characteristic town landscape patch is clearer; when $P_{fd} \leq 2$, the more complex the rural characteristic town landscape patch shape. Let R_{il} denote the area of all patches in the landscape of rural characteristic towns, and the formula for calculating the average patch fractal dimension of the landscape of rural characteristic towns is as follows:

$$P_{fd} = \frac{\sum_{l=1}^m (2 \ln R_{il} / \ln b_{il})}{m_{\iota}}. \quad (9)$$

5.1.5. Obtaining the Landscape Pattern Index of Characteristic Rural Towns. By calculating the total area of landscape types of characteristic rural towns, the density of landscape patches of characteristic rural towns, the patch shape index of characteristic rural towns, and the average patch dimension of characteristic rural towns, the landscape pattern index of characteristic rural towns the formula is as follows:

$$H = \ln m + \sum_{l=1}^m P_{fd} \cdot L_{XZC}. \quad (10)$$

5.2. Construction Method of the 3D Model of Rural Characteristic Town Landscape Area. Based on the acquisition as mentioned above of the landscape pattern index of characteristic rural towns, a method for constructing a three-dimensional model of rural characteristic town landscape area based on point cloud transformation is proposed. This function calculates the 3D translation transformation amount, the rotation matrix of the 3D model, and the scaling factor of the 3D model, converts and constructs the 3D model of the landscape area of the characteristic rural town, and completes the construction of the 3D model of the landscape area of the rural characteristic town. Assuming that δ_1 represents the overall pattern point cloud model, and δ_2 represents the partial pattern point cloud model, the same points are δ_{φ_1} and δ_{φ_2} , the minimum function calculation formula of the three-dimensional rural characteristic town landscape cloud fusion transformation is as follows:

$$S(\delta_{\varphi_1}, \delta_{\varphi_2}) = \|\delta_{\varphi_1} - (\sigma \cdot \delta_{\varphi_2} \cdot \eta + T + H)\|. \quad (11)$$

In the formula, σ represents the three-dimensional scaling factor. η represents the rotation matrix of the 3D model. T represents the three-dimensional translation transformation. According to formula (11), the specific steps for transforming the three-dimensional model of the rural characteristic town landscape area using the required function are as follows.

5.2.1. 3D Translation Transformation. Suppose G represents the geometric center point of the 3D rural characteristic town landscape point cloud model. R_{τ} represents the τ coordinate point in the 3D rural characteristic town landscape point cloud model. O represents the number of 3D landscape point clouds of characteristic rural towns, and the calculation formula of the set center point of δ_{φ_1} and δ_{φ_2} is as follows:

$$G = \sum_{\tau=1}^O \frac{R_{\tau}}{O}. \quad (12)$$

According to formula (12), let the geometric center points of δ_{φ_1} and δ_{φ_2} be G_1 and G_2 , respectively, and the coordinate normalization method is used to translate the geometric center point to the position of the origin G . The

calculation formula of the set translation transformation is as follows:

$$T = (G_1 - G_2) + (G - G_1). \quad (13)$$

5.2.2. Rotation Matrix of the 3D Model. When δ_{φ_1} and δ_{φ_2} are processed by coordinate normalization, the simplified formula for formula (1) is as follows:

$$S(\delta_{\varphi_1}, \delta_{\varphi_2}) = \|\delta_{\varphi_1} - \delta_{\varphi_2} \cdot T\|. \quad (14)$$

If it is ensured that the landscape point cloud model of characteristic rural towns remains unchanged during conversion, the OPP algorithm is used to limit the rotation matrix. When $\det(T) = 1$, the calculation formula of the optimal rotation matrix is as follows:

$$J = I \cdot U^v. \quad (15)$$

5.2.3. Scaling Factors for 3D Models. Let $l\mu(\cdot)$ represent the traces of the matrix, and the calculation formula of the scaling factor is as follows:

$$\eta = \frac{l\mu(\delta_{\varphi_1}^v \cdot \delta_{\varphi_2} \cdot T)}{l\mu(\delta_{\varphi_1}^v \cdot \delta_{\varphi_2})}. \quad (16)$$

After transforming the translation transformation value, rotation matrix value, and scaling factor, the expression of the point cloud in G_2 transformed to the G_1 coordinate system is as follows:

$$G_2'' = \eta \cdot G_2 \cdot J + T. \quad (17)$$

When the overall pattern points cloud and the partial pattern point cloud are integrated, namely $G_1 \cup G_2$, the construction of the three-dimensional model of the rural characteristic town landscape area is realized.

6. Landscape Planning and Design Methods for Tourism-Oriented Characteristic Towns

6.1. General Layout. In this design, the landscape planning is carried out for the characteristic tourist towns in the north, and the overall planning and design are carried out under the condition that the natural landscape, industrial park landscape, living area landscape, and infrastructure construction meet people's daily needs and highlight the tourism function. It includes commercial streets, theme plazas, residential areas, industrial parks, and usual scenic spots. To this end, the characteristic town should have three primary functions: (1) the essential functions of tourist attractions in the general sense; (2) meet the basic requirements of people's life and travel; and (3) satisfy the essential elements of residents' work and entrepreneurship. To become a thriving tourist town, it is indispensable to have distinct commercial complexes and characteristic industrial parks that can drive the town's rapid economic development and build a characteristic town with an intense cultural atmosphere, complete functions, and a healthy economic model.

6.2. Design Method

6.2.1. Traffic Route. In the design and planning of the characteristic tourist town in the north, combined with the research on the road traffic design strategy in this study, the topography, surrounding, and internal environment of the town itself are investigated and analyzed, and the roads and traffic routes are redivided to meet the flow of people. The traffic flow is large, but the number of short-term stagnations is small compared with the interior. Wider roads (6–9 meters) should be designed and planned to avoid traffic jams, and secondary arterial roads (2–4 meters) should be designed. To avoid exceptional circumstances, the surrounding greenery is designed to be simple and yet connotative as adjustment and improvement to satisfy the visual experience of tourists and improve the level of the ecological environment. The planning and design of the roads in the park should ensure convenience and efficiency and integrate the roads with the surrounding environment and the characteristics of the town to enhance the interest and comfort of the roads. According to the specific conditions of the town, a parking lot area with an appropriate scale will be constructed to meet people's parking needs. The most crucial point is that the road should make the flow of people and vehicles "live," and loops should be designed to avoid problems such as congestion and fire protection to the greatest extent. The above are the main roads in the town, and the roads should be designed with broader pavement and distinct areas, or the garden area should choose a narrower road, and the overall road system of the town should complement each other without disrupting the pattern so that the space is diversified and the traffic system route is fast.

6.2.2. Scenic Spots. This section accounts for the most significant proportion of the characteristic tourist towns in the north. The local intangible cultural heritage museum in the characteristic town and the tourist area composed of the surrounding park landscape is taken as an example. The historical development process as the background, the history, status quo, and complementary products of characteristic industries and enterprises are displayed as the core content, and the follow-up promotion and publicity are developed with interactive links such as sales. Negotiations, office, and other functions are carried out after the visit. The surrounding parks integrate culture into life and have better contact with local cultural characteristics. They are the best places for people to relax and travel and are an essential part of characteristic towns suitable for travel and vacation.

The Industrial Culture Museum can also be designed as a local modern history museum. Through the transparency and interaction of the industry, visitors have the opportunity to have close contact with the product production process and craftsmanship of the industry to promote better the subsequent development of the industry and economic growth. The design of the surrounding area of the Industrial Culture Museum and the park environment should also be different from other areas. The combination of the two

should not be incompatible with the general town design. An ecological landscape system that is unified with the town style should be built in the area. The type and scale of the building are equipped with the corresponding greening and water system. The elements should be designed and planned according to the corresponding theme: rockery, landscape pavilions, sketches, water features, flowers, etc. The spatial structure can be upgraded in terms of water bodies. For example, waterwheels and artificial springs add some interactive items in different seasons to add to the area's characteristics. Figure 4 shows the landscape design near Baotu Spring in Jinan. In the large-scale waterscape, the flexibility of water is fully used to create a spatial level of opening and closing so that it can form a dynamic and static combination with other elements. In summer, you can rest by the river to achieve the effect of adjusting your mood and promoting the experience. In winter, designing an ice-skating rink can improve local economic benefits and be the best place to play.

6.2.3. Living Park Segment. The area of this planned plot is divided into two parts, one is the original residential area, and the area is the residential house of the locals in the town. Town hotels, country-style restaurants, etc., can relieve the economic pressure in the initial stage of the town and increase the vitality of the characteristic town, making the town more distinctive. On the other hand, it is to build commercial and residential houses on the original basis, build communities, and provide housing for the foreign population, which can be sold to long-term residents or rented to tourist tenants.

6.2.4. Commercial Area Segment. This section mainly comprises cultural and commercial streets and industrial parks, ensuring that residents and tourists are one of the economic sources of the characteristic town. The business park connects the residential area with "zero distance" to experience the convenience of being located in the "city center."

6.2.5. Industrial Park Sector. The industrial park sector must satisfy three elements. 1. In production, to meet production needs, the design plan should be based on human text to provide a better working environment. 2. In transportation, the plate area should meet the transportation needs and be planned on the periphery of the town to facilitate a better transportation environment. 3. Tourists can visit the tourism environment with local characteristics and the industrial park. The vitality of local culture is shown. Introducing industrial culture into characteristic towns can add a new color to tourism.

6.2.6. Greenland Landscape

(1) Green Space in the Tourist Area. Greenland landscapes in tourist areas refer to natural landscapes such as woodlands and grasslands within the environment of characteristic



FIGURE 4: Baotu Spring.

towns, which account for the most significant proportion of characteristic tourist towns and have the most local characteristics. How systematically, rationally, and scientifically plan this part of the area is a characteristic of the focus of the town's natural landscape. Therefore, it is necessary to plan the design of the green space in the site first and artificially plant the areas that need to be repaired to ensure sustainability and integration. Second, the plant resources around the characteristic town are rationally planned and utilized to improve the town's economic income or viewing ability.

(2) Green Space in the Living Area. The greening of the community's public areas, the greening of the adjacent roads, and the greening of the areas connected to other areas belong to the green space landscape of the living area. To ensure the balance of the ecological environment, the green space in the living area is planned to meet the aesthetics of the residents and facilitate the residents' travel. When constructing a new road, on the premise of ensuring the smoothness of the road, the area with existing trees on both sides is preferentially selected, and the trees that hinder the project are transplanted, which can not only preserve the integrity of the town but also reduce the expenditure. In the area connecting with tourist areas and business parks, the construction of a green space landscape should reflect local cultural characteristics and increase the viewing value of green areas.

(3) Green Space in an Industrial Park. There are many industrial parks, and green areas are planned according to the local conditions. Different types of green space planning have differences and similarities. Most of the green landscapes in industrial parks are scattered, and this ecological landscape structure composed of small areas frequently appears in landscape planning and design. The shape, color, size, location, etc., of these small areas, should be reasonably planned, and the planning structure most suitable for the green space of the industrial park should be made. The area of the characteristic town itself is contacted, the scope of green space is adjusted, and the stable development of the industrial park and the ecological environment is ensured [8]. The landscape of farmland is divided into two types:

natural and nonnatural. The landscape of natural farmland is a farmland landscape that is produced independently without any human factors involved. The landscape of the nonnatural farmland park includes two kinds of subjective factors and nonsubjective factors. The subjective factor refers to the relevant design of the designated area before the landscape construction, and the actual construction is carried out. Nonsubjective factors mean that human factors only affect the selection of farmland areas, and the rest of the factors are naturally generated. Through data review and on-the-spot investigation, it is concluded that most of the landscapes of farmland parks are the planning methods of nonnatural farmland parks that can most stimulate the development of economic income. The above two forms of expression can also be combined with the local and regional culture based on the original landscape, without affecting the original custom and culture, to create the characteristic farmland landscape that the area should have.

Aquaculture parks are mainly oriented to production parks in rivers, ponds, and sea areas. They have inherent advantages. Through Internet +, with the continuous expansion of their scale, they have gradually become industrial park landscapes with unique characteristics and an essential part of the town [9]. The aquaculture landscape is also transformed from the traditional free-range method to the large-scale, ecological, and intensive method according to the connotation concept of the characteristic town. That is to say, we are gradually guiding and promoting the scale and diversification of aquaculture and strengthening water management. At the same time, it can have a particular viewing ability. The achievements have replaced the original aquaculture industry model using scientific and technological breeding technology. First of all, we can promote the multidimensional breeding model, add the traditional aquaculture production model to the economic and ecological breeding model, and establish a breeding method that can increase the income of the town, enhance the cultural characteristics, and scientifically utilize resources, such as artificial breeding of hairy crabs (Figure 5). Another example is the combination of lotus root and soft-shelled turtle, which can improve water quality while increasing the ornamental value (Figure 6).

6.2.7. Water Landscape

(1) *River. Plane.* The rivers within the scope of the characteristic tourist town in the north should consider factors such as water storage capacity, turbulence and gentleness, and water quality. According to statistics, most of the rivers in the northern characteristic towns are relatively gentle, and there is rarely a situation where the water element is turbulent. The water volume is too much [10]. Because when planning and designing at the plane level, priority is given to conforming to the original flow direction and route, modifying some areas, and expanding according to the actual situation to ensure smooth water flow, ecological stability, and visual aesthetics.



FIGURE 5: Hairy crab breeding base.



FIGURE 6: Coculture of lotus root and soft-shelled turtle.

Section. Section means that the bottom of the river will change with the change in the water level under the influence of geology, and there is a flexible contact space between the hard part along the river and the river. During planning and design, the water level is investigated and summarized, and the hydrophilic platform and coastal area are designed according to the actual situation. No matter how the water level changes, the use function and aesthetics of the water level are guaranteed as much as possible. At the cross section, an artificial ladder is set up, and aquatic plants are planted simultaneously to prevent tourists from feeling bored when viewing the waterscape, which can not only enrich the configuration of the coastal landscape but also prolong the service life of both sides of the river.

Revetment. In the river landscape planning and design, the revetment, the area with the highest utilization rate, is the primary design object [11]. The revetment is divided into two types: natural and artificial, and the natural revetment is divided into two types. One is to reinforce the revetment only by the adsorption of the plant to the soil, making the revetment more natural. The other is moderate human intervention. In addition to the functions of plants, the revetment is further strengthened using the existing local natural resources.



FIGURE 7: Landscape image of the original rural characteristic town.

River Derivative Zone. The ecological reserve area, the planning, and design of this area are significant to the ecological environment of the town. The town's local species configuration and ecological structure are analyzed and summarized, artificial components are minimized, wild and cluttered plants in the derivative belt of the river are adequately removed, and finally, a leisure space for tourists to watch is further established.

(2) *Pond.* In characteristic towns, in addition to ponds that can generate economic effects, there may also be natural ponds of different scales and shapes, all of which significantly contribute to the ecosystem. These ponds change the climate on a small scale and serve multiple functions. Restoration management of natural ponds should reduce manual intervention and leave room for free development. For the construction of artificial ponds, trees with high survivability can be planted appropriately to protect the existing vegetation growth space, to promote the pond to play its function better, and then enrich the plant types to make it more ornamental and regular.

(3) *Sea Area.* To develop tourism in the sea area, first of all, the proper restoration and protection of this area should be carried out, the garbage should be removed, and the waters should be kept clear [12]. The infrastructure is perfect, the beach is organized, and the influence of the sea area is improved. The overall planning needs to be unified if there is a sea aquaculture industry. The route planning problem of a chain of production, transportation, and sales will not be affected. The development of the tertiary industry will not only improve the local economy. The income can also be used to develop tourism through unique local products.

(4) *Nullah.* At present, open channels are usually divided into two types: complex state and peaceful state. Soft open channels are widely used in water-rich areas. The distribution of rivers in the north is relatively sparse, and the precipitation is not high, so the characteristic towns in the

north are more suitable for complex open channels, which can reduce water loss and increase the degree of sealing [13]. Regular maintenance is enough to enhance the open channel's size further and gradually develop it into an open channel ecological area. This can enhance the local ecological environment and ornamental.

7. Simulation and Analysis

A landscape image of the typical rural town is selected from the rural characteristic town landscape, the primary frequency is 4.2 GHz, the memory for a 4 GB computer, a comparative experiment between the literature method and the construction method of the 3D model of rural characteristic town landscape based on point cloud fusion and transformation was completed, and the C++ language was used as the simulation platform in the VS2018 environment. According to Figure 7, a landscape image of a rural characteristic town is selected in the experiment. The literature method and the construction method of the three-dimensional model of the rural characteristic town landscape based on point cloud fusion transformation are used to construct the three-dimensional image of the rural characteristic town landscape, as shown in Figures 8 and 9.

Figure 7 is a landscape image of a typical rural town. The image is used to compare the deep learning algorithm method and the point cloud fusion and transformation-based method for constructing a three-dimensional model of the rural characteristic town landscape to construct the three-dimensional image effect of the rural characteristic town landscape. Figure 8 is a three-dimensional map of the rural characteristic town landscape constructed using the deep learning algorithm [14]. It can be seen from the figure that the gray distribution of the image is uneven, the overall pattern of the rural characteristic town landscape is poorly integrated with the image points of the image, and the error is relatively high. Figure 9 is a three-dimensional map of rural characteristic town landscape constructed by constructing a three-dimensional model based on point cloud



FIGURE 8: Deep learning algorithm method to construct a three-dimensional map of rural characteristic town landscape.

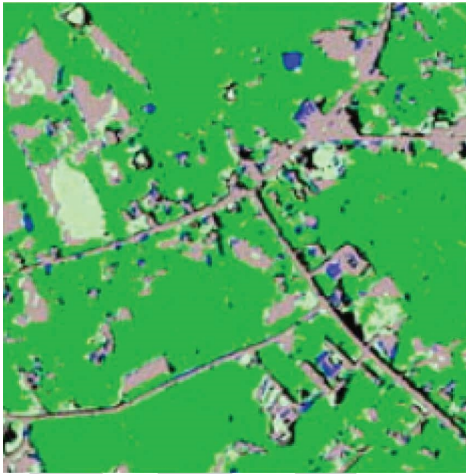


FIGURE 9: Method of point cloud fusion to construct a three-dimensional map of rural characteristic town landscape.

fusion transformation. It can be seen from the figure that the gray distribution of the image is relatively uniform, and the overall pattern of the rural characteristic town landscape is similar to that of the rural characteristic town landscape. The fusion degree of each pixel point of the image is good, and the error is small, indicating that the construction method of a 3D model of rural characteristic town landscape based on point cloud fusion transformation is better than the deep learning algorithm method to construct the 3D image of rural characteristic town landscape.

To further test the effectiveness of the proposed method, the registration results of different point cloud data calculated by the proposed method and the deep learning algorithm method [15–19] are used for simulation. The registration time of the three-dimensional landscape model

TABLE 1: Registration time and convergence of the two methods on point cloud data.

SDJ	PZT		PZSL	
	WF	SF	WF	SF
4094	3.70526	1.17895	0.01214	0.01202
16829	26.66737	7.70526	0.01193	0.01179
39639	64.94632	19.73684	0.01226	0.01181

construction method and the convergence of the registration results are compared in Table 1. Let SDJ denote point cloud data. PZT stands for registration time. PZSL represents the convergence of registration results. WF stands for deep learning algorithm method. SF represents the construction method of a 3D model of rural characteristic town landscape area based on point cloud fusion transformation.

It can be seen from Table 1 that when the cloud point data continue to improve, the registration time of the deep learning algorithm method and the proposed method is constantly rising, and the time used by the deep learning algorithm method is higher than that of the proposed method, which proves the registration time of the proposed method [20–25]. The proposed method is more efficient methods than deep learning algorithms. When the cloud point data registration results of the deep learning algorithm method [26–29] and the proposed method are obtained, and the cloud point data are continuously improved, the convergence of the proposed method's cloud point data registration results is lower than that of the deep learning algorithm method. It is proved that the convergence of the proposed method is better than that of the deep learning algorithm method. It also shows that the proposed method can reduce the redundancy of the construction data of the three-dimensional model of the rural characteristic town landscape, reduce the complexity of the three-dimensional model construction method, and improve the characteristic rural town and landscape 3D model building speed. A method for constructing a three-dimensional model of rural characteristic town landscape based on point cloud fusion transformation is proposed. The experimental comparison with the deep learning algorithm method proves that this method can improve the degree of fusion and reduce the error. At the same time, the algorithm can improve the registration time and convergence and the construction speed of the 3D model of rural characteristic town landscapes.

8. Conclusion

With the rapid development of modern science and technology, due to the influence of urbanization and ecological environment changes, a method for constructing a three-dimensional model of rural characteristic town landscape based on point cloud fusion and transformation is proposed. The minimum function of fusion transformation is used to calculate the 3D translation transformation amount, the rotation matrix, and the 3D model's scaling factor of the 3D

model. The 3D model of the rural characteristic town landscape area is converted and constructed. The 3D model of the rural characteristic town landscape area is completed. It is proved by simulation that the proposed method can enhance the degree of fusion, reduce the error, and improve the construction rate of the 3D model of the rural characteristic town landscape.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Retraction

Retracted: Evaluation of Physical Education Teaching Effect Based on Big Data

Mathematical Problems in Engineering

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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] X. Shu, Q. Wang, H. Tang, and Y. Ge, "Evaluation of Physical Education Teaching Effect Based on Big Data," *Mathematical Problems in Engineering*, vol. 2022, Article ID 7329334, 9 pages, 2022.

Research Article

Evaluation of Physical Education Teaching Effect Based on Big Data

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In order to provide a new vision and a broad idea for the evaluation of physical education in colleges and universities, a physical education teaching effect evaluation system based on big data is proposed. This study uses the method of a questionnaire survey to understand the problems encountered in the current sports evaluation of a college in China and to determine the evaluation index and its weight coefficient of college sports. The foundation of big data applications is mainly used for the establishment of college sports evaluation. The results showed that 50 percent of physical education teachers and 44.2 percent of students thought physical education examination was unnecessary, while only 16.67 percent of physical education teachers and 24.2 percent of students thought it was necessary. However, 90 percent of physical education teachers and 90.4 percent of students think school physical education evaluation is very important. At the same time, 63.33% of P.E. teachers think that the evaluation of the college P.E. curriculum is not enough and there is no responsibility. At present, there are many problems in the evaluation of physical education courses in colleges and universities, such as the curriculum, model, and scale being simple and unclear, the process is not scientific, there being no good model, and the guarantee mechanism is not good. It is concluded that the current evaluation of physical education in colleges and universities in this province has many problems, such as single subject and model, simple and fuzzy index, unscientific method, lack of individuality in the standard, imperfect guarantee mechanism, and imperfect feedback mechanism.

1. Introduction

Evaluation is an important intervention method to carry out a teaching activity and an important factor influencing educational development and reform. Scientific and effective evaluation of classroom teaching is the basic guarantee of cultivating sports talents with moral education. In early 2020, COVID-19 occurred in Wuhan City, Hubei Province, and many other places. This serious public health security crisis quickly spread to the whole country, causing a serious crisis in the health of the general public. In order to overcome the crisis and hold the teaching time, the Ministry of Education has requested to delay the opening of schools in all primary and secondary schools in China and take various precautions. In this case, online learning effectively integrates physical education in schools while being alone to

support teaching students at home. With the development of science and technology, network education has become an important part of a college education. For network education to develop rapidly in the new era, appropriate educational measures should influence the development and guidance of education. After “Internet Plus,” the evaluation of physical training in public universities still faces new challenges. How to perfect the network education mode and improve the value of network physical education is an urgent problem to be solved. Therefore, the development of online education in colleges and universities ensures the quality and content of education, breaks down the process and content, and satisfies students and teachers to use advanced skills and technologies. As the curriculum is constantly being updated, the evaluation content of the physical education courses should be kept up to date. At the same time, with the

deepening of education, some of the problems of existing education are gradually revealed. It is an important tool for measuring the progress and overall results of the training and is a good evaluation of the training [1]. It can not only show the physical education teachers' advantages and disadvantages in teaching but also identify the students' learning shortcomings. It is of great help to improve the teaching level of physical education teachers in colleges and universities and improve the academic performance of students [2]. However, in many colleges and universities, public PE classes are evaluated based on daily test scores. Not only does this not provide good advice for research, but also hinders research. Figure 1 is a summary of the research evaluation based on big data analytics.

Promote the sports community set up community classes to promote the better development of the sports community. Network courses and network courses make the content of college physical education rich and diverse. Formulate new measures to provide ideas for the reform of physical education. It provides a clear understanding of teaching and public education. It plays an important role in the training of school teachers and students. He supervised the work of the teachers and the success of the students. To be successful in physical education in colleges and universities, we must evaluate teaching skills, and encourage teaching quality and excellent teachers. Therefore, assessment is very important for course adherence and learning outcomes [3]. Effectively carry out content evaluation as teaching guidance. Take the evaluation content of development as the work of the instructor. The educational research has enriched and expanded the theory of public sports in Chinese universities and the new information and development have provided new ideas to improve the quality of teaching in Chinese universities.

2. Literature Review

Lv and Li believed that the evaluation content of classroom teaching effect included four parts: exercise load, psychological load, mastering the three bases, and ideological education, with corresponding weights of 0.3, 0.3, 0.3, and 0.1, respectively. Among them, the subindexes of exercise load were the average heart rate of the whole class and the practice density of the whole class, and the subindexes of mental load were students' attention, classroom emotion, and practice consciousness [4]. Khan et al. The development of students' intellectual skills, theoretical accumulator, and physical fitness are considered important points that show the effectiveness of physical education. He believes that the traditional methods of measuring the effectiveness of physical education based on the knowledge of teachers are not objective and quantitative and are not suitable for evaluating the effectiveness of studying the body [5]. Duan et al. in order to determine the quality of physical education evaluation from two factors, such as the influence of physical education teachers in the classroom and the learning of students, used two methods of evaluation general assessment of SPA. The content of the student's physical education assessment includes knowledge of physical education,

sports, sports, sports, various skills, and so on [6]. Lee and Park constructed the evaluation index system of physical education teaching effect in middle schools from three types of middle schools with different regional characteristics: urban, town, and rural middle schools. The subordinate indicators of student performance included the students' learning ability, self-expression, sports knowledge and skills of application ability, learning effects (gains in knowledge and skills, physical fitness, emotional attitudes, and values), evaluation ability, protection and help, learning time, cooperation spirit, learning mood and goal achievement [7]. Li et al. Using the Delphi method, an evaluation was made to evaluate the quality of physical education in colleges and universities, and then, using the analytic hierarchy process (AHP) and the standard fuzzy math, a value is assigned to each parameter and an evaluation model is determined. A quantitative tool for evaluating physical performance [8]. Zhao and Zhao The evaluation of the quality of the physical education of colleges and universities in Guangxi Province was used from the perspective of teaching activities, and the weight of each index was given, and the rating scale is determined with a total of 100 points. Then, the effectiveness of physical education was evaluated by measuring four levels [9]. Wang et al. believed the first level index of the evaluation index system included theoretical knowledge of sports, sports skills, physical constitution, physical and mental experience, and sports participation. The theoretical knowledge of physical education included three secondary indicators: physiological and biochemical knowledge, technical key knowledge, and fitness knowledge. Motor skills included two secondary indicators: individual and team motor skills. The physical constitution includes three secondary indicators: body shape, basic physical quality, and functional level. The secondary indicators of psychosomatic experience included active intelligence and psychological and physical experience. Sports participation included three second-level indicators: the enthusiasm for activity participation, the degree of activity participation, and the creativity of activity participation [10]. Tarraga-Minguez et al. thought from the angle of students, believing that the evaluation index system should include the sports participation (strength, density, and strength index), students' psychological (self-esteem, self-confidence, the spirit of competition, and regulation of emotions), social (mutual cooperation and respect, love), motor skills (students progress degree), and students' learning interest [11]. Chen et al. investigated high school physical education teachers through questionnaire surveys and interviews and found that there were problems in sports participation, sports skills, mental health, social adaptation, and other aspects. The evaluation methods are teacher evaluation and self-evaluation, lacking the link of mutual evaluation among students, and the evaluation subject is not comprehensive [12]. In the process of PE teaching in the network environment, students complete the content they are good at in free space, and upload their homework in the form of a video report according to the standard requirements put forward by the teacher. Students can choose to submit the video content that they are most satisfied with among the multiple

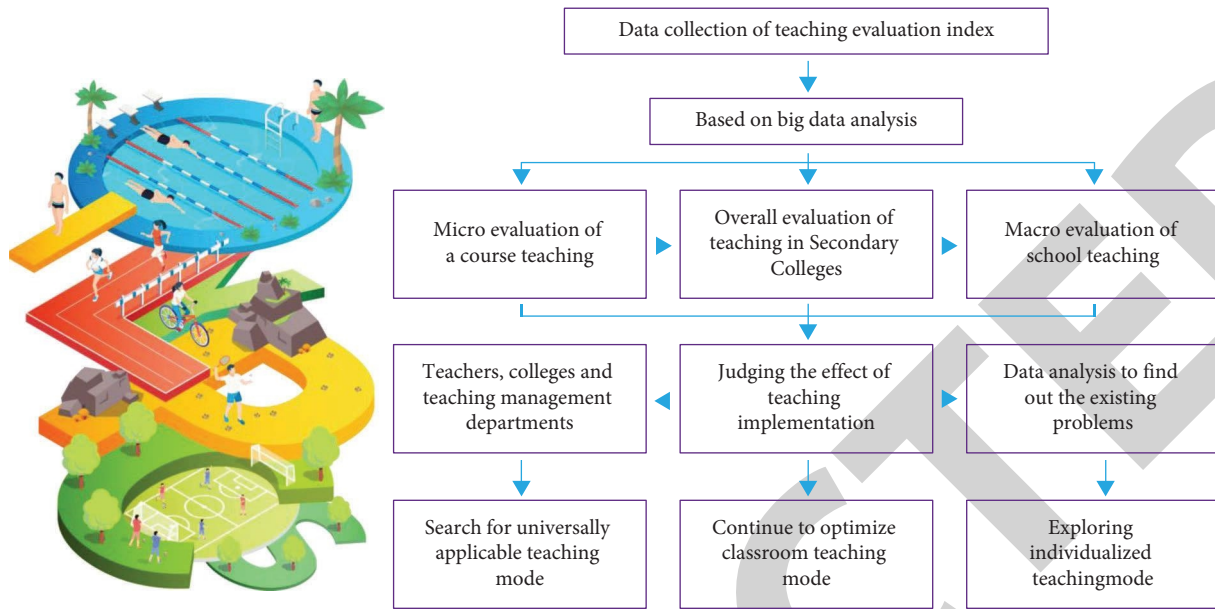


FIGURE 1: Research on the teaching evaluation system based on big data analysis.

recorded videos. Through online comments, teachers repeatedly play and watch students submit assignments, it allows students to evaluate their learning more objectively and effectively, provide feedback and exchange in time, build relationships between teachers and students, and improve student autonomy.

3. Research Methods

3.1. The Development Trend from the Traditional PE Teaching Evaluation to Internet + PE Teaching Evaluation. With the rapid development of the Internet and information technology, the concept of modern information development has penetrated deeply into people's minds, has had a great impact on pre-physical education assessment standards, and has encouraged changes in assessment materials. Physical activity in the data-rich world, physical education evaluation data, together with smart data and the latest technology, are gradually removing the limitations of time and space, creating opportunities for face-to-face teaching between teachers and students, and creating evaluations (see Table 1) [13]. Assessment in physical education differs from other subjects in that it has a positive effect on physical education. Therefore, the evaluation of physical education in the environment of "Internet + education" should not only be used for the application of other subjects, but also identify and distinguish the contrary, pay attention to the person's characteristics of physical development, and understand its characteristics. Strengthen the relationship between physical participation, the characteristics of their studies, and "Internet + education."

In the process of PE teaching in the network environment, students complete the content they are good at in free space, and upload their homework in the form of a video report according to the standard requirements put forward by the teacher. Students can choose to submit the video content that they are most satisfied with among the multiple

recorded videos. Through online comments, teachers repeatedly play and watch students submit assignments, it allows students to evaluate their learning more objectively and effectively, provide feedback and exchange in time, build relationships between teachers and students, and improve student autonomy [14].

3.2. Exploration of the Evaluation Form of "Internet + Physical Education". "Internet Plus" will support sports reform measures. Internet technology is the driving force that pushes human progress to a new level. In terms of educational evaluation, "Internet Plus" will promote new evaluations in terms of evaluation tools and evaluations. The combination of online assessment and physical assessment is a new direction of assessment research and development. In "Internet Plus," this will ensure the effectiveness of training and promote objective and fair evaluation [15]. At the same time, "Internet + Sports evaluation" lists many teaching methods, and the defects of the evaluation methods have been reformed.

The new theory of the development of modern information technology combines physical learning and measurement techniques, especially physical learning and data analysis techniques technology will play a greater role. Internet + sports assessment has broken the traditional sports assessment method and provided a new way for physical education teaching. He knows the latest fitness tools and uses all modern science and technology to help teach physical education. Internet + physical examination, with its new basis and research, has promoted the development of previous physical examination methods, making physical examination play an important role in product evaluation.

Understanding the knowledge processes of sports, such as teacher-student interaction, based on information from the use of sports can facilitate online learning, which enables the rapid and easy development of information security measures.

TABLE 1: The traditional physical education evaluation combined with the “Internet +” characteristic attribute table.

No.	Type	Characteristics
1	Evaluation content	Students can use online resources to participate in PE teaching evaluation, which strengthens the quality of teachers’ and students’ PE teaching evaluation.
2	Evaluation means	The evaluation method is more flexible and diversified, and the evaluation effect is greatly improved.
3	Evaluation method	The continuous development of the school network innovation information technology helps physical education assessment to support various improvements and improvements, and enable teachers and students to nice physical examinations.

3.3. *Research Objects.* In the framework of the big data application, the evaluation of the physics class of the country is taken as a research object, and the evaluation of the course of the school organization text is created by the rules.

3.3.1. *Current Situation Questionnaire.* The present situation of physical health evaluation of physical education teachers and students in 5 colleges and universities was studied and evaluated based on the content of physical education assessment in college. Six physical education teachers were selected from each school, and more than 60 teachers were examined by the teacher survey. Since there are no junior or senior students, 200 and 100 students are selected from each school, including the number of male and female students and the ratio of male and female students. First-year students are not aware of the special conditions of physical education, so only second-year students are trained.

The content and returns of the status questionnaire are shown in Table 2.

(1) *Validity Test.* As part of the research, 20 experts in physical education were asked to verify the validity of the questionnaire. Table 3 shows that 70% of experts believe that the question is appropriate, and 30% believe that it is necessary. Therefore, the questionnaire on the current problem is generally accepted by experts and has good use.

(2) *Reliability Test.* Test-retest reliability is used to assess the overall reliability of the questionnaire. 5 teacher and 10 student records were distributed 15 days apart. From SPSS’s “Kappa” coefficient of consistency, once the coefficient of the questionnaire is 0.864 [16].

Kappa coefficient is calculated by the following Formula (1).

$$K = \frac{P_o - P_e}{1 - P_e}. \quad (1)$$

In Formula (1), $P_o = \sum A_{ii}/N$, $P_e = \sum a_i b_i / N$, $a_i = A_i/N$, $b_i = B_i/N$. P_o and P_e are the observed concordance rate and the expected concordance rate of the two test results respectively. $P_o - P_e$ is the actual consistency rate. $1 - P_e$ is the undesired consistency rate. A_{ii} is the actual value on the main diagonal in the $C \times C$ contingency table. A_i and B_i are the marginal values of the i th row and the i th column respectively. a_i and b_i are the marginal frequencies in the i th row and the i th column, respectively. Since the expected consistency rate is the expected consistency under the assumption that the two tests are independent, it is calculated according to the multiplication theorem of probability.

3.3.2. *Index Questionnaire and Index Weight Advisory Table.* The body weight measurement scale and body weight scale of colleges and universities were determined by comparing with 22 physical education experts.

(1) *Content Design.* Based on the current state of physical examination in college, interviews with experts, related documents, evaluation statements, and serious questions for teachers the flesh, and the students are put together [17]. In the physical education principal evaluation form, there are 3 indicators at the first level and 14 indicators at the second level.

(2) *Distribution and Collection.* In the research, two rounds of questionnaires are distributed, and the distribution and recovery of questionnaires are shown in Table 4.

(3) *Questionnaire Operation Procedure.* First, the evaluation index table of the first round is distributed, and data statistical analysis is carried out after the collection. According to the suggestions of experts, indicators that needed to be added or deleted are counted, and a new evaluation index table is formed for the second distribution [18].

Second, the second round of consultation forms is issued and collected. The results show that the opinions of all the experts are consistent.

4. Result Analysis

4.1. *Analysis of the Current Situation of Physical Education Evaluation in Colleges and Universities.* In general, 50% of physical education teachers and 44.2% of students think the current physical examination is not necessary, only 16.67% of physical education teachers and 24.2% of students think it is necessary, but 90% of physical education teachers think skin is necessary. 90.4 percent thought that school physical examination was very important. This paper investigates physical education teachers and students in a college in Shanxi Province.

4.1.1. Analysis of the Current Situation of Physical Education Teachers’ Teaching Evaluation

(1) *Evaluation Subject and Mode.* In Tables 5 and 6 below, the assessment content is mainly the assessment of students and tutors, and the type of assessment is mainly the assessment of cadres and students.

TABLE 2: Distribution and recovery statistics of questionnaire survey.

	Distribution (copy)	Recovery (copy)	Valid (copy)	Recovery rate (%)	Valid rate (%)
Physical education teachers	60	60	60	100	100
Students	1000	1000	1000	100	100

TABLE 3: Statistical table of the validity of the status quo questionnaire (N = 10).

The questionnaire items	Reasonable	Basically reasonable	Unreasonable
Number of expert questionnaires	14	6	0
Proportion	71%	29%	0

TABLE 4: Statistical Table of distribution and recovery (N = 22).

The questionnaire items	Number of the distributed questionnaires	Number of the collected questionnaires	The recovery rate (%)	Number of valid questionnaires	Valid rate (%)
The first round	22	22	100	22	100
The second round	22	22	90.92	22	100

TABLE 5: Evaluation subjects (N = 30).

Evaluation subjects	The personnel in charge	Fellow teachers	Students	The teacher	Unknown
The number	30	10	36	2	4
The proportion	50%	16.67%	60%	3.33%	6.67%

TABLE 6: Evaluation model (N = 30).

Evaluation model	The superior evaluate the subordinate	Peer evaluation	Students evaluation	Self-evaluation	Unknown
Number	30	14	34	6	2
Proportion	50%	23.33%	56.67%	10%	3.33%

TABLE 7: Evaluation content.

Evaluation content	Number of teachers (N = 60)	Ratio (%)	Number of students (N = 1000)	Ratio(N = 60)
The teacher's attitude towards teaching	28	46.67	884	88.40
The teaching methods of teachers	26	43.33	788	78.80
The teaching effect of teachers	26	43.33	556	55.60
Teacher's motor skill ability	14	23.33	702	70.20
The creative ability of teachers	20	33.33	370	37
Teachers' scientific research ability	18	30	72	7.20
The moral level of teachers	26	43.33	382	38.20
The classroom atmosphere	2	3.33	50	5
The level of student involvement	2	3.33	22	2.20
Unknown	4	6.67	10	1

(2) *Evaluation Content.* As can be seen from Table 7, in the evaluation of physical education teachers, teachers' attitude, teaching, motor skills, ethics, and leadership are often remunerated, while physical education teachers' ability, teaching and research ability are negligible, student participation, and classroom atmosphere [19, 20].

(3) *Feedback.* A questionnaire survey was conducted among 60 physical education teachers and repeated voting was conducted according to the results. From the content of the

discussion (as shown in Table 8), 53.33% of the P.E. teachers did not know the specific content of the discussion, so more than half of the P.E. teachers did not know the concept of evaluation and feedback. With regard to meeting times (as shown in Table 9), meeting times are usually at the beginning of a new period and sometime later (semester). Therefore, the lack of timely feedback is the reason why most PE teachers do not listen to feedback. In terms of feedback methods, the most common feedback methods are personal discussion, whiteboard and written feedback, and feedback strategies such as normal and closed feedback network. In

TABLE 8: Feedback content ($N=60$).

Feedback content	The grades of the classes taught	Strengths and weaknesses demonstrated during the work	Suggestions for improvement	Expectations and encouragement	Unknown
Number	10	12	10	4	32
Proportion	16.67%	20%	16.67%	6.67%	53.33%

TABLE 9: Feedback timing ($N=60$).

Feedback timing	Direct feedback after evaluation	Feedback after some time	Feedback in the new term	Unknown
Number	0	24	34	2
Proportion	0	40%	56.67%	3.33%

TABLE 10: Feedback mode ($N=60$).

Feedback mode	Online feedback	Written feedback	Feedback in private	The bulletin board	Unknown
Number	6	14	34	18	2
Proportion	10%	23.33%	56.67%	30%	3.33%

TABLE 11: Evaluation subjects ($N=60$).

Evaluation subjects	School related leaders	Physical education teachers	Students themselves	Classmates	Unknown
Number	0	50	6	0	10
Proportion	0	83.33%	10%	0	16.67%

TABLE 12: Evaluation mode ($N=60$).

Evaluation mode	The superior evaluate the subordinate	The student's evaluation	Self-evaluation	Unknown
Number	52	0	6	8
Proportion	86.67%	0	10%	13.33%

order to enable physical education teachers to prioritize the benefits of psychological counseling, it should be more open (see Table 10).

4.1.2. Analysis of the Current Situation of Students' Physical Education Evaluation

(1) *Evaluation Subject and Mode.* Tables 11 and 12 show that physical education teachers are the most important evaluation, and the highest evaluation is the most important type of evaluation, and the students' respect for self is ignored. Therefore, when evaluating the physical education of students, the problems of classmates and self-esteem are ignored.

(2) *Evaluation Content.* As can be seen from Table 13, the content of students' physical education evaluation mainly focuses on sports knowledge, sports skills, academic skills, physical education, and other aspects, while ignoring the evaluation of students' new ability, interest in sports, mental health, and other aspects. As a result, the content of the evaluation focuses too much on the specific content and ignores the differences between students.

(3) *Evaluation Methods.* In terms of assessment methods (as shown in Table 14 and Figure 2), summative assessment is specifically introduced, ignoring individual progress of

education at all levels. Second, quantitative assessment is emphasized, while qualitative assessment is ignored, which lacks the flexibility and strength of evaluation and does not support the development of students.

(4) *Feedback.* According to the research results, 5 colleges and universities voted on the evaluation results after evaluating the physical education teaching of students. From the input content (Table 15), the main content is student sports. Physical education scores include physical fitness tests, emotional intelligence, and skills, games, and performance in regular classes. As a result, the content of feedback is inconsistent and it is difficult for students to see their strengths and weaknesses in the feedback (as shown in Table 16). The results of students' evaluation of physical education teaching in 5 schools mainly come from network feedback.

To sum up, the evaluation of college physical education courses usually involves the following questions. First, the meaning of evaluation is the same as the type of evaluation. The key point of physical education teacher effectiveness evaluation is staff evaluation and student evaluation. The assessment model is still based on top-level assessment and ignores the opportunity for students to self-assess. Second, the evaluation content is simple and vague. First, the evaluation of all schools, including different majors, is the same, regardless of the characteristics of different activities, majors, and classes. Second, there

TABLE 13: Evaluation content ($N = 60$).

Evaluation content	The number of teachers	Proportion (%)
Physical quality	22	36.67
Motor skills	36	60
Sports participation	12	20
Classroom performance	32	53.33
Theoretical knowledge of physical education	38	63.33
Mental health level	4	6.67
Interest in sport	4	6.67
The innovation ability	2	3.33
Learning attitude	14	23.33
Unknown	4	6.67

TABLE 14: Evaluation methods ($N = 60$).

Evaluation results	Diagnostic evaluation	Formative evaluation	Summative evaluation	Quantitative evaluation	Qualitative evaluation	Unknown
Number	2	8	44	40	10	8
Proportion	3.33%	13.33%	73.33%	66.67%	16.67%	13.33%

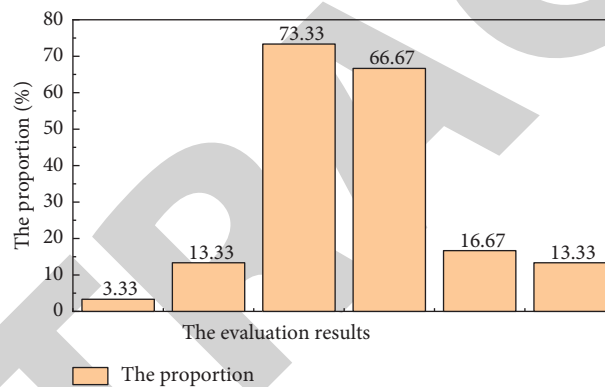


FIGURE 2: The proportion of evaluation methods.

TABLE 15: Feedback content.

Feedback content	Number of teachers ($N = 60$)	Ratio (%)	Number of students ($N = 1000$)	Ratio (%)
Sports scores	50	83.30	918	91.80
Advantages and disadvantages of learning	8	13.33	86	8.60
Suggestions for improvement in the new term	4	6.67	42	4.20
Expectations and encouragement	4	6.67	38	3.80
Unknown	10	16.67	82	8.20

TABLE 16: Feedback timing.

Feedback timing	Number of teachers ($N = 60$)	Ratio (%)	Number of students ($N = 1000$)	Ratio (%)
Feedback to the students directly after the evaluation	4	6.67	38	3.80
Feedback to students over time	22	36.67	312	31.20
Feedback to students at the beginning of the new term	24	40	584	58.40
Unknown	10	16.67	66	6.60

are no appropriate indicators for all parts of the physical activity process. Evaluation is often presented as a first-stage evaluation, ignoring individual progress at all levels of education. Second, the emphasis on quantitative

evaluation, neglects qualitative evaluation. Finally, the safety mechanism is not perfect, the investment mechanism is not perfect. Football evaluations and career counseling do not do it all.

4.2. Characteristics and Principles of the Construction of the Physical Education Evaluation System in Colleges and Universities under the Background of Big Data Application

4.2.1. *Characteristics of College Physical Education Evaluation System Construction.* Starting from the main purpose of using big data, the following characteristics of college sports evaluation are summarized.

First, the different measures are based on experience and evidence. In traditional sports evaluation, the evaluation of students is usually based on the student's athletic performance, while the coach's evaluation is based on personal opinion, so it is more effective than objective evaluation. Physical education teachers and students can collect sports content from big data and evaluate it accordingly to have a better understanding and accuracy of sports.

Second, the evaluation method is holistic rather than quantitative. At present, physical education examination in colleges and universities is very important, but it does not affect the physical quality of students and professionals at all levels. The evaluation combines the evaluation process with the evaluation process and introduces the evaluation process that balances the result and the process.

The third is the content of the evaluation, from single evaluation to multiple evaluations. The difference between the measurement points is the difference between the measurement points. For example, when assessing physical education instruction to students, it is important not only to measure strength, motor knowledge, and physical ability but also to learn behaviors, skills, and movements.

Fourth is the evaluation tool from product evaluation to intelligent evaluation. Manual testing is time-consuming and error-prone. Intelligent assessment is simple, fast, and accurate. Therefore, the tools of college sports measurement should be changed from data collection, statistics, and analysis to writing, doing more, and reviewing more.

Fifth, the evaluation suggested from closed to open. The data collected from big data are processed and analyzed, and the results are presented to physical education teachers and students, which can help teachers and students clearly understand the work and monitoring usage in physical education classrooms.

4.2.2. Principles for Constructing the Evaluation System of Physical Education in Colleges and Universities

(1) *Research and Objective Details.* Based on the size and characteristics of The Times newspaper, based on policies and practices, research evaluation and goals for higher education and school bodies are created. For example, when selecting measurement methods, research should be carried out according to the collected data and appropriate methods should be selected, so as to ensure the effectiveness of science and the purpose of the technological process.

(2) *The Principle of Success and Perfection.* In other words, the establishment of a college physical education evaluation system, the selection of evaluation system should be multifaceted, can not be repeated, must have a design, must have universality, and must be able to reflect all the systems of the body.

(3) *The Principle of Rationality and the Principle of Judicial Rationality.* Validity refers to the effectiveness and efficiency of PE assessment, and validity refers to the verification of the accuracy and effectiveness of the assessment criteria.

5. Conclusion

The sources of college sports evaluation include physical education teachers, students, peers, athletes, and other big data sources. The sports coaches were evaluated by self-evaluation, student evaluation, peer evaluation, and staff evaluation. The process of "individual assessment, group assessment, and teacher assessment" was introduced to the students. The evaluation scale includes the physical education teacher evaluation scale and student evaluation scale. This study discusses the model of health physical examination in colleges and universities to provide a reference for the reform of health physical examination in colleges and universities, but it is still in short supply. Due to the limitation of performance, it is not enough to only select sports indicators in big data. Therefore, the conclusion of this paper may have some limitations and deficiencies. And the empirical research is not carried out, it still needs further investigation and study in the future. It is suggested that physical education should be summarized, supplemented, and perfected in the future.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis and Evaluation of Engineering Job Demand Based on Big Data Technology

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This paper carried out an analysis and evaluation research of engineering job demand based on big data technology. By collecting the semistructured or unstructured recruitment information of engineering positions on the recruitment website, text mining technology is used to mine the knowledge model hidden in the market by building a relatively perfect Dictionary of professional skills of engineering positions. Based on the large sample data, a comprehensive, multidimensional and high-precision post-demand characteristic model is constructed. The model can not only interpret the existing recruitment market and elaborate the specific skill needs of different positions but also predict and analyze the model and estimate the required skills in combination with the specific postresponsibility characteristics, which can not only enable candidates to submit resumes reasonably, Moreover, it provides suggestions for colleges and universities or other relevant employment institutions to have an accurate, comprehensive and in-depth insight into market demand and carry out effective talent training for all units. Through the analysis of the experimental results, it is proved that the established engineering postdemand analysis model is consistent with the actual situation, and has certain explanatory significance for the current economic and social recruitment phenomenon, and the model has reference value.

1. Introduction

1.1. Research Background. Since the 21st century, the country has paid more and more attention to the cultivation of talents and has invested more and more in education. People have also paid more attention to the improvement of their own and the cultural level of the next generation, which has led to the continuous expansion of the enrollment scale of colleges and Universities [1–4]. In recent years, the number of graduates in the country has increased linearly. These phenomena have resulted in an increasing number of people waiting for employment, but the employment positions are limited and becoming saturated, The employment situation is getting more and more serious [5–7]. Therefore, it is very necessary to carry out the research of engineering job demand analysis and evaluation.

Nowadays, online recruitment has become the most popular recruitment method in the talent recruitment department of enterprises [8–13]. Online recruitment is not limited by time and space and has low cost and fast

efficiency. Enterprises only need to publish recruitment information in the web page, which can be seen by candidates all over the world, covering a huge area.

Online recruitment announcements contain a large amount of text information. Generally speaking, the recruitment information includes the job description, responsibility requirements, salary and welfare, and other recruitment related information provided by the enterprise, as well as the enterprise capital injection, business operation, enterprise scale, workplace, and other information [12, 13]. However, these information are in the form of text in the web page, which basically belongs to the unstructured or semistructured form, The traditional statistical analysis method for structured data is not suitable.

1.2. Research Meaning. Based on the knowledge of computer, statistics, informatics, and other disciplines, this paper comprehensively uses statistical analysis, text mining, machine learning, and other methods to mine the job

recruitment information of engineering job, aiming to find out the hidden related information from the extracted demand characteristics, and further expand the application of text mining technology in real life.

From the perspective of research methods, the data studied in this paper is from online recruitment data, which is different from the data obtained by single research and questionnaire survey. The data obtained from the online recruitment website is that the recruitment enterprises are located in all major provinces in China, covering all enterprise sizes, from private enterprises with dozens of people to state-owned enterprises and listed companies with hundreds of thousands of employees. The enterprise field involves all aspects. It completely makes up for the one-sided conclusion brought by the simple questionnaire survey. Secondly, this paper uses Chinese text mining technology to intelligently and efficiently extract key feature words from a large number of recruitment information, which greatly saves the cost and time of manual coding and analysis.

From the research results, this paper uses Chinese text mining technology to mine and analyze the demand characteristics of recruitment information. From the results, we can get the corresponding conclusions: for colleges and universities, on the one hand, the training plan for specific majors should be formulated in combination with the real talent demand of the market and the teaching advantages of colleges and universities, so as to provide a reference for cultivating all-round and high-quality applied talents, on the other hand, The school can set up a special employment department to pay attention to the recruitment information in the society at any time. Once there is a position suitable for students to apply, the employment information will be forwarded to students in time so that students can more accurately locate their employment direction; for students, in the face of massive recruitment information, students can quickly locate key information, find their own suitable positions for application, and consciously cultivate their professional qualities in daily learning and life, aiming at a certain type of enterprise or a specific position in advance; for enterprises, making recruitment announcements based on job requirements will be more conducive to the delivery of resumes by suitable candidates, and enterprises can also recruit qualified talents.

2. Related Theory and Technology

2.1. Text Mining Definition. Text mining involves a wide range of fields. According to different knowledge structure systems and research directions, scholars' understanding and definition of text mining will be different, and the core technologies in various fields are also different. However, generally speaking, the definitions proposed by experts in any field are basically interpreted on the basis of text data, text information, and text knowledge definitions. Text data is composed of natural language text sets that people can understand but can not be fully used, so text data also has the fuzziness and ambiguity of language itself; text information refers to the processing of text data through some methods and means, encoding the data into a set of formatted data

that can be recognized by the computer, which is structured and unambiguous; Text knowledge refers to extracting useful knowledge or models from text data.

Big data technology [13–15] can provide a reliable tool for this study. Based on the definitions of text data, text information and text knowledge [16–20], this paper summarizes the definition of text mining. Text mining refers to the process of extracting knowledge structures that are unknown in advance, but in fact are potential, and can also be extracted, utilized, and understood from a large number of text data. Of course, text data exists in the form of unstructured or semistructured, so text mining can be seen as an extension of traditional data mining in text information processing.

2.2. Text Mining Process. The premise of the text mining process [21–25] is to collect text data with research value and significance and start text mining after cleaning and sorting out the “impurities” in the text data. Figure 1 below is a typical whole process of text mining.

2.2.1. Text Collection. This stage is mainly to collect, mine, and sort out the text data to be studied by the task. Data is displayed in the form of text, that is, most of them exist in semistructured or unstructured form. There are various forms of text collection. The simplest form is to copy and paste existing content to create text data, but in most cases, the object of research will be in the web page. For the data that exists on the web page, you can use a crawler to obtain it, use search engine technology to retrieve the required information, analyze web page elements and structures, grab data through web crawler technology, and establish a text database for research. However, there will be some irrelevant information in web pages, such as navigation, advertising, copyright, and other content, which is commonly referred to as “noise.” Before crawling data, it is necessary to set certain text extraction rules, which play an important role in purifying data. Through the setting of rules, useful information is retained, and unimportant disturbing information is discarded, so as to achieve the purpose of purifying data.

2.2.2. Chinese/English Word Segmentation. Because text mining technology [26–29] mainly deals with unstructured or semistructured text data, the existing traditional computer recognition methods are difficult to understand the semantics of the natural language, so the text data cannot be directly applied by computer after being collected, and appropriate processing should be carried out to extract metadata that can represent its characteristics, save it in a structured form, and form a text feature library. For English documents, stemming and lemmatization are required, and sometimes the two methods are directly referred to as stemming. Both of these methods are aimed at recognizing the transformation form of words to get the basic word form. However, there is still a certain difference between the two. The main purpose of stemming is to obtain word stems by using writing rules, while lemmatization is to obtain the

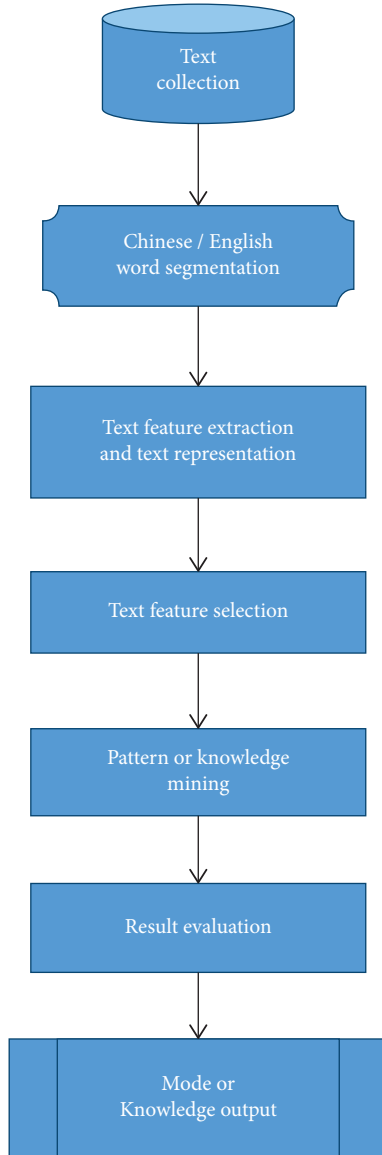


FIGURE 1: Typical whole process of text mining.

exact word form of words through complete morphological analysis with the help of dictionaries. English words have roots, and there are obvious spaces between words. On the contrary, as far as Chinese is concerned; there is no fixed spacer between words as in English, so certain word segmentation methods need to be used for word segmentation.

2.2.3. Text Feature Extraction and Text Representation. The text data processed by Chinese/English word segmentation technology is decomposed into a single feature word, with a huge vocabulary, but only some feature words are useful for text analysis, and some words have no meaning for the research content. Similar to the research in this paper, the main research is the job skills requirements of enterprises for job seekers, and the feature words describing the advantages and benefits of enterprises can be deleted. The deletion has no impact on the analysis results and can greatly

reduce the computing space and save costs. So far, researchers at home and abroad have proposed a variety of models to represent texts, including vector space model (VSM), probability model, N-gram model, and hybrid model.

2.2.4. Text Feature Selection. When the amount of data is large, the amount of feature word segmentation obtained also increases correspondingly. Using spatial vectors for representation can sometimes be as high as tens of thousands of dimensions, but such a large feature data set is not necessarily useful for the research and analysis process and even leads to a significant reduction in the efficiency of calculation. It is very beneficial to find text feature sets with low dimensions but little difference from the analysis results of the original data set. The text feature is a search process, the purpose of which is to find feature subsets that can represent the original data set but have much lower dimensions. Information gain, cross entropy, mutual information, word frequency method, document frequency method, statistics, and evidence weight are common methods for text feature selection.

2.2.5. Pattern or Knowledge Mining. After selecting the text features, we use appropriate analysis methods to mine knowledge and structural models for the obtained feature sets. Text classification, clustering, correlation analysis, association rule analysis, and so on are common text mining task methods.

2.2.6. Result Evaluation. The models or knowledge obtained are not all useful. Some models are not consistent with the actual situation and have little significance. Therefore, corresponding evaluation rules need to be used to judge which models are useful and which are not. Among them, precision and recall are the most common evaluation indicators.

2.2.7. Mode or Knowledge Output. This is the last step in the process of text mining. For the obtained model or knowledge output that meets the requirements.

2.3. Association Rule Technology

2.3.1. Association Rule Implementation Process. Association rule mining has now become one of the important technologies in the field of data mining. Correlation means that there is a certain law between the values of two or more variables. Data association is a kind of important, potential but discoverable knowledge in a database. The purpose of association rules is to find out the hidden association network in the database. For unstructured or semistructured text, after transforming it into structured text feature vectors in a certain way, we can find text frequent patterns or text association rules in large-scale text sets.

2.3.2. Apriori Algorithm. This paper uses the classical frequent itemset mining algorithm Apriori algorithm in traditional association rules to mine. This algorithm is the most influential Boolean association rule mining algorithm at present, and it is also the basic algorithm of most frequent itemset mining algorithms of width first search type.

3. Data Collection and Preprocessing

3.1. Results of Data Collection. The data in this article comes from three websites: Zhaopin Limited, 51job, and Lagou. Retrieved the positions of engineering job nationwide from the website; the text data fields include job title, company name, enterprise-scale, work location, enterprise nature, financing, salary, job description, and job requirements. The research object is the text data of 30,000 valid recruitment analyst positions I obtained from three professional websites.

3.2. Data Preprocessing

3.2.1. Data Cleaning. The text data obtained from web pages also contain a lot of “impurities;” for example, special symbols, useless numbers, etc.; sometimes, the same company will publish recruitment information on different websites simultaneously, and data duplication will occur. The overlapping text data needs to be cleared. In addition, some entries that are not meant for recruitment classification are also deleted. Similar to some companies, there are no specific requirements in the recruitment announcement for engineering job positions, just a simple introduction to the corporate culture. Such job postings are not helpful for us to capture the characteristic words of engineering job positions and must be deleted.

3.2.2. Chinese Word Participle. This paper uses the jieba tokenizer in R software for participle, where the participle engine uses a hybrid model. This model combines the advantages of the maximum probability method and the hidden Markov model, and the participle effect is better. Then, the keyword extraction technology based on the TF-IDF algorithm is used to obtain words with higher frequency in the text than in other texts, and such words are extracted as characteristic keywords.

Part of the participle results are listed as follows:

Before participle: job requirements: (1) more than three years of work experience, has experience in user growth, and engineering job is preferred; (2) have a relatively in-depth understanding of the Internet industry and have specific strategic thinking; (3) have more strong of team collaboration ability and communication ability, thinking active, and learning ability strong; (4) stable and meticulous, able to withstand certain work pressure; (5) proficient data warehouse; proficient in data query languages such as hive/SQL and statistical analysis software such as SAS/R; familiar with scripting languages such as Python/Shell; familiar with the Linux environment and common commands.

After participle: job/requirement/1./Three Years/More Than/Work/Experience/Has/Users/Growth/And/Data/Analytics/Experience/Is/Preferred/2./Hava/Internet/Industry/Hava/Comparison/In-depth/Understanding/Hava/Certain/of/Strategy/Thinking/3./Hava/More than/Strong/of/Team/Collaboration/Ability/And/Communication/Ability/Thinking/Active/Learning/Ability/Strong/4./Stable/Meticulous/Able to Withstand/Certain/Work/Pressure/5./Proficient/Data/Warehouse/Proficient/Hive/SQL/etc/Data/Query Language/And/SAS/R/etc/Statistics/Analysis/Software/Familiar/Python/Shell/etc/Scripting/Language/Familiar/Linux/Environment/and/Common Commands.

3.2.3. Text Stop Word Filtering. As seen from the above-given participle results, many words are not helpful for us to extract the feature words of engineering job positions. For example: of, have, who, right, and equivalent conjunctions, prepositions, auxiliary words, and other function words. Some words frequently appear in the text but do not affect the analysis results, such as job, requirement, or possess. After filtering by using stop words, the final participle results are as follows:

Three Years/More Than/Work/Experience/Has/Users/Growth/And/Data/Analytics/Experience/Is/Preferred/Hava/Internet/Industry/Hava/Comparison/In-depth/Understanding/Hava/Certain/of/Strategy/Thinking/Hava/More than/Strong/of/Team/Collaboration/Ability/And/Communication/Ability/Thinking/Active/Learning/Ability/Strong/Stable/Meticulous/Able to Withstand/Certain/Work/Pressure/Proficient/Data/Warehouse/Proficient/Hive/SQL/etc/Data/Query Language/And/SAS/R/etc/Statistics/Analysis/Software/Familiar/Python/Shell/etc/Scripting/Language/Familiar/Linux/Environment/and/Common Commands.

It can be seen from the above-given participle results that the text after participle has become a collection of words, which is conducive to quantitative analysis, but there are still unsatisfactory places. For example, “strategic thinking,” “teamwork ability,” and “communication ability” are a whole; once the split makes the subsequent feature extraction inaccurate. Therefore, a dictionary of professional skills in the field of engineering job is constructed in this paper. The dictionary is constructed by searching the professional catalogs in colleges and universities. And, the professional terms involved in the analysis and summary of the recruitment information are summarized and sorted to generate a dictionary. The obtained keywords can be further selected and refined through professional dictionaries to mine text features deeply.

4. Empirical Analysis of Engineering Job Demand

4.1. Distribution of Work Locations. After the feature extraction of the acquired text data, a statistical analysis of the geographic location of the recruiting unit was carried out. Figure 2 is distinguished by the different shades of color.

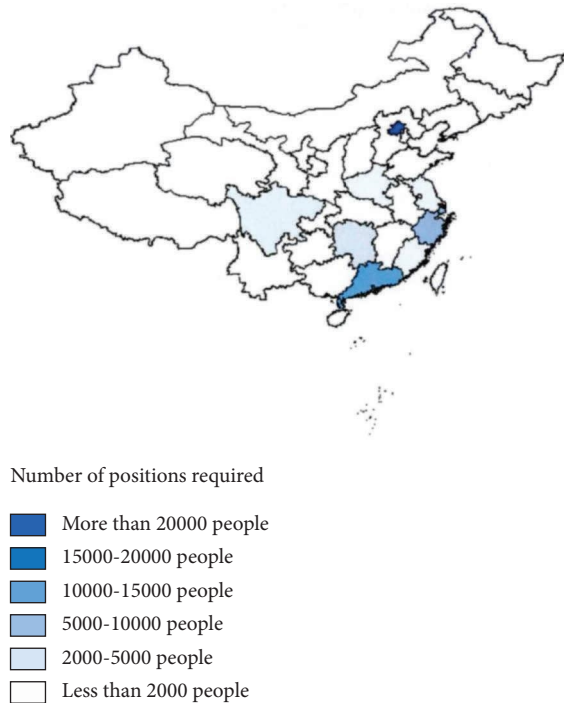


FIGURE 2: Map of the regional distribution of engineering job positions.

Provinces with darker colors indicate larger demand, while lighter provinces have smaller demand to show the demand for an engineering job in different provinces. Overall, engineering job positions are concentrated in Beijing, Guangdong, Shanghai, and Zhejiang where the proportions are 49.33%, 18.21%, 11.16%, and 11.05%, respectively. These four provinces and cities are the most advanced domestic economic and technological development areas. All have superior geographical environment and resource allocation advantages, so many Internet giants are located in these significant areas. For example, famous Internet companies such as Alibaba, Tencent, Huawei, JD.com, and Baidu have significantly increased the demand for an engineering job. But other provinces also have some demand, but the number is not much, only 10.45% of the total.

Although Beijing, Shanghai, Guangzhou, Shenzhen, and Hangzhou have great demand for engineering job, they all have their characteristics. Various job-hunting positions in Beijing bring more development opportunities and have relatively high salaries. But it also comes with the same price: more overtime hours and times and more significant life pressure. The entire industry in Shanghai is relatively competitive, and people's spending power is also very strong. Today's Shenzhen is a metropolis where our country's strategic emerging industries and cutting-edge technology companies gather. Salaries are higher than those in other parts of the country, and there is a steady increase. However, people are under considerable living pressure due to the high rent and living standards. However, in Guangzhou, the cost of living is lower, and opportunities and salaries are less than those in Beijing, Shanghai, and Shenzhen. But less overtime and less stress. These cities have

their own advantages, but they are all ideal places for career development.

In general, our country's engineering job position is concentrated in economically developed areas such as Beijing, Shanghai, Guangzhou, Shenzhen, and Hangzhou. Therefore, job-seekers considering a job in engineering job in the future can consider this area with rapid economic development and high demand for this position. But often, where there are more opportunities, the competition will be greater, and the pressure will be more significant. Therefore, making more adequate preparations and improving your professional ability to obtain the ideal job position and the salary level is necessary.

We conducted an in-depth analysis of Beijing, Shanghai, Guangzhou, Shenzhen, and Hangzhou, cities with many engineering job positions. It is found that the proportion of its engineering job in the urban area of each city is also very different.

Engineering job positions are concentrated in Beijing and Shenzhen and are only distributed in individual areas. The engineering job positions in Beijing are mainly distributed in Chaoyang Area and Haidian Area; The distribution of engineering job positions in Shenzhen is primarily concentrated in Nanshan Area; engineering job positions in Hangzhou, Shanghai, and Guangzhou are relatively scattered. Almost every urban area has the distribution of its engineering job posts, but its distribution is not uniform. Hangzhou is mainly concentrated in Gongshu Area and Xihu Area. Shanghai is primarily located in Pudong New Area, while Guangzhou is mainly in Tianhe Area.

4.2. The Situation of Corporate Financing. Most companies need external financing in the process of growth. Generally speaking, the more mature the company is, the more financing it will take. Angel investment rounds are generally projects in the early stage of the company's startup. At this time, the company has a preliminary product prototype, business model, and Core users, some of whom do not have a complete product and business plans. The subsequent A rounds, B rounds, C rounds, D rounds, and above-given are all the external financing needs of enterprises from losses to profits and gradually mature until they are about to go public. However, some small private enterprises do not require external financing due to the small scale of their development. As far as listed companies are concerned, they can conduct internal financing by issuing additional shares and stock shares and usually do not need external financing. As can be seen from Figure 3, in the recruitment of engineering job positions, it can be seen from the financing status of enterprises that for small enterprises that have not yet raised funds or are in angel round financing, the proportion is tiny, accounting for only 4.3% %, listed companies, C rounds, D rounds and above, and enterprises that do not need financing account for 75% of the total. That is to say; the more mature companies need to recruit engineering job; this is also consistent with the job responsibilities of engineering job. For small companies, vast amounts of data will not be generated in daily business activities. Through

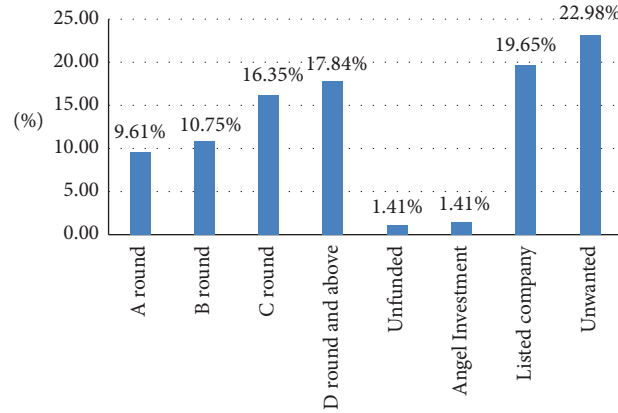


FIGURE 3: The situation of corporate financing.

TABLE 1: Recruitment position category statistics.

Position class	Specific position	Frequency	Positions class	Specific position	Frequency
Production class		1311	Marketing and selling class		7573
	Production	1311		Selling	5825
				Marketing	1748
Technical class		8759	Operation class		7602
	Develop	5235		Operation	2823
	Test	1439		Customer service	2122
	Operation and maintenance	1732		Edit	1519
	Optimization	353		Promote	821
				Data manage	317
Functional		2301	Design class		4963
	Administrative	1316		Web page	2888
	Finance	822		Visual	2075
	Human resources	163			
Sum					31198

relatively simple statistics, Analytical methods are enough to make decisions, which is why there is not much demand for an engineering job in small businesses.

4.3. Distribution of Job Classes. The job responsibilities in the characteristic vocabulary are subdivided into six classes and 17 positions, as shown in Table 1. Among all position postings, the most technical positions are technical, with a total of 8,759 jobs, accounting for 28.08% of the total. Followed by operation class (7602, 24.37%), marketing class (7573, 24.27%), design class (4963, 15.91%), functional class (2301, 7.38%), and production class (1311 items, 4.20%). During data collection, the most in-demand jobs for an engineering job in the talent recruitment market include marketing, development, operations, and web design positions.

5. Conclusions

The imbalance between the supply and demand of social talents has always been a major problem in the development process of our country. With the continuous expansion of

the enrollment scale of colleges and universities, the number of college graduates is increasing year by year. A large number of fresh graduates are facing employment problems, while a large number of enterprises cannot recruit talents that meet the requirements. The main reasons for the above difficulties are the disconnection between the professional talents cultivated in Colleges and universities and the real market demand, the unreasonable professional curriculum system, and the lack of accurate insight into the talent market demand.

In order to solve the above problems, this paper takes the recruitment of Engineering posts as an example, collects more than 30000 recruitment information on the recruitment network, uses text mining technology to build a multi-dimensional postdemand feature analysis model, uses natural language processing technology and machine learning to create a relatively perfect skill dictionary for engineering posts and analyzes the market demand and employment skills from multiple perspectives. This method makes up for the time-consuming defects of traditional research, manual statistical analysis, and other methods and realizes the rapid, efficient, and intelligent mining of postdemand characteristics, especially in the case of a large amount of data and

complex structure. In the past, the data used in the mining and research of the demand characteristics of recruitment positions were obtained through questionnaires and surveys. The amount of data obtained by these methods is small, the coverage area is limited, and there is no applicability. The data in this paper is from the recruitment announcement information data of engineering positions in the three major recruitment websites in China. The recruitment enterprises are all over the country, but there is no lack of zero demand for engineering positions in some regions. In short, the data is persuasive.

Compared with the traditional analysis methods, this paper has the following characteristics in the construction of the model and the selection of methods: the research data comes from online recruitment websites, and the enterprises that publish recruitment announcements are distributed nationwide, with a large amount of data, a more perfect structure and more persuasive; in terms of data processing, by building a relatively perfect Dictionary of professional skills of data analysts and using Chinese word segmentation technology for text data preprocessing, we can greatly give play to the existing computer technology to process text data efficiently and intelligently through algorithms and machine learning.

Different from the previous data mining, which only aims at structured data, this paper starts with semistructured or unstructured text information, deeply excavates the hidden knowledge model in the text, and makes the output of the results more meaningful; in terms of engineering job technology, text mining algorithm, statistical analysis method, correlation analysis, association rule analysis, and other methods are used to mine the postdemand characteristics and the implicit relationship between the characteristics.

Data Availability

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

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Quantitative Impact Analysis of Financial Support on Regional Science and Technology Innovation and Productivity Based on the Multivariate Statistical Model

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Science and technology (S&T) innovation is a significant driving force for regional productivity, and strong financial support can effectively promote S&T innovation. As the regional main body of S&T innovation, the first thing that enterprises need to address is the demand for funds. Internal funds are needed to maintain the overall daily operation of enterprises, and regional science and technology innovation funds mainly come from external financial support. Using the factor analysis method, multiple indicators were adopted to comprehensively evaluate the level of S&T innovation in each province and city as the variables and financial scale, financial structure, and financial efficiency as the variables, and the impact of financial support on science and technology innovation in four major regions was empirically studied using a panel data model. The degree of development of banking institutions and capital markets in different regions of China varies, and the financial system's support for China's S&T innovation varies widely. Therefore, it is important to study the impact of financial support on science and technology innovation among different regions in China for the balanced development of China's regions.

1. Introduction

S&T innovation is the primary driving force for development and an important driving force for economic growth and structural optimization. The relationship between finance and S&T innovation is very close; as an important force supporting the development of S&T innovation, finance can not only provide financial support but also help disperse the risks in the process of innovation. At the same time, scientific and technological innovation brings about the innovation of tools, which leads to a high production efficiency [1–4]. As for the influence of finance on scientific and technological innovation, most scholars believe that financial development can promote scientific and technological innovation. For example, Chowdhury et al. collected relevant data from developed and emerging countries and believed that the development of the financial market is conducive to improving the efficiency of enterprises' research and development (R&D) investment. Maskus et al.

took the relevant data of 18 OECD countries from 1990 to 2003 as samples to study the influence of domestic and international financial market development on their manufacturing R&D intensity, and the results showed that the diversity of financial development forms was an important factor determining R&D intensity. In addition, the degree of financial development has a different impact on technological innovation. The study found that countries with a high level of financial development had little positive effect of financial development on technological innovation. Middle-level countries have a greater positive effect on S&T innovation. However, in countries with a low level of financial development, its impact on S&T innovation is uncertain. [5, 6].

Finance plays a significant role in promoting S&T innovation. Sun et al. [7] believe that at the national level, financial development plays an increasingly important role in technological innovation. From the regional point of view, financial development promotes technological

innovation in China's provinces and regions with efficiency and consistency. Zhang et al. [8] studied the impact of finance on regional S&T innovative enterprises by taking 559 S&T innovative listed companies in 30 provinces and regions of China as examples and found that finance has a significant positive impact on regional S&T innovative enterprises. Financial development can provide more financing convenience and guarantee for enterprises, thus promoting the efficiency of innovation-oriented enterprises. Du et al. [9] also believe that finance can significantly promote the improvement of regional innovation ability, and this influence also has a spillover effect in space. Sun et al. [10] refined financial development indicators and analyzed the mechanism of financial development on technological innovation from the aspects of development scale, structure, and financial ecological environment. The effect of finance on S&T innovation is a double-edged sword, and finance can positively promote S&T innovation through credit constraint easing effect, resource allocation effect, external scale effect, and reverse crowding-out effect through excessive competition effect and cost effect [1, 11–15]. Whether the agglomeration of the financial industry has a positive or negative impact on S&T innovation depends on the relative magnitude of its positive promotion and reverse extrusion. On the one hand, for carrying out scientific and technological innovation activities, one needs to invest a large amount of capital, while financial agglomeration can solve the financing problem of capital demand by gathering idle social funds and investing them in scientific and technological innovation projects [16–20]. On the other hand, the risk dispersion function of financial agglomeration can help alleviate the uncertainty in the R&D process of scientific and technological innovation projects. The second is the information spillover effect. Financial agglomeration strengthens information sharing between financial institutions and enterprises, effectively avoids adverse selection through the full exchange of financial information between transaction parties, and promotes the improvement of technological innovation efficiency of enterprises through the information spillover effect. The third is the economies of scale [21–27]. The integration and convergence of huge financial resources in a specific region and the complementarity and innovation of various resources will produce an obvious “scale effect.” Financial agglomeration improves the efficiency of scientific and technological innovation by providing investment and financing facilities for innovative enterprises, reducing their financing costs and risks, thus accelerating the capital flow of enterprises. In addition, financial agglomeration accelerates the diffusion of core technologies and knowledge, which will also promote the improvement of the technological innovation level. [28–33].

Based on the financial support of the multivariate statistical model, this article analyzes and studies the regional S&T innovation and its production efficiency, further explores the impact of financial support on regional development, and uses scientific methods to reflect the comprehensive strength of the region.

2. Multivariate Statistical Model

2.1. Principal Component Analysis. Principal component analysis is a method of condensing data information from many indicators into composite indicators (principal components) and ensuring that these composite indicators are independent of each other. In the study of practical problems, in order to reduce the difficulty of analysis and improve the efficiency of analysis, the m -dimensional random vector $X=(x_1, x_2, \dots, x_m)$, but the first linear transformation of X transforms the original m -dimensional random vector into a new comprehensive variable L_1, L_2, \dots, L_m .

$$\begin{aligned}\mu &= E(X), \\ \Sigma &= D(X).\end{aligned}\quad (1)$$

Taking the linear transformation of X , we get

$$\begin{cases} Y_1 = t_{11}X_1 + t_{12}X_2 + \dots + t_{1p}X_p = T_1X \\ Y_2 = t_{21}X_1 + t_{22}X_2 + \dots + t_{2p}X_p = T_2X \\ \vdots \\ Y_p = t_{p1}X_1 + t_{p2}X_2 + \dots + t_{pp}X_p = T_pX \end{cases} \quad (2)$$

Let $Y = T'X$, where $Y = (Y_1, Y_2, \dots, Y_p)$ and $T = (T_1, T_2, \dots, T_p)$.

Y_1, Y_2, \dots, Y_n ($n < p$) are obtained by conversion, and these are independent of each other.

$$D(Y_i) = D(T_i'X) = T_i'D(X)T_i' = T_i'\Sigma T_i, i = 1, 2, \dots, n. \quad (3)$$

In order for Y_1, Y_2, \dots, Y_n ($n < p$) to fully reflect the information of the original variables, it is required that T_i maximizes $D(Y_i) = T_i'\Sigma T_i$. Assuming that T_i satisfies $T_i'T_i = 1$, or $|T| = 1$, the unbounded increase of $D(Y_i)$ due to multiplying T_i by any of the constants is eliminated:

The first principal component Y_1 satisfies $Y_1 = T_1'X$, where $T_1'T_1 = 1$ and $D(Y_1) = T_1'\Sigma T_1$ reaches its maximum value

The second principal component Y_2 satisfies $Y_2 = T_2'X$, where $T_2'T_2 = 1$ and $D(Y_2) = T_2'\Sigma T_2$ reaches its maximum value

The k -th principal component Y_k satisfies $Y_k = T_k'X$, where $T_k'T_k = 1$ and $D(Y_k) = T_k'\Sigma T_k$ reaches its maximum value

To find the first component, the objective function is constructed as follows:

$$\varphi_1(T_1, \lambda) = T_1'\Sigma T_1 - \lambda(T_1'T_1 - 1), \quad (4)$$

$$\frac{\partial \varphi_1}{\partial T_1} = 2\Sigma T_1 - 2\lambda T_1 = 0, \quad (5)$$

$$\left(\Sigma - \lambda I\right)T_1 = 0, \quad (6)$$

$$T_1' \sum T_1 = \lambda. \quad (7)$$

The covariance array \sum of X is a nonnegative definite, assuming that the roots of equation (6) are λ_i , and $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_p \geq 0$, where $i = 1, 2, \dots, p$. The variance of Y_1 is λ_1 from equation (7); then, the maximum variance of Y_1 is λ_1 , and the corresponding unitized eigenvector is T_1 .

Transforming equation (5) yields $T_2' \sum T_1 = \lambda T_2'$. Since Y_1 and Y_2 are independent of each other, we have $T_2' T_1 = 0$ or $T_1' T_2 = 0$. The objective function of the second principal component is given by the following equation:

$$\varphi_2(T_2, \lambda, \rho) = T_2' \sum T_2 - \lambda(T_2' T_2 - 1) - 2\rho(T_1' T_2), \quad (8)$$

$$\frac{\partial \varphi_2}{\partial T_2} = 2 \sum T_2 - 2\lambda T_2 - 2\rho T_1 = 0, \quad (9)$$

$$T_1' \sum T_2 - \lambda T_1' T_2 - \rho T_1' T_1 = 0, \quad (10)$$

$$\left(\sum - \lambda I \right) T_2 = 0, \quad (11)$$

$$T_2' \sum T_2 = \lambda. \quad (12)$$

The covariance array \sum of X is a nonnegative definite, assuming that the roots of equation (11) are λ_i , and $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_p \geq 0$, where $i = 1, 2, \dots, p$. The variance of Y_2 is λ_2 from equation (12); then, the maximum variance of Y_2 is λ_2 , and the corresponding unitized eigenvector is T_2 .

The k -th principal component Y_k satisfies $Y_k = T_k' X$, where $T_k' T_i = 1$ and $T_k' T_i = 0$ ($i \leq k$), and $D(Y_k) = T_k' \sum T_k$ reaches the maximum. The construction objective function of the k -th principal component is as follows:

$$\varphi_k(T_k, \lambda, \rho) = T_k' \sum T_k - \lambda(T_k' T_k - 1) - 2 \sum_{i=1}^{k-1} \rho_i(T_i' T_k), \quad (13)$$

$$\frac{\partial \varphi_k}{\partial T_k} = 2 \sum T_k - 2\lambda T_k - 2 \sum_{i=1}^{k-1} \rho_i T_i = 0, \quad (14)$$

$$T_i' \sum T_k - \lambda T_i' T_k - T_i' \left(\sum_{i=1}^{k-1} \rho_i T_i \right) = 0, \quad (15)$$

$$\left(\sum - \lambda I \right) T_k = 0, \quad (16)$$

$$T_k' \sum T_k = \lambda. \quad (17)$$

The covariance array \sum of X is a nonnegative definite, assuming that the roots of equation (15) are λ_i , and $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_p \geq 0$, where $i = 1, 2, \dots, p$. The variance of Y_k is λ_k from

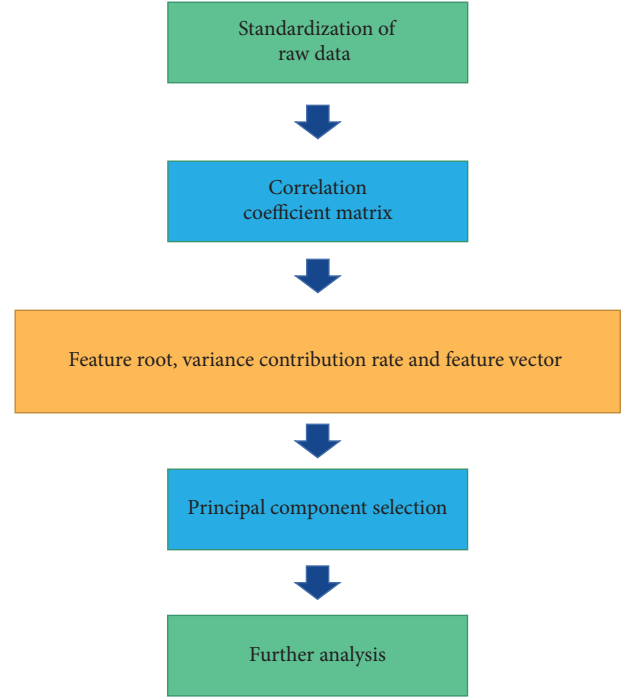


FIGURE 1: Calculation steps of principal components.

equation (16); then, the maximum variance of Y_k is λ_k , and the unitized eigenvector is T_k . The calculation steps of principal components are shown in Figure 1.

2.2. Factor Analysis. The basic purpose of factor analysis is to use a few factors to describe the relationship between many indicators or factors; that is, several closely related variables are grouped in the same category, each category of variables becomes a factor, and a few factors reflect most of the information of the original data. It is used to describe some of the more basic but not directly measurable variables hidden in a set of directly measurable variables. Using the idea of dimensionality reduction, starting from the intrinsic correlation of the original variable correlation matrix, the essence of the same variable is reduced to a factor, so as to achieve the purpose of dimensionality reduction.

We assume that there are n samples, and each sample has p indicators with a strong correlation among these p indicators. We then standardize the original data, use $X = (X_1, X_2, \dots, X_p)$ to represent the standardized variable, and use F_1, F_2, \dots, F_m ($m < p$) to represent the common factor, and E is the special factor of X_i ($i = 1, 2, \dots, p$).

- (1) $X = (X_1, X_2, \dots, X_p)$ is a p -dimensional random variable, the mean vector $E(X) = 0$, covariance matrix

$cov(X) = \sum$, and covariance matrix is equal to correlation matrix R .

- (2) $F = (F_1, F_2, \dots, F_m)$ ($m < p$) is not observable, the mean vector $E(F) = 0$, and covariance matrix $cov(F) = 1$, where F_1, F_2, \dots, F_m are mutually independent and the variance is 1.
- (3) F and $\varepsilon = (\varepsilon_1, \varepsilon_2, \dots, \varepsilon_p)$ are independent variables, where the mean vector $E(\varepsilon) = 0$ and the covariance matrix $\sum \varepsilon$ is a diagonal matrix, denoted as follows:

$$cov(\varepsilon) = \sum_{\varepsilon} = \begin{bmatrix} \sigma_{11}^2 & 0 & \dots & 0 \\ 0 & \sigma_{22}^2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \sigma_{pp}^2 \end{bmatrix}. \quad (18)$$

$\varepsilon_1, \varepsilon_2, \dots, \varepsilon_p$ are also independent, but the variances do not have to be equal.

- (4) $cov(F, \varepsilon) = 0$; that is,

$$\begin{cases} X_1 = a_{11}F_1 + a_{12}F_2 + \dots + a_{1p}F_p + \varepsilon_1 \\ X_2 = a_{21}F_1 + a_{22}F_2 + \dots + a_{2p}F_p + \varepsilon_2 \\ \dots \\ X_p = a_{p1}F_1 + a_{p2}F_2 + \dots + a_{pp}F_p + \varepsilon_p \end{cases}, \quad (19)$$

$$X = AF + \varepsilon,$$

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1p} \\ a_{21} & a_{22} & \dots & a_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ a_{p1} & a_{p2} & \dots & a_{pp} \end{bmatrix}.$$

A is the factor load matrix, a_{ij} is the factor load, and A represents the load of the i th variable on the j -th factor.

The codegree considers the relationship between all the common factors F_1, F_2, \dots, F_m and one of the original variables and calls $a_{i1}^2 + a_{i2}^2 + \dots + a_{im}^2$ the codegree of X_i , denoted as h_i^2 ($i = 1, 2, \dots, p$). The following equation can be obtained by the premise of the factor model:

$$\begin{aligned} D(X_i) &= h_i^2 + D(\varepsilon_i), \\ D(X_i) &= h_i^2 + \sigma_i^2. \end{aligned} \quad (20)$$

The coefficient h_i^2 is complementary to the residual variance σ_i^2 .

Placing the p principal components in the order from the largest to the smallest, they are written as Y_1, Y_2, \dots, Y_p in order; then, the relationship between the principal components and the original variables is as follows:

$$\begin{cases} Y_1 = t_{11}X_1 + t_{12}X_2 + \dots + t_{1p}X_p \\ Y_2 = t_{21}X_1 + t_{22}X_2 + \dots + t_{2p}X_p \\ \vdots \\ Y_p = t_{p1}X_1 + t_{p2}X_2 + \dots + t_{pp}X_p \end{cases}, \quad (21)$$

where t_{ij} is the component of the feature vector. The equation of the relation from Y transformed into X is as follows:

$$\begin{cases} X_1 = t_{11}Y_1 + t_{12}Y_2 + \dots + t_{1p}Y_p \\ X_2 = t_{21}Y_1 + t_{22}Y_2 + \dots + t_{2p}Y_p \\ \vdots \\ X_p = t_{p1}Y_1 + t_{p2}Y_2 + \dots + t_{pp}Y_p \end{cases}, \quad (22)$$

$$\begin{cases} X_1 = t_{11}Y_1 + t_{12}Y_2 + \dots + t_{m1}Y_m + \varepsilon_1 \\ X_2 = t_{12}Y_1 + t_{22}Y_2 + \dots + t_{m2}Y_m + \varepsilon_2 \\ \vdots \\ X_p = t_{1p}Y_1 + t_{2p}Y_2 + \dots + t_{mp}Y_m + \varepsilon_p \end{cases}$$

Since the principal components Y_i are uncorrelated with each other, transforming the principal components Y_i into variables with variance 1 makes the principal components become a common factor.

$$\begin{cases} X_1 = a_{11}F_1 + t_{12}F_2 + \dots + t_{1m}F_m + \varepsilon_1 \\ X_2 = a_{21}F_1 + t_{22}F_2 + \dots + t_{2m}F_m + \varepsilon_2 \\ \vdots \\ X_p = a_{p1}F_1 + t_{p2}F_2 + \dots + t_{mp}F_m + \varepsilon_p \end{cases}. \quad (23)$$

Suppose $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_p$ are the eigenvalues and their corresponding standard orthogonal eigenvectors are T_1, T_2, \dots, T_p . Since $m \leq p$, the solution set of the load matrix A is given by the following equation:

$$\begin{aligned} A &= (\sqrt{\lambda_1}t_1, \sqrt{\lambda_2}t_2, \dots, \sqrt{\lambda_m}t_m), \\ h_i^2 &= a_{i1}^2 + a_{i2}^2 + \dots + a_{im}^2, i = 1, 2, \dots, p. \end{aligned} \quad (24)$$

The load matrix A is multiplied by the orthogonal array K to give the factor orthogonal rotation. The factor loading matrix after rotation is A' , which gives the following equation:

$$A' = AK = (a'_{ij})_{p \times m}, \quad (25)$$

$$d_{ij} = \frac{a'_{ij}}{h_j}, \quad (26)$$

$$\bar{d}_j = \frac{1}{p} \sum_{i=1}^p d_{ij}^2. \quad (27)$$

The relative squared difference of the elements in the first column of A' can be defined as W_j .

$$W_j = \frac{1}{p} \sum_{i=1}^p (d_{ij}^2 - \bar{d}_j)^2. \quad (28)$$

We used the Thomson regression method to calculate the factor scores. The regression equation is

$$F'_j = b_{j0} + b_{j1}X_1 + \dots + b_{jp}X_p, j = 1, 2, \dots, m. \quad (29)$$

According to the statistical significance equation (27) of factor load AI_j , it can be seen that for any $i = 1, 2, \dots, p$ and $j = 1, 2, \dots, m$,

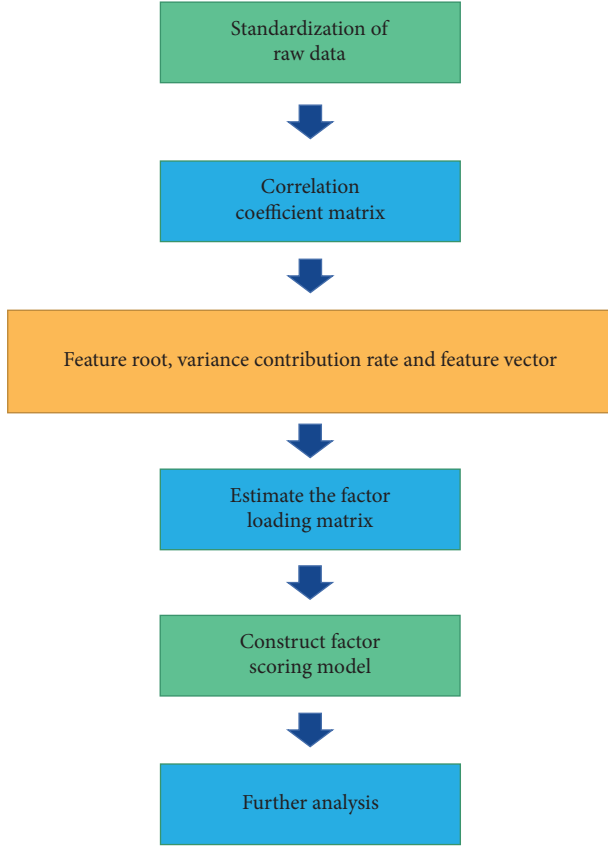


FIGURE 2: Steps of factor analysis.

$$\begin{aligned}
 a_{ij} &= r_{x_i, F_j} \\
 &= E[X_i(b_{j1}X_1 + b_{j2}X_2 + \cdots + b_{jp}X_p)] \\
 &= b_{j1}r_{i1} + b_{j2}r_{i2} + \cdots + b_{jp}r_{ip}, \\
 B &= \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1p} \\ b_{21} & b_{22} & \cdots & b_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ b_{m1} & b_{m2} & \cdots & b_{mp} \end{bmatrix}, \\
 A &= RB', B = A'R^{-1},
 \end{aligned} \tag{30}$$

where R is the coefficient matrix and A is the load matrix; then, the factor scoring formula can be calculated as

$$F' = \begin{bmatrix} F'_1 \\ F'_2 \\ \vdots \\ F'_m \end{bmatrix} = \begin{bmatrix} b'_1X \\ b'_2X \\ \vdots \\ b'_mX \end{bmatrix} = BX = A'R^{-1}X. \tag{31}$$

The steps of factor analysis are shown in Figure 2.

3. Regional Development Analysis of Financial Support

3.1. Evaluation and Analysis of the S&T Innovation Level. The investment in S&T innovation includes human and capital investment. R&D activities require the application of scientific methods to create new knowledge or create new applications. The scale and intensity of R&D activities can reflect the S&T strength of a region, so the budgeted R&D personnel and R&D expenses are used as variables, and the proportion of local government S&T expenditures to local fiscal expenditures reflects the local government's funding for S&T innovation. The output of S&T innovation includes patent output and product output. Patent output includes the number of patent applications and the number of patents granted. A technology market is a place for the exchange of commodity technology results, and the turnover of the technology market refers to the total amount of the subject matter of technology contracts. New product sales revenue refers to the sales revenue achieved through the sale of new products (products manufactured using new technology principles or new design concepts).

China's financial industry supports technological innovation from three aspects: banking institutions, general capital market, and venture capital. However, due to the direct and obvious effect of venture capital on high-tech enterprises and the late start of venture capital in China, the relevant data statistics of various provinces and cities are not standardized and perfect. In view of the reality and availability of data, this article studies the financial support of regional S&T innovation in China from two aspects, that is, banking and the capital market. Furthermore, in order to reflect the financial structure, deepen the longitudinal and transverse wide degree, and, at the same time, show the level of financial industry overall development impact on scientific and technological innovation, this article does not directly select banking institutions and capital market as a financial variables, but, in reference on the basis of domestic and foreign scholars' study, selects financial scale, financial structure, and financial efficiency as indicators to measure the level of financial development.

The focus of this study is to analyze the financial structure and its changes. The financial correlation ratio can better measure the degree of financial deepening, so the index of the financial correlation ratio is selected to represent the financial scale. The total value of financial assets includes money supply, stock market value, and bond balance. The sources of financial assets related to enterprise scientific and technological innovation mainly include indirect financing dominated by bank loans and direct financing represented by the capital market. Considering data availability and representativeness, the calculation method of financial scale is as follows:

$$FSC = \frac{\text{total bank loans} + \text{total stock market value}}{\text{GDP}}. \tag{32}$$

Financial structure: the financing of Chinese enterprises' S&T innovation comes from the banking industry and the

TABLE 1: Total variance.

	Total	Initial eigenvalue		Extraction of the sum of squares and load			Rotation of squares and load		
		Variance %	Accumulate %	Total	Variance %	Accumulate %	Total	Variance %	Accumulate %
1	4.38	71.16	71.16	5.25	71.16	71.16	3.98	63.65	63.65
2	2.42	21.74	92.90	1.45	21.74	92.90	2.73	29.26	92.90
3	0.33	0.83	95.81						
4	0.12	0.83	94.99						
5	0.02	0.21	96.10						
6	0.005	0.07	96.72						
7	0.001	0.02	100						

TABLE 2: The factor loading matrix and factor score matrix table.

	Factor load matrix		Rotation factor load matrix		Factor scoring coefficient matrix	
	1	2	1	2	1	2
X1	0.956	-0.120	0.926	0.268	0.194	-0.004
X2	0.951	-0.163	0.937	0.227	0.203	-0.030
X3	0.590	0.758	0.242	0.929	-0.100	0.507
X4	0.956	-0.147	0.936	0.242	0.201	-0.020
X5	0.930	-0.242	0.951	0.145	0.221	-0.080
X6	0.520	0.807	0.158	0.948	-0.125	0.532
X7	0.934	-0.248	0.956	0.141	0.224	-0.084

financial market. The rapid development of the security market in recent years highlights the changes in the financial structure and reflects the degree of financial globalization. Therefore, the total market value of stocks represents the financing method of the security market, and the variable of financial structure FST = the total market value of stocks / total bank loans. The larger the value is, the greater the support of the capital market for S&T innovation is. Financial efficiency: the function of the financial system is to centralize and redistribute capital, and the efficiency of capital distribution is directly related to the use of capital. In China's financial system, banks account for a large proportion. This article studies the conversion efficiency of banking institutions between deposits and loans from the perspective of financial intermediation. FEF = total bank loans / total bank deposits. The higher the conversion efficiency is, the more active the financial intermediary and the greater the support for S&T innovation are.

Before the comprehensive evaluation of the scientific and technological innovation level, the data collected from 31 regions in Mainland China for 14 years are standardized according to the method introduced above, so as to eliminate the differences caused by different dimensions of variables, and then, the factor analysis is carried out. As there are many provinces which are being studied, the calculation process is not listed one by one. A province is taken as an example to illustrate the factor analysis process of a comprehensive evaluation of scientific and technological innovation levels. In the adaptability test of factor analysis, the KMO value obtained is 0.835, and the significance level of the Bartlett sphericity test is $P = 0.00$. The null hypothesis is that variables that cannot correlate are rejected, and it can be considered that there is a strong correlation between these seven

TABLE 3: Technological innovation level of a province in 14 years.

Year	F ₁	F ₂	STI
1	0.287	-0.467	0.069
2	0.267	-0.431	0.066
3	0.267	-0.431	0.071
4	0.271	-0.437	0.082
5	0.296	-0.481	0.087
6	0.298	-0.485	0.095
7	0.292	-0.474	0.096
8	0.313	-0.511	0.108
9	0.308	-0.503	0.113
10	0.315	-0.514	0.108
11	0.313	-0.512	0.116
12	0.346	-0.570	0.126
13	0.356	-0.587	0.127
14	0.373	-0.618	0.133
15	0.388	-0.639	0.134

variables, which is suitable for factor analysis. Therefore, the total variance of interpretation can be obtained through software operation, and the number of extracted factors can be determined. The details are listed in Table 1.

As can be seen from Table 1, the eigenvalues of the first two factors are greater than 1, and the cumulative variance contribution rate reaches 92.90%. Selecting the first two factors can better reflect the original data information. F₁ and F₂ are used to represent the selected factors, and the factor load matrix and the factor score coefficient matrix can be obtained to describe the composition of the two principal components, as shown in Table 2.

The rotated factor load matrix more clearly describes the classification of factors. As can be seen from the table, the main factor F₁ mainly explains five variables including the number of R&D personnel, internal expenditure of R&D funds, patent applications, patent grants, and sales revenue of new products. The main factor F₂ mainly explains two variables: the proportion of science and technology expenditure in local financial expenditure and the turnover of the technology market. According to the common factor score coefficient matrix analyzed by the software, the scores of the two factors in each year are calculated, and then, the extracted variance contribution rate is weighted to each factor to obtain the comprehensive score STI of each year.

TABLE 4: Unit root test results.

Area	Inspection methods	Original sequence		Difference of first order	
		t	Probability	T	Probability
Eastern region	ADF-Choi Z-stat	-0.642	0.246	-6.440	0.000
	PP-Choi Z-stat	-1.420	0.069	-7.091	0.000
	Levin, Lin, and Chut	-2.455	0.019	-9.938	0.000
	Im, Pesaran, and Shin W-stat	-0.626	0.251	-7.140	0.000
Central region	ADF-Choi Z-stat	2.930	0.968	-2.281	0.009
	PP-Choi Z-stat	2.361	0.962	-2.811	0.002
	Levin, Lin and Chut	2.153	0.956	-4.994	0.000
	Im, Pesaran, and Shin W-stat	3.455	0.969	-2.778	0.002
Western region	ADF-Choi Z-stat	2.771	0.967	-4.136	0.000
	PP-Choi Z-stat	3.545	0.969	-4.666	0.000
	Levin, Lin, and Chut	1.113	0.848	-6.367	0.000
	Im, Pesaran, and Shin W-stat	2.754	0.967	-4.311	0.000
Northeast region	ADF-Choi Z-stat	2.038	0.952	-1.321	0.084
	PP-Choi Z-stat	2.988	0.968	-2.276	0.009
	Levin, Lin, and Chut	0.549	0.692	-3.313	0.000
	Im, Pesaran, and Shin W-stat	1.944	0.947	-1.393	0.073

$$\begin{aligned}
 F_1 &= 0.194X_1 + 0.203X_2 - 0.1X_3 + 0.201X_4 + 0.221X_5 \\
 &\quad - 0.125X_6 + 0.224X_7, \\
 F_2 &= -0.004X_1 - 0.03X_2 + 0.507X_3 - 0.20X_4 \\
 &\quad - 0.08X_5 + 0.532X_6 - 0.084X_7.
 \end{aligned} \tag{33}$$

Among them, X_1, X_2, \dots, X_7 are the standardized data of each variable after processing. The comprehensive score $STI = (F_1 * 63.65 + F_2 * 29.26) / 92.90$ was calculated.

From the result of factor analysis, it can be seen that the comprehensive level of scientific and technological innovation of all regions in China in 14 years shows an overall upward trend, and it fluctuates slightly in the second and fifth years, basically showing strong S&T innovation ability. From the comparison between provinces and cities, Guangdong province has the highest level of S&T innovation, followed by Jiangsu, Zhejiang, Beijing, Shanghai, and other places, while Qinghai, Ningxia, Xizang, and other provinces have a very low level of S&T innovation, and many years are negative, that is, below the standard value. Therefore, the results of empirical analysis show that there are obvious regional differences in the level of S&T innovation in the four regions. The eastern region has the highest level of S&T innovation, which is higher than the central region and northeast region, and the western region has the lowest comprehensive evaluation value of S&T innovation as shown in Table 3.

3.2. Analysis of Financial Support. The comprehensive evaluation level of S&T innovation of each province in 14 years calculated by factor analysis was taken as the variable, and the financial scale, financial structure, and financial efficiency were taken as the variable to calculate the quantitative relationship between S&T innovation and financial support in four regions. In order to eliminate the possible influence of variable heteroscedasticity and avoid the

occurrence of false regression, it is necessary to perform logarithmic processing on panel data first and then conduct a unit root test to determine whether the variable data are stable. Under the operation of Eviews software, a unit root test was carried out on the four regions, respectively. Test results are shown in Table 4. Among the original sequence data, only PP-Choi Z-Stat and Levin, Lin, and Chut tests were significant at 10% and 5% levels in the eastern region. The test results of the other two methods accepted the assumption that the original sequence had unit roots, and the ADF test results should be mainly referred to at this time. Therefore, it can be considered that the original sequences of the four regions have unit roots and belong to nonstationary sequences. In first-order difference series data, except for ADF and Im in northeast China, Pesaran and Shin W-Stat tests are significant at a 10% level, and the other test results are significant at a 1% level. Therefore, first-order difference data in the four regions reject the null hypothesis of the existence of unit roots and consider them as stationary series.

According to the results of the unit root test, each variable is a first-order integration sequence, and the cointegration test can be carried out to verify whether there is a long-term equilibrium relationship between variables through the results of the cointegration test so that the design of the regression equation can be more reasonable. There are many ways to test for cointegration, which include 4 intragroup statistics (panel V statistics, panel RHO statistics, panel PP statistics, and panel ADF statistics) and 3 intergroup statistics (group RHO statistics, group PP statistics, and group ADF statistics). When the number of samples is large, these 7 statistics have good stability and testing efficiency. When the number of samples is less than 20, panel ADF and group ADF statistics become the optimal test methods. Since this study needs to carry out the cointegration test for the four regions and each region contains samples less than 20, only the test results of panel ADF and group ADF statistics are considered. Table 5 shows

TABLE 5: Cointegration test results.

Area	Inspection methods	Statistics	Probability	Weighted statistics	Probability
Eastern region	Panel ADF statistics	-2.281	0.009	-3.025	0.001
	Group ADF statistics	-2.395	0.006		
Central region	Panel ADF statistics	-4.590	0.000	-2.541	0.004
	Group ADF statistics	-4.611	0.000		
Western region	Panel ADF statistics	0.642	0.723	-2.726	0.002
	Group ADF statistics	-2.644	0.003		
Northeast region	Panel ADF statistics	-2.899	0.001	-2.478	0.005
	Group ADF statistics	-2.767	0.002		

TABLE 6: Regression results.

Area	Variable	Coefficient	Standard deviation	t statistics	Probability
Financial scale (FSC)	Eastern	0.03204	0.00605	5.12925	0.00000
	Central	0.01967	0.00308	6.19772	0.00000
	Western	0.01510	0.00038	38.11605	0.00000
	Northeast	0.02092	0.00615	3.29635	0.00165
Financial structure (FST)	Eastern	0.04612	0.01019	3.77706	0.00019
	Central	0.03157	0.00387	9.35948	0.00000
	Western	0.01777	0.00061	35.83719	0.00000
	Northeast	0.02914	0.01121	7.98095	0.00000
Efficiency of the financial structure (FEF)	Eastern	0.00493	0.00203	2.35151	0.01609
	Central	0.00109	0.00061	1.74352	0.07364
	Western	0.00089	0.00011	4.98282	0.00000
	Northeast	0.00118	0.05506	1.23784	0.08634
Intercept item	Eastern	0.04343	0.00790	5.32830	0.00000
	Central	0.01377	0.00196	6.80450	0.00000
	Western	0.03523	0.00027	126.68435	0.00000
	Northeast	0.02479	0.00862	2.40021	0.01405

the cointegration test results of the four regions calculated by Eviews software.

The results of the cointegration test showed that panel ADF within the group was significant at a significance level of 1% after weighting, and group ADF between the groups was also significant at a significance level of 1%. Therefore, the test results reject the null hypothesis that there is no cointegration relationship between variables, and we believe that there is a cointegration relationship between variables in the four regions, which is convincing for regression analysis.

3.3. Analysis of Regression Results. According to the results of the unit root test and cointegration test, the data of the four regions in 14 years were analyzed by regression analysis. In order to determine which panel data model to adopt, it is necessary to first determine the form of influence and determine whether it is fixed influence or random influence. The Hausman test is generally used to test the form of influence, but this method often results in counterproductive results. In addition, according to the nature of the data, it can also decide which form of influence to choose. If there is random sampling and the sample reflects the overall nature, the random form of influence is suitable. If the data are aggregate data with small differences and need to be compared with each other, the fixed influence form is suitable. The purpose of this study is to explore the data consistency within the region and to compare the differences between regions, and a fixed-effect model needs to be established.

According to the calculation results of Eviews software, the regression model of panel data of the four regions is obtained. The details are listed in Table 6.

As shown in Table 6, the regression coefficients of variables have all passed the significance level test, and the regression equations of the four regions can be further obtained as follows:

Eastern region:

$$STI = 0.04343 + 0.03204 * FSC + 0.04612 * FST + 0.00493 * FEF. \quad (34)$$

Central region:

$$STI = 0.01377 + 0.01967 * FSC + 0.03157 * FST + 0.00109 * FEF. \quad (35)$$

Western region:

$$STI = 0.03523 + 0.01510 * FSC + 0.01777 * FST + 0.00089 * FEF. \quad (36)$$

Northeast region:

$$STI = 0.02479 + 0.02092 * FSC + 0.02914 * FST + 0.00118 * FEF. \quad (37)$$

It can be seen from the regression results that the coefficient of financial scale is positive, indicating that the

expansion of the financial system scale can promote the improvement of technological innovation levels in the four regions. However, the influence degree of financial scale on scientific and technological innovation is different among different regions, and the order from large to small is eastern region > northeast region > central region > western region. The influence coefficient of the eastern region is the largest because the financial system of the eastern coastal provinces is relatively perfect. The rapid development of banks and security markets represented by Beijing, Shanghai, and Guangdong greatly promotes the improvement of regional scientific and technological innovation levels. At the same time, due to the large scale of enterprises and many listed companies, the expansion of the scale of the financial system can quickly transfer to the scientific and technological innovation of enterprises. Due to the remote location of most provinces in western China, the banking industry develops slowly, and the security market as a new financing method is also in its infancy. Local governments and enterprises do not pay enough attention to scientific and technological innovation, which is ultimately manifested in the insufficient support for regional S&T innovation from the expansion of financial scale.

There is a positive correlation between financial efficiency and the technological innovation level, and the improvement of financial efficiency can promote the improvement of the regional technological innovation level. Financial efficiency reflects the capital conversion efficiency of bank intermediary institutions. The greater the efficiency, the faster the banking institutions can convert deposits into loans and invest in enterprises. Relatively speaking, the use of capital efficiency is higher, and the promotion of scientific and technological innovation is greater. In general, the coefficient of financial efficiency is relatively small compared with the other two variables because banking institutions convert deposits into loans and issue them to enterprises, which then partially apply these funds to scientific and technological innovation. After capital transfer and filtering twice, the impact of financial efficiency on scientific and technological innovation is reduced.

4. Conclusion

This study analyzes the relationship between financial support and regional science and technology innovation and productivity in different regions of China through multivariate data statistics. The intrinsic influence mechanism of financial [34] support on S&T innovation and production efficiency is explored, and the current development status of S&T innovation in different regions of China and the current status of direct and indirect financing support for S&T innovation are analyzed, and the constraints of financial support on S&T innovation in China are derived. The results of the empirical analysis show that the financial scale, financial structure and financial efficiency variables are all positively related to the level of S&T innovation, but the influence coefficients are different for the four regions. In terms of the degree of influence of each variable, the financial support for S&T innovation in the eastern region mainly

comes from the general capital market, which is mainly stock based, and the openness and maturity of the capital market directly affect the supply of funds to enterprises. Strong financial support can effectively improve the region's S&T innovation, and innovation in S&T can effectively improve production efficiency.

Data Availability

The data supporting the current study are available from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Retraction

Retracted: The Quality Evaluation of Business English Classroom Teaching Using Improved DA-BP Algorithm

Mathematical Problems in Engineering

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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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Research Article

The Quality Evaluation of Business English Classroom Teaching Using Improved DA-BP Algorithm

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With the international development of China's economy, there is an increasing demand for complex talents who are proficient in English and familiar with business operation and management of enterprises. However, it is worth exploring how to explore a proven teaching quality monitoring model for business English (BE) majors. The evaluation system of business English classroom teaching quality should not focus on the effect of teachers' "teaching," but on students' "learning" experience and the effect of "learning." English teaching should take into account the actual situation of students, especially that some students have a poor English foundation and insufficient understanding of English learning. They can improve their English cultural literacy and enhance their intercultural communication skills from learning English. Therefore, when evaluating teaching quality, indicators such as teaching methods and learning strategies should be introduced and emphasis should be placed on motivating students' learning attitudes, emotions, awareness, and experiences to promote cooperative inquiry learning. In this paper, we propose an improved DA-BP algorithm to measure the teaching quality of BE, which has achieved good evaluation results with an accuracy rate of 93%, enriched the content of business English classroom teaching and cultivated more comprehensive and better composite talents for the society.

1. Introduction

The process of economic globalization is bound to be accompanied by the cross-border and cross-regional flow of production factors such as commodities, technology, information, and services. As a necessary means of communication, language is becoming more and more important, especially business English as an international language. When recruiting employees, many companies, especially export-oriented companies, not only require applicants to have good professional knowledge and skills but also must have a high ability to use business English [1]. Now that China's economic development has entered a new normal, it is facing enormous pressure from the transfer of production capacity. With the in-depth advancement of the "One Belt, One Road" project, tens of thousands of high-quality and skilled talents will go abroad for employment or entrepreneurship, which is very important for vocational education talents. Cultivation puts forward higher new requirements,

requiring vocational colleges to cultivate technical and technical talents with certain foreign language communication skills who are suitable for "going out" [2].

Due to historical and practical reasons, business English classroom teaching has been facing a huge dilemma. Over the years, most of the students recruited by the school have low comprehensive cultural quality, unclear learning goals, insufficient learning interest and motivation, and poor autonomous learning ability. Especially in the level of business English, the scores vary greatly. The students' foundation is generally weak, the knowledge of pronunciation and grammar is quite lacking, the vocabulary is seriously insufficient, the listening and speaking ability is extremely poor, and they have no interest in learning business English or even disgust. They think that choosing a vocational school is a helpless move, just to learn a skill and find a job after graduation. Therefore, most students and parents, including schools, have the idea of "focusing on majors and ignoring culture" [3]. In addition, the society also has some unfair

views on the students of vocational schools, believing that the students of vocational schools have poor quality and low ability. Therefore, business English teachers will also feel hard and difficult in classroom teaching, which makes the teaching of business English courses in an embarrassing situation of “students are tired of learning and teachers are difficult to teach” [4].

This requires us to build a strong position for business English work in colleges and universities, build a high-quality teaching team, scientifically plan a high-level talent training system, and improve and perfect the business English work system and mechanism. Among them, the quality of business English classroom teaching is directly related to the cultivation of talents. The so-called teaching quality evaluation is to evaluate the standard, efficiency, and quality of teaching activities according to the teaching objectives, and to estimate and judge the teaching value [5]. Although many teachers who are engaged in business English teaching also attach great importance to the research and summary of teaching experience and methods, the research results on the evaluation index system of classroom teaching are few and far between. The new forms, new methods, new approaches, and new ideas of based on the above analysis, how to improve the teaching level and quality of business English courses in colleges and universities, the research on classroom teaching evaluation index and its system is the fundamental to improve the level and quality. Aiming at the influence of the BP evaluation accuracy by its parameter selection, this paper applies the Dragonfly algorithm [(Dragonfly Algorithm, DA)] to the parameter optimization of the initial connection weight c_j , w_{ij} and the threshold ε , θ of the BP model, and proposes a DA-BP-based algorithm [6]. A method for evaluating the quality of business English classroom teaching. The research results show that DA-BP can effectively improve the evaluation accuracy of business English classroom teaching quality and provide a new method and approach for business English classroom teaching quality evaluation.

2. Related Work

Based on the problems existing in business English teaching at this stage, in order to improve the effectiveness of business English classroom teaching, both front-line business English teachers or business English teaching researchers are based on the traditional teaching mode, according to the specific situation of students, Effective classroom teaching reform to mobilize students' interest in business English learning has been carried out, and rich research results have been obtained on business English teaching reform [7].

The theoretical basis of the “layered teaching” model comes from the “teaching according to aptitude” proposed by Confucius. Many front-line teachers have conducted detailed research on this model. [8] The teacher made a relatively complete exposition on this in the relevant research. She pointed out that in recent years, the overall quality of students in schools has declined as a whole, and the two-level differentiation is serious. If these students with great individual differences are organized according to the

same standard and model, it will bring many difficulties to teachers' classroom teaching and affect the entire teaching plan. And, the smooth progress of teaching objectives, it is difficult to achieve the established talent training goals, which not only affects the overall improvement of students' quality but also seriously affects the competitiveness of students' further education and employment after graduation [9]. In view of the particularity of education, teaching activities should take into account the differences between individual students, pay attention to the actual situation of students, follow the principle of individualization, classify them according to their performance, divide them into different levels, implement hierarchical teaching, and target each student. Different characteristics of students at different levels, teach students in accordance with their aptitude [10]. When implementing tiered teaching, a thorough examination can be organized at the beginning of the students' admission, and then students can be divided into two levels of fast and slow or three levels of fast, medium, and slow according to their entrance scores and preliminary results and then formulate different teaching plans for different levels. Provides different teaching objectives, adopts different teaching methods, and combines various auxiliary forms such as “preclass tutoring and after-school tutoring, individual tutoring and group tutoring, in-class tutoring, and after-class tutoring” to meet the specific needs of students at different levels. Many scholars have also conducted a lot of research on the stratified teaching of business English and published many articles, such as [11] “Prominent the main body position, try to promote the stratified promotion—the exploration and practice of business English, mathematics stratified teaching.” “The Practice and Exploration of Implementing Hierarchical Education in “Higher Vocational Education.” [12]. In addition, many vocational schools have also carried out active exploration and research on stratified teaching, and the stratified teaching practice of business English has also made important progress [13].

Students' business English learning ability is low, and they are disgusted or even repelled by the traditional teaching methods of knowledge-based narration, and language learning is still a cultural learning in the final analysis [14]. “Internet and computer learning are very common for students, and the use of the Internet and multimedia for business English teaching has become a major trend in teaching.” Teacher [15] said in her “Exploration and Analysis of Business English Teaching Reform.” The situation created by multimedia teaching can well stimulate students' interest and make business English teaching more efficient [16].

Through the investigation and research on the current situation of business English teaching, teachers proposed strategies to use multimedia modern technology, create teaching contexts, and improve teaching effectiveness in response to the current problems in business English teaching [17]. He believes that with the help of modern multimedia technology, it is possible to “create a pure business English cultural situation”, “create a real life situation,” “create a good dialogue situation,” “build a strong reading situation,” and “preset a strong situation.” Explore the situation” [18]. The teaching content that integrates light,

color, sound, and shadow can enable students to expand their imagination in the three-dimensional space where sight and hearing are intertwined, as if they are in various real language environments, and they can better and faster devote themselves to the teaching process [19]. In business English learning, use the knowledge of business English that has been learned to express their feelings, help students to think directly in business English, and use business English to communicate [20].

“Educational Psychology” pointed out, “Interest is a unique intention to show a certain kind of thing, is a strong desire to recognize a certain kind of thing, it reflects people’s enthusiasm for a certain activity, is a person’s subjective A Personalized Sign of Motivation” [21, 22]. Curiosity is a description of people’s motivation for learning, a strong interest in the tireless pursuit and desire for truth and knowledge, and a specific emotional activity with bright colors and clear goals, which directly reflects the intensity of people’s interest in learning. The interest in learning is inseparable from people’s thirst for knowledge, rational emotions, and positive learning attitude, and it is the desire to learn accompanied by obvious emotional characteristics [23, 24].

Many studies have shown that the degree of student interest in learning has a significant impact on the final learning effect [25]. Students in secondary vocational schools have certain characteristics, and their overall quality is generally not high, mainly manifested as weak willpower, poor self-control, poor emotional regulation, irritability, inability to concentrate for a long time, misbehavior, and behavior. Not right. Compared with many peers, they do not have the pressure to go to school. Whether they study or not depends to a large extent on their own preferences. Therefore, teachers have more responsibility and obligation to carefully study topics that can stimulate students’ interest in learning and establish a learning guidance mechanism suitable for students, to help students correct their learning attitude, enhance their interest in learning, further improve their learning ability, and continuously improve their comprehensive literacy.

3. Methods

The teaching process in the classroom and the teaching effect after the class, which requires breaking the original teaching quality evaluation pattern, getting close to the BE classroom teaching mode, collaborating on the relationship between before, during, and after the class, and realizing a multichannel and multi-faceted comprehensive evaluation. As shown in Table 1, we give the evaluation indicators of students’ classroom learning effect. And, we further propose an improved DA-BP algorithm to evaluate the classroom teaching quality.

DA is a new type of swarm intelligence optimization algorithm proposed by MIRJALILI et al. It is an algorithm optimization process that searches both global and local at the same time by simulating the behavior of dragonfly swarm flight navigation, hunting and avoiding natural enemies to find the best hunting behavior. The movement of dragonfly colonies can be divided into the following five behaviors.

- (1) Separation behavior, which refers to the separation between a single dragonfly and adjacent dragonflies, and its behavior expression is

$$S_i = - \sum_{j=1}^N (X - X_j). \quad (1)$$

Here, S_i is the separation degree of dragonfly i and adjacent dragonfly; X is the current position of dragonfly; X_j is the position of adjacent dragonfly j ; N is the number of adjacent dragonfly.

- (2) Alignment behavior, which means that the speed of a single dragonfly matches the adjacent dragonfly, and its behavior expression is

$$A_i = \frac{\sum_{j=1}^N V_j}{N}. \quad (2)$$

Here, A_i is the alignment of the dragonfly i with the adjacent dragonfly; V_j is the speed of the adjacent dragonfly.

- (3) Cohesion behavior, which represents the collective gathering of a single dragonfly and neighboring dragonflies, and its behavioral expression is

$$C_i = \frac{\sum_{j=1}^N X_j}{N} - X. \quad (3)$$

Here, C_i is the cohesion degree of dragonfly i .

- (4) Foraging behavior, refers to a single dragonfly looking for food, and its behavioral expression is

$$F_i = X^+ - X. \quad (4)$$

Here, F_i is the foraging ability of dragonfly i ; X^+ is the location of food.

- (5) Enemy avoidance behavior, which means that a single dragonfly avoids foreign enemies, and its behavioral expression is

$$E_i = X^- + X. \quad (5)$$

Here, E_i represents the ability of dragonfly i to avoid the enemy; X^- represents the location of the enemy.

The DA algorithm is the algorithm for updating the position of the dragonfly, and there are two situations.

The first type, when dragonflies have close neighbors, dragonflies can search for the flight direction ΔX and the air position X through the above five behaviors, and change the direction and position, and finally find the best result. $t = 1$ is the next generation of t . An expression whose position and orientation are iteratively updated:

$$X_{t+1} = X_t + \Delta X_{t+1}, \quad (6)$$

$$\Delta X_{t+1} = (sS_i, aA_i, cC_i, fF_i, eE_i) + \Delta w \Delta X_t. \quad (7)$$

TABLE 1: Evaluation index system of student learning effect of English flipped classroom in higher vocational universities.

Tier 1 indicators	Secondary indicators	Three-level indicators
A1: independent study before class (33%)	B1: task completion (44%)	C1: studying the learning materials provided by the teacher carefully (38%) C2: completion of precourse tasks (32%) C3: ability to obtain relevant resources (30%)
	B2: learning attitude (56%)	C4: active participation in group activities and willingness to communicate (51%) C5: active learning and problem identification (49%)
	B3: demonstration of learning outcomes (32%)	C6: active in sharing results and willing to express (47%) C7: use language accurately and fluently (53%) C8: cooperate and help others (52%)
	B4: cooperation spirit (37%)	C9: clearly divide the work and perform their own duties (48%)
A2: classroom communication and cooperation (36%)	B5: effectiveness of classroom learning (33%)	C10: participate actively in class discussions (45%) C11: able to internalize knowledge and skills (55%) C12: proactive in completing tasks (54%)
	B6: task completion (27%)	C13: active in summarizing problems and shortcomings (46%) C14: improved overall English skills (35%)
	B7: effectiveness of learning (35%)	C15: improved intercultural communication awareness (35%) C16: improvement of creative ability (30%)
	B8: reflection on learning (38%)	C17: reasonable and fair self-assessment and mutual assessment (35%) C18: be able to sort out knowledge points and summarize skills (22%) C19: use teaching platform for personalized learning (43%)
A3: post-class reflection (31%)		

Here, s is the separation weight; a is the alignment weight; c is the cohesion weight; f is the foraging factor; e is the natural enemy factor; Δw is the inertia weight.

The second type, dragonflies have no neighbors, and the *Levy* / function is used to update the position of dragonflies to find the group. The *Levy* / function expression is as follows:

$$Levy(x) = 0.01 \times r_1 \times \sigma |r_2|^{\frac{1}{\beta}}, \quad (8)$$

$$\sigma = \left\lceil \tau(1 + \beta) \times \sin \frac{\pi\beta}{2} \right\rceil \tau \left(\frac{1 + \beta}{2} \right) \times \beta \times 2 \left(\frac{\beta - 1}{2} \right) \frac{1}{|\beta|}. \quad (9)$$

Here, $\tau(x) = (x - 1)!$; $\beta = 0.5$ is a constant; r_1, r_2 is a random number between 0 and 1. The mathematical expression of dragonfly position update is as follows:

$$\Delta X_{t+1} = X_t + Levy(d)\Delta X_t, \quad (10)$$

where d is the dimension.

It can be seen from the above that the DA algorithm has a good global search ability, which can help the BP neural network algorithm to optimize the weights and thresholds globally. However, it still has shortcomings, because there is not too much information exchange between dragonflies, and the optimization of each generation does not make full use of the excellent individuals of the previous generation,

which affects the convergence of the algorithm and is prone to premature convergence.

3.1. Evaluation of Business English Classroom Teaching Quality Based on DA-BP. BP neural network is a multilayer feedforward neural network composed of input layer, hidden layer, and output layer. If the input dimension and output dimension of the BP network are m and 1, respectively, and the number of hidden layers is P , then the BP neural network The mapping mathematical expression of the network is

$$x_{i+1} = f(X_i) = \frac{1}{1 + \exp\left(-\sum_{j=1}^P c_j b_j + \varepsilon\right)} \quad j = 1, 2, \dots, p. \quad (11)$$

Here, f is the activation function of the hidden layer; ε is the threshold of the output layer; c_j, b_j is the connection weight from the hidden layer to the output layer, and the output of the hidden layer node.

Therefore, the output of the hidden layer node of the BP neural network can be expressed as

$$b_j = \frac{1}{1 + \exp\left(-\sum_{i=1}^m w_{ij}x_i + \theta_j\right)} \quad i = 1, 2, \dots, m. \quad (12)$$

Here, w_{ij} is the connection weight from the input layer to the hidden layer; θ_j is the threshold of the hidden layer node.

Since the prediction result of BP neural network is easily affected by the initial connection weight of c_j, w_{ij} and the threshold of ε, θ_j , and it is easy to fall into the local

extreme value problem, this paper uses DA to optimize the initial connection weight and threshold of the BP neural network.

3.2. DA-BP Algorithm Flow. The algorithm flow of business English classroom teaching quality evaluation based on DA-BP can be summarized as follows:

Step 1. Initialize the BP neural network model and determine the network structure. Determine the number of layers of BP neural network, transfer function and training function type, and the number of nodes in each layer according to the data samples; read the quality evaluation data of business English classroom teaching, and preprocess the data to divide the data into training set and test set.

Step 2. Coding. The DA algorithm uses real number coding to encode the connection weight c_j, w_{ij} and the threshold ε, θ_j as a whole. The search space dimension of the algorithm is m . If the number of nodes in the input layer, hidden layer and output layer are R, S_1, S_2 , respectively, the encoding length S can be expressed as follows:

$$S = RS + S_1S_2 + S_1 + S_2. \quad (13)$$

Step 3. DA algorithm parameter initialization: population size N , maximum number of iterations T .

Step 4. Randomly initialize the step size vector ΔX and randomly generate the initial position X of the dragonfly individual.

Step 5. Set the current number of iterations $t = 1$, input the training set into BP, calculate the fitness of all dragonfly individuals according to the fitness function formula (14), and sort and record the current optimal solution.

The mean square error is chosen as the fitness function, which is shown in the following equation:

$$fitness = \frac{1}{k} \sum_{i=1}^k \left(y_i - \hat{y}_i \right)^2. \quad (14)$$

Here, $y_i - \hat{y}_i$ is the actual output and expected output of the i nd sample, respectively; k is the number of samples [26].

Step 6. Update the food source position X^+ (the current optimal solution) and the natural enemy position X (the current worst solution), and update the 5 behavioral weights s, a, c, f, e and the inertia weight training.

Step 7. Update S, A, C, E , and F according to formulas (3)–(7).

Step 8. Update the step vector and the position vector according to formulas (8) and formula (9).

Step 9. If the number of iterations $f > T$, save the optimal connection weight c_j, w_{ij} and the threshold ε, θ_j ; otherwise, $t = t + 1$, return to Step 5.

Step 10. Take the connection weight c_j, w_{ij} and the threshold ε, θ_j corresponding to the optimal solution as the initial connection weight and threshold of the BP neural network, train the BP neural network, and make predictions.

4. Experiments

4.1. Data Set. Combined with references and teaching experience, the AHP structure model of business English classroom teaching quality evaluation is constructed by using the analytic hierarchy process, as shown in Figure 1.

The teaching quality evaluation indicators in Table 2 are constructed according to two comparison methods.

4.2. Evaluation Indicators. In order to test the quality evaluation results of business English classroom teaching in colleges and universities, the evaluation indicators are selected root mean square error (Root Mean Square Error, RMSE) and correlation coefficient R , and the evaluation indicators are formulas (15) and (16).

$$RMSE = \sqrt{\frac{1}{n} \sum_{k=1}^n \left(x_k - \hat{x}_k \right)^2}, \quad (15)$$

$$R = \frac{\sum_{k=1}^n x_k \hat{x}_k}{\sqrt{\sum_{k=1}^n x_k^2} \sqrt{\sum_{k=1}^n \hat{x}_k^2}}. \quad (16)$$

Among them, x_k, \hat{x}_k represents the actual value and predicted value of the k nd sample; n lines represent the number of sample sets; RMSE is mainly used to measure the degree of dispersion of the model; R is mainly used to describe the degree of correlation between the predicted value and the actual value, R of The closer the absolute value is to 1, the higher the correlation between the predicted value and the actual value.

4.3. Results. According to the literature, the quality of business English classroom teaching is divided into 5 grades, namely, very good, good, average, poor, and very poor. The evaluation grades are shown in Table 3.

The collected data is scored by experts, and a total of 10 groups of data are obtained. The data are divided into two parts. The first six groups of data are used as training sets to establish the DA-BP business English classroom teaching evaluation model; the last four groups of data are used as test sets to test the DA-BP business English classroom teaching evaluation model. correctness. DA algorithm parameters; dragonfly population size $N=10$, maximum iteration number $T=100$, DA-BP model business English classroom teaching evaluation results are shown in Figure 2.

In order to verify the accuracy and effectiveness of the DA-BP model, DA-BP is compared with GA-BP, PSO-BP, and BP. Population size $N=10$, learning factor, search interval $[-1, 1]$. Genetic algorithm (Genetic Algorithm, GA) algorithm parameters: population size $N=10$, maximum

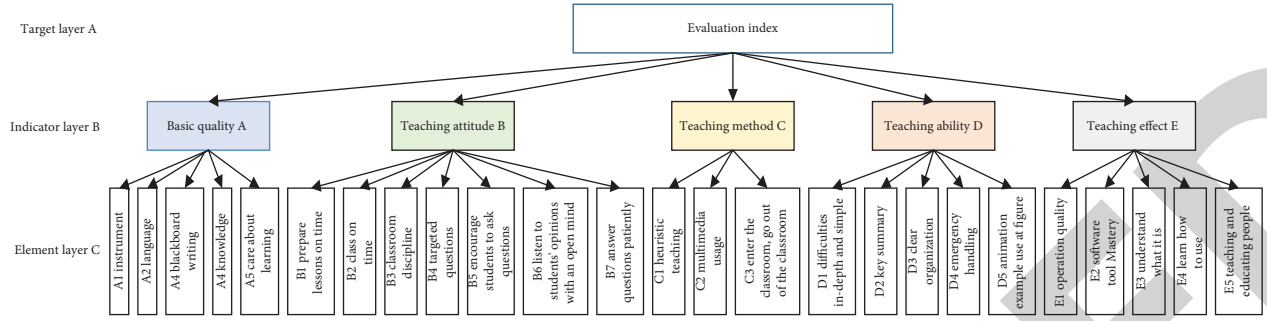


FIGURE 1: BE classroom teaching quality measure index.

TABLE 2: Scores of evaluation indicators of ideological and political teaching quality.

Index serial number	12	13	14	15	16	17	18	19	20	21
1	0.0255	0.0328	0.0455	0.0575	0.05	0.0608	0.0974	0.1065	0.1353	0.1467
2	0.1149	0.1218	0.1496	0.1694	0.1488	0.132	0.1795	0.1694	0.2058	0.2113
3	0.1658	0.1755	0.1796	0.1832	0.1895	0.1966	0.1977	0.2431	0.2543	0.2866
4	0.1622	0.1851	0.1956	0.1977	0.2044	0.2044	0.2473	0.2536	0.2611	0.2601
5	0.2194	0.2395	0.2155	0.1881	0.1662	0.1555	0.1572	0.1572	0.2778	0.2868
6	0.0485	0.0485	0.0534	0.0728	0.103	0.1068	0.1313	0.1563	0.1845	0.1894
7	0.0361	0.0373	0.0427	0.0553	0.0808	0.1097	0.1388	0.1598	0.1758	0.2182
8	0.0565	0.0556	0.0543	0.0687	0.084	0.0916	0.1034	0.1026	0.1132	0.1163
9	0.0336	0.052	0.0741	0.0702	0.0661	0.0756	0.0925	0.0944	0.0898	0.1025
...
24	0.05	0.0747	0.0605	0.0584	0.0612	0.0586	0.0584	0.0833	0.1115	0.1455
25	0.1097	0.1311	0.1212	0.1028	0.0425	0.0467	0.0602	0.072	0.0894	0.1137
26	0.013	0.0155	0.0237	0.0237	0.0357	0.0385	0.0517	0.0655	0.0877	0.1156

TABLE 3: Classification of evaluation grades.

Corresponding score	Evaluation results
(4.3, 6)	Very good
(3.5, 4.1)	Better
(2.5, 3.5)	Generally
(1.9, 2.5)	Poor
(1, 1.7)	Very bad

number of iterations = 100, crossover probability $P_c = 0.7$, mutation probability $P_m = 0.1$; BP neural network parameters are set as follows: input layer nodes inputnum = 25, hidden layer nodes The number hiddennum = 50 and the number of output layer nodes outputnum = 1, the maximum training times of the BP neural network is 1000, the transfer functions of the hidden layer and the output layer are logsig and purelin, the training function is trainlm, and the learning rate is 0.01. The comparison results of different algorithms are as follows shown in Figure 3 and Table 4.

As shown in Figures 3 and 4: (1) in the general education English level assessment, Improved DA-BP scores were higher than others. BP has the smallest mean square error and the largest correlation coefficient r , which shows that the Improved DA-BP Business English learning evaluation model is most relevant, and the effect prediction is the best; (2) The evaluation accuracy of DA-BP, GA-BP, and PSO-BP is higher than BP. In the PSO-BP algorithm, the pace factor $C_1 = C_2 = 1.86$, initial and maximum inertia weights are set to $W_{in} = 0.8$, $W_{max} = 0.4$ and maximum velocity $V_{max} = 0.6$, respectively. The standard BP algorithm was used. In order to

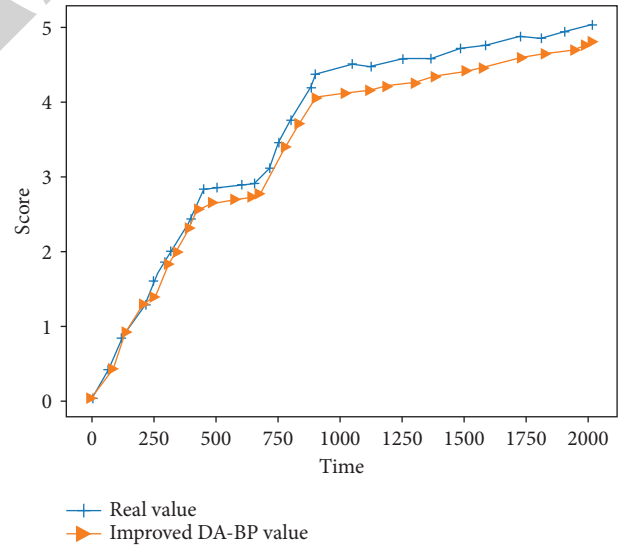


FIGURE 2: DA-BP business English teaching quality evaluation results.

accurately reflect the speed of the three algorithms, the mean square error (MSE) convergence trend of the three algorithms during the operation is compared, as shown in Figure 4.

Because BP is prone to improper initialization weights and thresholds when there is no other algorithm optimization, which will greatly reduce the speed of the BP algorithm. Whether it is PSO optimization or Improved-DA

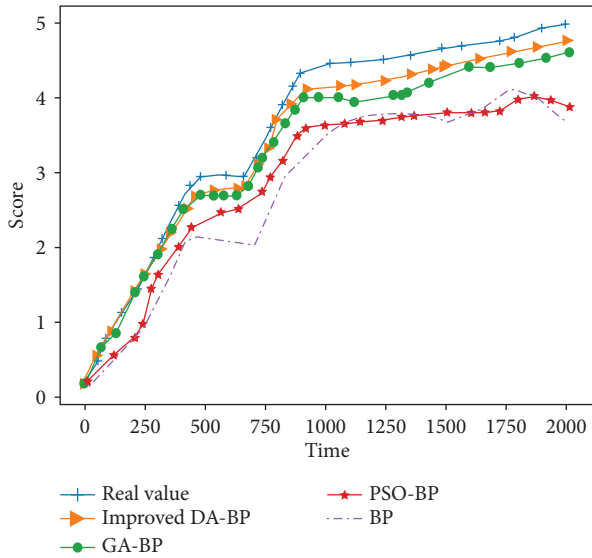


FIGURE 3: Evaluation results of ideological and political teaching quality with different algorithms.

TABLE 4: Comparison of evaluation results of different algorithms.

Method	Training		Test	
	RMSE	R	RMSE	R
DA-BP	0.0088	0.9955	0.0372	0.9892
GA-BP	0.0163	0.9777	0.0381	0.9732
POS-BP	0.0157	0.9774	0.0448	0.9652
BP	0.0187	0.9663	0.0483	0.9445

optimization, their purpose is to select the global optimal weights and thresholds, to improve efficiency while avoiding local minima. Improved-DA-BP algorithm than PSO-BP algorithm, the mean square error is smaller, because Improved-DA convergence accuracy and search ability are higher than PSO-BP algorithm, and PSO-BP algorithm there is premature convergence.

Finally, three algorithms are used to teach BE in the classroom, and the comparison between the prediction accuracy and the MSE calculated during the period is shown in Table 5.

4.4. Countermeasures and Suggestions Based on Teaching Evaluation. The recognition degree and distribution characteristics of the teachers' group for the teaching quality evaluation system in this paper are shown in Figure 5. It can be seen that the vast majority of teachers recognize the teaching evaluation model in this paper.

Through DA-BP course evaluation, it is of great help to improve the quality of business English classroom teaching, so the following countermeasures and suggestions are put forward: (1) strengthen the attention of university leaders and increase supervision; (2) innovate and improve teaching models and teaching methods; (3) fully motivate the main body of students; (4) strengthen student guidance according to the actual situation; (5) clarify the purpose, evaluation

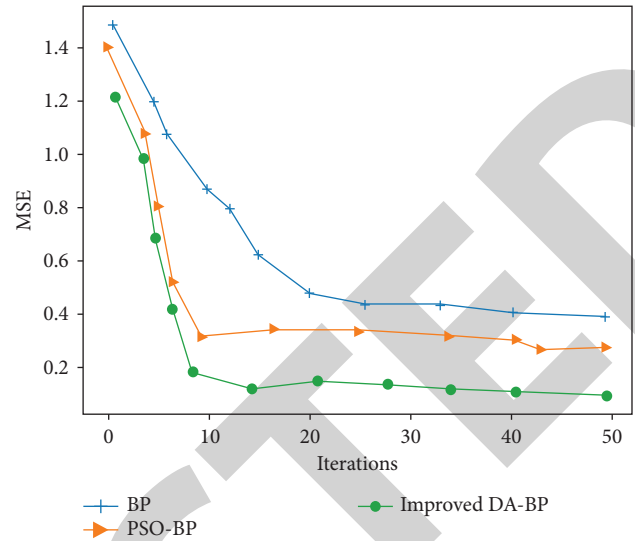


FIGURE 4: Comparison of MSE convergence of the three algorithms.

TABLE 5: Comparison of the accuracy and the best MSE of the three algorithms.

Parameter	Algorithm		
	EIDA-BP algorithm	PSO-BP algorithm	BP algorithm
Best MSE	0.0164	0.0188	0.0226
Accuracy (%)	98.2	94.5	88.1

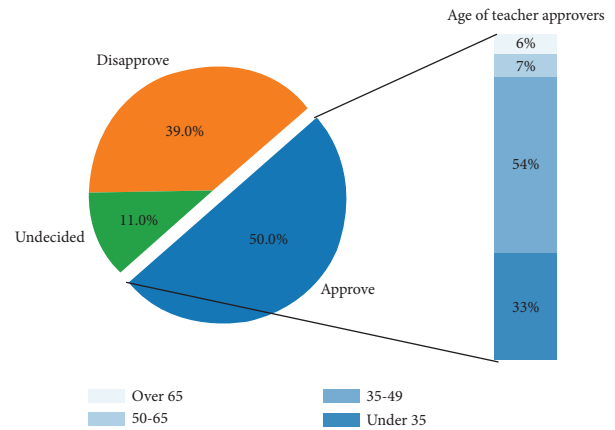


FIGURE 5: Teachers' recognition of this teaching quality evaluation system.

index and evaluation of teaching evaluation; (6) strengthen case teaching to improve students' comprehension and perception.

5. Conclusion

In order to improve the evaluation accuracy of business English classroom teaching quality, this paper proposes a business English classroom teaching quality evaluation method based on DA-BP. Based on the analytic hierarchy

process to construct the evaluation index system of business English classroom teaching quality, the 25 evaluation index scores that affect the quality of business English teaching in colleges and universities are taken as the input of DA-BP, and the comprehensive score of business English teaching quality in colleges and universities is taken as the output of DA-BP. The research results show that, compared with GA-BP, PS-BP, and BP, DA-BP can effectively improve the evaluation accuracy of business English classroom teaching quality and provide a new method and approach for business English classroom teaching quality evaluation.

Data Availability

The raw data supporting the conclusions of this article will be made available by the author upon request.

Conflicts of Interest

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

Acknowledgments

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Research Article

Teaching Design of English Writing Based on UMU

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With the development of time, traditional teaching methods cannot meet the needs of education and society for innovative talents. Blended learning conforms to the reform of education and teaching and is becoming the new normal of future education. Blended learning is a kind of teaching mode that integrates face-to-face teaching and online learning after people reflect on online learning to improve the learning effect. This kind of teaching mode that transcends the limitation of time and space brings great convenience to students and teachers. Blended learning can not only satisfy students' personalized learning style and the independent construction of personalized knowledge but also fully reflect the characteristics of students as cognitive subjects in the learning process. Compared with traditional education, blended learning pays more attention to the perspective of students and creates a truly highly participatory and personalized learning experience for students by using the Internet, mobile technology, and face-to-face teaching, which is the promotion and improvement of classroom teaching. In mixed learning in the Internet age, various online teaching platforms can provide students with diversified learning resources and learning methods. Supported by information technology, the UMU interactive learning platform provides independent learning methods, open learning space, and two-way interaction. The platform has the basic functions of online discussion, uploading and downloading learning resources, and submitting assignments. At the same time, it can be used on the Web and mobile phones to organize classes and interactions at any time. Teachers can create a variety of activities and courses on the platform and can also add interaction in the content link to improve the quality and experience of traditional education through mobile Internet technology.

1. Introduction

With the development of time and technology, information technology has already penetrated into all aspects of social life. Profound changes are taking place in people's production mode, lifestyle, and learning mode. In the Information Age, education for all, quality education, personalized learning, and lifelong learning are the main characteristics and objectives of education development. In recent years, many countries in the world have shown great concern about the important role of education informatization in the improvement of national quality and the enhancement of national innovation ability. With the rapid development of modern information society, society has higher and higher requirements for people's information literacy. Basic education is an important part of the project of improving national quality and also an important part of the development of national education. If we want to

cultivate information literacy on this basis, we must give full play to the important role of information technology discipline in the basic education stage. In the basic education stage, information technology education should keep pace with time, so that students can systematically master the basic knowledge and skills of the subject, and comprehensively improve students' information literacy to meet the needs of information society. In the basic education stage, information technology discipline plays an important role in improving students' awareness and ability to use their basic knowledge and skills to solve practical problems and handle information [1].

With the development of education, the disadvantages of the traditional teaching mode are gradually obvious [2]. The traditional teaching mode is "transmission acceptance" teaching. Although this mode can give full play to the leading role of teachers, and it is easy for teachers to realize the management, organization, and control of classroom

teaching, it ignores subjectivity, initiative, and creativity of students. Teachers blindly instill knowledge into students and make them passively accept it. For a long period, students are likely to lose interest in knowledge they have learned, and it is almost impossible to achieve the cultivation of divergent thinking, reverse thinking, and creative thinking, which is equivalent to a fundamental lack of foundations needed for the breeding and growth of innovative talents; it is difficult to achieve a relatively ideal teaching effect. This mode has long been unable to meet the needs of society for innovative talents and the development requirements of national education informatization. To cultivate talents who meet social needs, it is necessary to strengthen practical ability, innovate the way of education, start from basic education, reform the traditional teaching mode, pay attention to cultivating students' interest in learning, scientific interest, and innovation consciousness, and at the same time, strengthen the training of scientific methods, and gradually improve students' logical and dialectical thinking ability to meet social requirements [3].

The teaching ideas and methods are backward. In the basic concept of most English teachers, the basic purpose of English writing teaching is to enable students to "master" English knowledge and to mainly achieve a good result, but it does not take into account whether students have a basic understanding of English knowledge. Consequently, many students, even if they have "mastered" English knowledge, do not know how to learn English and do not know all kinds of learning skills, so the efficiency of students in learning English is very low. At the same time, under the pressure of the general environment in which the concept of examination-oriented education is the mainstream [4], in order to enable students to successfully enter the school and pass the examination, quite a number of teachers almost choose this cramming and rote English teaching method. The cramming teaching method also has some advantages. It can greatly reduce the teaching workload of teachers on the basis of ensuring the test results of students. However, it must be recognized that the cramming teaching method cannot adapt well to the fast-paced teaching state in the current educational environment [5]. At the same time, it has a great impact on the ontological interest of knowledge and will hinder the good cultivation of students' learning interest. In addition, teaching refers to "teaching" + "learning," which deviates from the essence of teaching and seriously affects our teaching efficiency.

At present, "Internet +" has become the mainstream of society [6]. Cloud computing and big data technology have an extraordinary impact on various fields, and education naturally cannot be separated from these means. Nowadays, under the information-based teaching practice of schools, the traditional classroom has been gradually pushed to the direction of digitalization, intellectualization, and mobility from the initial role as an auxiliary tool to the deep integration of information technology and curriculum. Many schools have opened and used intelligent multimedia teaching rooms, e-book bags, learning intelligent mobile terminals, etc. From this, we can see that the Internet era is gradually moving towards mobile Internet. The UMU

interactive learning platform has injected new vitality into classroom teaching. In classroom teaching, classroom activities such as electronic check-in, question guidance and opinion voting, intelligent knowledge testing, efficient questioning and discussion, and group task-driven interactive teaching based on the UMU learning platform can greatly stimulate students' interest in learning. The practice shows that it is highly feasible and effective to carry out English writing teaching in the information-based teaching environment based on UMU, which can guide students to think actively and participate actively and improve the effect of classroom interaction teaching. Therefore, the author thinks about classroom interactive teaching supported by information technology, in order to promote deep integration of information technology and curriculum teaching.

Under the above background, this study takes the network-teaching platform as the main basis and combines the unique functions of the UMU interactive platform to apply the learning platform to English writing teaching. In order to improve students' English writing performance and explore the impact on teaching, we cultivate students' active learning attitude. At present, there are not a few cases of teaching research based on online teaching platforms such as Moodle [7] and blackboard [8]. In recent years, various learning platforms, such as Rain Classroom, Blue Ink Cloud Class, learning link, and enterprise WeChat, have gradually been loved by teachers and students and applied to the classroom. However, there is little research on the UMU mobile learning platform, and the research on the theoretical basis and application mode is not deep enough. By absorbing the essence of traditional English writing teaching design and combining the functions of the microvideo, check-in, and questionnaire on the UMU interactive learning platform, this study summarizes a new English teaching mode based on the UMU interactive learning platform, enriches the relevant theoretical content, greatly develops the English teaching design, and is more convenient to provide a theoretical basis for the use of UMU in English writing learning and promote the deep integration of information technology and subject teaching.

2. Relevant Concepts and Theoretical Basis

2.1. Related Concepts

2.1.1. English Writing Teaching. As a branch of the West Germanic language [9], English was spread to all parts of the world through the early British colonial activities and had a far-reaching impact. So far, English has become the official language of many countries in the world. With the further development of economic globalization, the world is connected and the use of English has further expanded. China has always attached importance to English education. English is one of the three major subjects in China's compulsory education stage and even the whole education stage, which has trained a large number of talents for China to move towards globalization and internationalization. English writing is a form of communication and information transmission in the process of English learning. It is an

important part of the English language and an important part of English teaching.

2.1.2. Network Teaching Platform. A network teaching platform is an important way to deeply integrate information technology and subject teaching and to promote the development of education with modern information technology. It makes the teaching process open, interactive, and cooperative. In recent years, with the in-depth development of intelligent education, the teaching platform actively integrates advanced information technology, presenting the characteristics of digitalization, networking, and intelligence. The network teaching platform came into being. The network teaching platform is an integrated teaching service system that connects online and offline paths and integrates services such as teaching, inquiry, discussion, homework, and testing and evaluation. The emergence and application of the network teaching platform have made a variety of intelligent and personalized teaching services such as multi-interaction in the classroom, real-time sharing of resources, anytime and anywhere learning, online testing and evaluation, personalized teaching based on big data, and students' independent learning. It is simple and easy to operate. As long as teachers and students or classrooms are equipped with intelligent terminal equipment that can carry the network teaching platform, the above network teaching process can be realized.

2.1.3. UMU Interactive Platform. A UMU interactive platform is an intelligent teaching platform developed by Beijing Youmu Technology Co., Ltd. which is dedicated to innovative teaching methods and redefined knowledge sharing and dissemination of learning. It is the abbreviation of you, me, and us. It advocates the interactive and open learning concept that everyone can learn and everyone can teach. Knowledge production is decentralized, and everyone is the disseminator of knowledge. The UMU interactive platform is characterized by interactivity, openness, sharing, collaboration, and intelligence.

2.2. Theoretical Basis

2.2.1. Constructivist Learning Theory. Constructivism theory is a systematic and complete learning theory gradually developed by Piaget and Vygotsky and others on the basis of criticizing and inheriting cognitive theory. It is one of the most influential learning theories in the contemporary era [10, 11]. Constructivism theory includes three aspects: knowledge view, learning view, and student view. A constructivist learning view holds that knowledge is a kind of cognition or hypothesis about the objective world, which will change with the change of objective existence. The constructivist learning view holds that learning is not rote and superficial cognition but a process of thinking collision and knowledge reorganization. When encountering new knowledge, students are required to connect with existing

knowledge and transfer knowledge and gradually understand and finally reach recognition.

2.2.2. Mixed Teaching Theory. Hybrid teaching is a teaching method that combines online teaching with traditional face-to-face teaching with the support of modern information technology [12] and combines "online" and "offline" teaching. Hybrid teaching is not only a simple change in teaching form brought about by adding online classroom to traditional face-to-face teaching but also a simple change in teaching form. After formulating teaching objectives, clarifying teaching contents, and analyzing teaching needs, it makes use of the advantages of face-to-face communication of traditional face-to-face teaching and open sharing of network online teaching to learn from each other's strong points and complement each other's weak points, so as to promote the improvement of teaching efficiency and teaching quality.

2.2.3. Learning Engagement Theory. Learning engagement was initially a concern and field of western scholars, studying the causal relationship between students' academic performance and their degree of learning engagement [13]. The theory of learning input generally believes that students must make enough behavior input to produce good learning results. For behavior input, psychological input is required. Psychological input can be divided into psychological cognitive input and psychological emotional input. Cognitive and emotional input depends on behavior input. When the input of behavior, emotion, and cognition tends to be unified and positive, the learning effect is the most ideal.

2.2.4. Master Learning Theory. Bloom and other educators put forward the theory of mastery learning in the 1960s [14]. Benjamin Bloom was a famous American psychologist and educator. He believed that almost all children can become excellent students. In short, the learning ability of different students is not the same. Whether the learning content can be mastered and whether the learning effect is good or bad do not depend entirely on the learning ability of students but depend on the length of time that students need to spend on a certain learning content. When a student finds learning conditions they like, the learning guidance that conforms to their own situation, and the corresponding learning time, they can master the knowledge they need to learn. The teaching process of mastering learning theory mainly includes the following steps: (1) student orientation: before the new learning task begins, the teacher needs to clearly convey learning objectives to students, stimulate students' goal awareness, and affirm their ability. (2) Give lectures: teachers teach through collective teaching and set the same learning time for each student. (3) Presentation errors: After teaching, the teacher will give an in class test, i.e., formative evaluation, to obtain the students' learning situation in time and know which students have not fully mastered and which students have learned the previous teaching contents. (4) Correct mistakes: Teachers teach those students who have

not fully mastered the knowledge and correct their mistakes according to feedback information obtained before, while those who have learned can choose to continue to learn the previous knowledge to consolidate the foundation or can choose to enter the next step to learn new knowledge. (5) Reevaluation. The students who fail to master the test will be given a chance to take the second test. The students who meet the standard will directly learn the next unit of knowledge, and the students who fail to pass the test will learn again. The idea of mastering learning theory is in line with the idea of teaching students according to their aptitude, but it is highly personalized, and it also puts forward higher requirements for students' initiative. It has obvious limitations in use and is not applicable to the existing teaching mode.

The UMU platform can integrate preclass, in class, and after class. Before class, teachers send microclass videos for students to preview, including voice explanations and videos. They can also design some small questions to test some students' mastery. In class, students interact with the teacher with questions. After class, students can see their mastery through homework. In this way, as long as there is enough learning time and guidance, students can quickly grasp the key and difficult points.

3. Teaching Design Based on the UMU Platform

3.1. Application Foundation of the UMU Interactive Learning Platform in English Teaching. The UMU interactive learning platform is a learning platform that includes multiple roles and is specially designed and arranged for students' learning. It has the characteristics of interaction and mobility and can realize the interaction between machines and people and the interaction between people. The UMU interactive learning platform has a lot of functions, including microclasses (mainly audios, videos, and live microclasses) and various interactions in the classroom (classroom discussion, learning questions, student examinations, and student daily check-in). From classroom upgrading to blended learning to online community learning, UMU promotes the revolution of learning.

English is characterized by humanism and instrumentality, which can enhance the interaction between people. Therefore, the use of the UMU platform can increase its interest. With the wide application of the learning methods of network learning, the learning field has gone out of the classroom. Through various network learning platforms, students can learn independently on the network. Through the network learning platform, students can arrange the time and place of learning themselves, arrange their own learning reasonably, and make learning more personal.

At present, according to the statistics from CNKI, researchers have practiced many intelligent online teaching platforms, including Rain Classroom, Blue Ink Cloud Class, and WeChat public platform. At present, the widely used online learning platforms are Rain Classroom and Blue Ink Cloud. They are online real-time teaching management platforms that appeared on the early Internet. However, for UMU, its interactive learning platform is new, mainly

relying on the mobile Internet, so it mainly shows mobility and interactivity. In addition, the platform is still in practice research, not widely used in teaching.

The biggest advantage of the UMU interactive learning platform over Rain Classroom and Blue Ink Cloud Class is that the UMU interactive learning platform is more interactive, and the microclass function is not available in other software. Nowadays, the use of microclass teaching has become a teaching tool for every teacher. The UMU interactive learning platform conforms to this development trend and fully increases the design of teaching resources, which is an advantage that Rain classroom and Blue Ink Cloud Class do not have. Once students start to use the mobile terminal to log in and learn, teachers can start to interact with students through their own UMU. In this app, students' real-time learning status can be monitored at any time, and online teacher-student exchanges and student-student exchanges can be conducted to increase the positive interaction in the classroom. Moreover, the platform does have strong advantages in mobile interaction. It can conduct classroom interaction through code scanning at any time and complete daily interaction between teachers and students through daily sign in, discussion after class, question and answer, questionnaire, information on the wall, etc. Now teachers and students can teach and learn through this platform, which is popular among the public.

3.2. Construction of the Teaching Mode Based on the UMU Platform. The teaching mode refers to a relatively stable teaching activity structure and activity procedure established under the guidance of certain teaching ideas or theories [15]. The teaching mode usually takes the form of a structural framework, which often conveys a certain teaching idea and teaching theory. The teaching structural framework and teaching procedures formed by different teaching ideas and teaching theories are also diametrically opposite, and the effects on teaching are also different. A new teaching idea can be improved in the actual process only under the promotion of a certain teaching mode, and then, a relatively perfect teaching model can be produced. According to the concept and definition of a teaching mode, the following design is carried out based on the UMU interactive learning platform, as shown in Figure 1.

3.3. Preliminary Analysis

3.3.1. Learning Demand Analysis. Learning needs mainly examine and analyze the gap between the current level of learners and the level that can be reached after efforts. This gap is mainly analyzed from the dimensions of knowledge, skills, emotions, and attitudes. Through the questionnaire survey, we learned that the learners' basic use of UMU is very limited and they do not know much about these online intelligent learning platforms. However, they are very open and active in accepting such apps, and their acceptance is relatively high. I am familiar with similar online applications. The students also have high evaluation and good feedback. The students' evaluation of these applications is

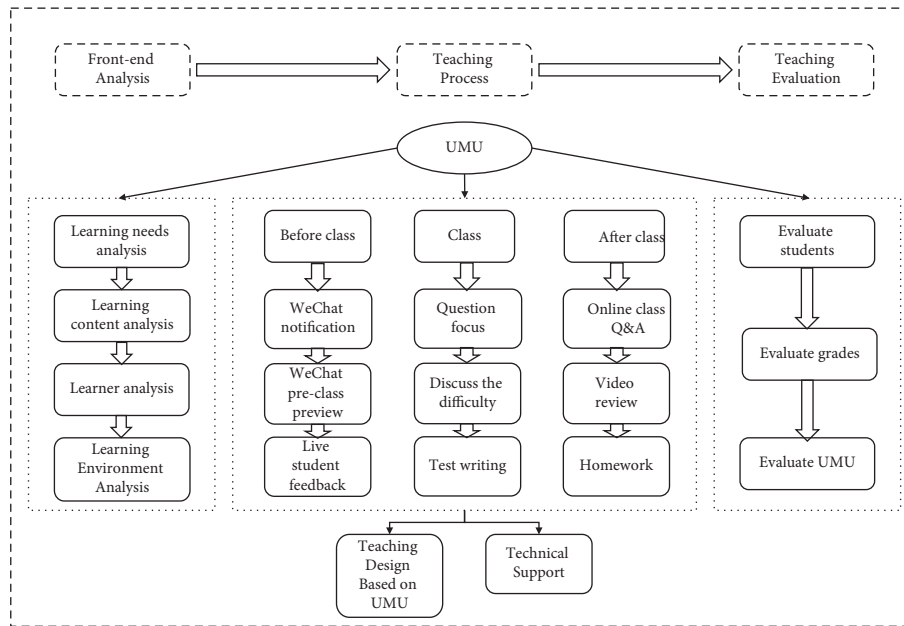


FIGURE 1: Teaching mode design based on the UMU platform.

also very high, and the feedback after use is also very good. For this kind of online teaching to be put into use in daily English courses, everyone's enthusiasm is still very high, and their expectations are also high.

3.3.2. Analysis of Learning Contents. After systematic learning, learners can acquire a lot of knowledge, practical skills, and various experiences, which are called learning contents. Learners learn the learning content mainly by improving their personal ability. Depth analysis of the learning content is based on understanding learners' learning expectations in depth after analyzing learners' learning requirements, so as to determine the difficulty of the learning content for the learners. Analyzing learning content is an indispensable part of instructional design. In general, it is necessary to analyze learners' learning content before instructional design.

English writing in the traditional classroom often lacks communication between teachers and students [16], which is difficult to fully mobilize students' enthusiasm, and the interaction between teachers and students is limited after class. Through the effective application of the UMU interactive learning platform in the learning content, especially in the dialogue, we can better change the current situation of English learning.

3.3.3. Learner Analysis. Before teaching, it is necessary to understand and analyze learners [17] and to understand the previous experience, existing knowledge level, learning psychology, characteristics, style, etc., of learners, so as to formulate a distinctive teaching plan according to needs of learners, so as to achieve scientific teaching.

Students are in the transition period of English learning. They have a certain English foundation and ability and have

a certain perception of contents of textbooks, and they are in adolescence, curious about new things, and good at quick thinking and accepting new things.

3.3.4. Analysis of Learning Environment. The so-called learning environment, in essence, refers to the external conditions that can have an impact on learners' learning. In a good environment, it can help cultivate learners' learning ability and also help learners to actively construct knowledge. Learning environments can generally be divided into physical and technical environments [18]. Physical environment mainly includes some physical resources such as class capacity, basic furnishings and decoration design of the classroom, and teaching teachers. These physical resources are closely related to the teaching mode used by teachers in teaching and will have a certain impact on the actual effect of teaching. For example, whether it is conducive to collaborative learning between groups in the actual learning environment. It is also important whether the learning model being explored can be carried out normally.

3.4. Teaching Process and Activity Design

3.4.1. Preclass Preview

(i) *Questionnaire Survey.* Before the beginning of the course, students should be investigated. This requires the use of the self-contained questionnaire function of UMU to investigate students' learning attitude, classroom interaction, and understanding of UMU [19]. After students submit questionnaires in class, the survey results can be put on the large screen in real time, which is clear and convenient for teachers to carry out teaching activities.

(ii) *WeChat Invitation* [20]. It is very simple for students to participate in the interaction and learning of UMU. Learners

and teachers build groups opposite each other in the classroom. After returning home, the teacher sends the UMU invitation code to the group. Participants do not need to download the mobile app and can participate by scanning the QR code or visiting the website link. Each interaction and course has a unique two-dimensional code and can be invited to participate in the course. When students enter the UMU learning group, they can sign in and punch in and discuss with the teacher about problems they do not understand, and the teacher can also supervise students to preview before class.

(iii) *Use UMU to Make Microlessons.* UMU microclass is the world's first microclass mode that can be taught by everyone [21]. Each UMU microclass supports up to 9 lecture notes and 5 minutes of voice content, and the production of the UMU microclass can be mastered in 3 minutes. The learning flow consumption of each UMU microclass is less than 1m, which is suitable for most weak network environments. Students can play smoothly through mobile phones and computers and participate in learning anytime and anywhere. Before class, teachers can share the content of the next day's lecture on the platform for students to preview. Because the microclass has a voice function, students can watch the PPT while listening to the teacher's explanation. The development of microcourses is generally divided into four steps, as shown in Figure 2:

(iv) *Live Broadcast Using UMU.* The teacher sets the time for previewing the PPT and then shares the link to the group. Students open the live broadcast and video with the teacher at the specified time and communicate and discuss with the teacher what they have just previewed. If only one or two people do not understand, the teacher can explain in the video. If mmcl is a topic that everyone does not understand, the teacher can write down the key points to explain in class tomorrow. This method is convenient for supervising students' preclass learning and also allows students to grasp students' preview at any time. The live broadcast can be played back. If some students do not join on time, they can also log on to the platform for playback. Teachers can view the completion of students in the background app for easy detection. This way of the live broadcast can shorten the distance between teachers and students and make the monitoring of a preview effect more authentic than the way of simply letting students read messages and write comments.

3.4.2. Discussion in Class

(1) *Game Opening.* Computer and mobile app invite to participate. Large screen QR Code: in the classroom, you can participate in the interaction through the large screen QR code. Through UMU, you can have a more novel warm-up and opening and orderly and efficient question interaction. (2) *Initiate Interactive Discussion.* What do you want to say? What is your biggest feeling? What do you think is the importance of? What problems do you think should be paid



FIGURE 2: Development process of the microclass.

attention to? After students publish their answers on the platform, teachers can review them. In this way, not only can every student participate in the discussion activities, but also students can answer questions carefully to avoid perfunctory work. The teacher can choose to reply or reply to the microclass.

(3) *Initiate Interactive Questions.* At the end of class, after the teacher has finished the important knowledge points, students can ask questions. Some students are often ashamed to speak up or dare not ask questions to the teacher because of poor grades. The teacher can use the platform to check what students do not understand in class. For example, it is time to ask questions. Welcome to ask questions: do you have anything to ask the teacher about the topic? In this way, the problems can be solved in the class, and the problems will not be left after class.

(4) *Take Photos on the Wall.* Through the UMU platform, students and teachers can share photos on their mobile phones to the large screen to realize the rapid and real-time sharing of photo content. This way of sharing photos can often be used to show students' homework or to show discussion notes, etc., and the classroom is made more lively by allowing students to share photos, tell a story, and discuss a topic, thereby attracting their attention. It is suitable for a small topic, small knowledge points, and grammar items in English. It requires students to take the form of individual or group cooperation, make it before class, and display and summarize it in class, such as making posters.

3.4.3. *Consolidation after Class.* (1) *Job Settings.* In the operation phase, students can submit audio, video, and graphic assignments. Teachers can assign homework and put forward homework requirements through a paragraph of text in the homework link [22]. Students need to use the app to edit and submit assignments. Students can use pictures and words to create an article in the homework link, or use pictures and voice to form a dynamic audio with pictures, or shoot a video to submit as homework. Teachers can comment on the submitted homework at any time.

(2) *Video Sharing.* Teachers can share some videos suitable for English learning and course content from Tiktok or English learning websites and send them to students for learning activities in entertainment.

3.5. *Teaching Evaluation Design.* According to set teaching objectives, data analysis is conducted on various relevant data and teaching information involved in the teaching process, so as to make value judgment on the actual effect of teaching, true learning attitude of learners, and learning behavior of learners. The judgment process is called teaching

evaluation [23]. Teaching evaluation is an important feedback link in the learning system, which can play an important role in checking learners' learning results and encouraging and promoting learners [24]. The subjects of teaching evaluation are relatively diverse, but the main evaluation subjects are teachers and learners, and the evaluation objects are mainly students and the UMU platform. Formative evaluation and summative evaluation are mainly used to evaluate learners. The two are organically combined. Formative evaluation is mainly used in this process because the feedback of formative evaluation is given on time and can supervise the learning process in real time. In UMU interactive learning platform, formative evaluation is mainly tracked through discussions, questions, examinations, etc. Summary evaluation is mainly aimed at the final results of the final examination and the students' learning attitude. For the UMU learning platform, it is mainly to evaluate students' satisfaction after using the platform and the degree of interaction on the platform.

4. Conclusion

The teaching design of English writing based on the UMU interactive learning platform breaks through the limitations of traditional teaching. The new teaching mode is combined with the traditional teaching mode, giving play to the advantages of the UMU interactive learning platform. For example, whether it is conducive to collaborative learning between groups in the actual learning environment. It is also important whether the learning model being explored can be carried out normally. At the same time, based on the UMU platform, teachers can conduct data analysis and statistics at any time before, during and after class, so as to give feedback at any time, adjust teaching strategies, and give overall guidance to the teaching process. Educational researchers are constantly exploring new educational and teaching methods. Starting from the most traditional face-to-face teaching, there are gradually various forms of online learning. These intelligent teaching methods have gradually changed our traditional concept of class and provided us with new teaching tools. By designing an English writing platform based on UMU [25], the author makes the following summary:

- (1) The popularity of the network and network equipment has increased the learners' acceptance of the UMU interactive learning platform, and most students can actively participate in the classroom.
- (2) For students, after the teacher releases the curriculum on UMU, students must pay attention to it and actively conduct teacher-student interaction, so as to better complete the predetermined learning objectives and better master the key knowledge. The submission status and the number of students on the list will be displayed on the large screen in real time, which helps teachers give timely feedback.
- (3) For teachers, using UMU will increase the workload of teachers, but at the same time, teachers are constantly encouraged to carry out classroom

innovation. Through reasonable and full use of various activities of the platform to carry out diversified teaching design, the traditional boring classroom will gradually turn to vivid, lively, and interesting, and it also has the function of performance detection and calculation, which can be counted as a part of the usual performance. It can see the completion of students at a glance and can also see the participation and completion percentage of students, so as to adjust teachers' teaching ideas.

First of all, students are the participants in the whole teaching process. They play a very important role in teachers' teaching and are also an important factor. The brand-new teaching method and the brand-new use of network equipment enable students to have a brand-new interest in the classroom. The key is to improve self-control ability, resist the temptation of the network, enhance the stability of attention, focus on classroom learning, and actively participate in classroom group discussions and questions. Teachers should take appropriate reward and punishment measures to punish students who do not cooperate in class or play mobile phones. Second, the teaching based on the UMU interactive learning platform is based on the mobile network equipment, which must be affected by the network. If the network environment is not good, it will inevitably affect the normal class progress, and it is difficult to ensure normal teaching work. Finally, the use and practice of the UMU interactive platform can effectively increase the interaction between teachers and students and inject new impetus into the whole class. However, it must be noted that this method is not applicable to all courses, so we must make a good choice, because if we make a wrong choice, it will cause great obstacles to teaching work. Therefore, teachers should reasonably choose whether to use this method for teaching according to the objectives and requirements of the curriculum. How to deeply integrate the contents of English textbooks and activities, and give better play to the work of the UMU interactive learning platform, is what educators need to consider and reflect in the future.

It has become an inevitable trend for information technology to enter the traditional classroom under the background of the current network era. It is imperative to improve the traditional teaching mode by using information technology. As a relatively new intelligent teaching tool, the UMU interactive learning platform is more and more used in classroom teaching because of its interactivity and the diversity and openness of activity design. However, we must constantly improve its internal functions, constantly acquire experience in practice, make its performance more optimized, and make better services for teaching work, so as to achieve the goal of teaching informatization. In the future, there will be more scholars and researchers participating in the informatization of education, which can really make practical contributions to the informatization of education, make good guidance for the informatization of education, provide better technology, and lay a solid foundation for the informatization of education. At present, artificial intelligence technology has been gradually applied to various fields

[26–29] and will have more extensive development in the field of education in the future.

Data Availability

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

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Research on the Evaluation of Ecotourism Resources: Based on the AHP Model

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The comprehensive evaluation of ecotourism resources in the Qinling Mountains scenic spot using the AHP method can provide a reference for the sustainable construction and development of ecotourism resources, as well as the development of other tourism areas. Based on the analytic hierarchy process, the evaluation system of Qinling Mountain Ecotourism Resources is constructed, and the construction system is used to evaluate tourism ecological resources. The results show that, among the subtarget levels, the highest score is the interaction of tourism areas in the same region and the second is the applicability of regulations. These two indicators have a high impact on the score of Qinling Mountain Ecotourism Resources. In the project layer, the source of passenger flow has the largest weight, which is 0.1717, and the distribution of resource types has a smaller weight. At the index level, participation needs to be considered for tourism participation design. The Qinling scenic area has high historical and cultural value, diverse resource types, good tourist source market conditions, and great tourism development potential. However, problems exist, such as low resource aggregation and imperfect tourism supporting facilities development. It is necessary to develop ecotourism resources on the premise of ensuring environmental quality while taking into account the in-depth excavation of the experience and ornamental values of tourism resources, establishing the tourism characteristics of scenic spots from many aspects, such as improving tourism participation.

1. Introduction

Ecotourism refers to tourism based on ecology. Attention is mainly focused on natural and cultural resources, such as scenic spots, fossil-producing areas, archaeological or historical sites, and wild animals and plants, especially rare and endangered species [1–4]. The development of ecotourism in the Qinling Mountains is mainly divided into mountain tourism and forest tourism resource development [5, 6]. Among them, mountain tourism resources refer to the ecotourism areas built mainly in the mountain environment, which are suitable for mountaineering, exploration, rock climbing, sightseeing, and other activities. Forest tourism resources refer to the ecotourism areas built mainly on forest vegetation and its habitat, which are suitable for camping, vacation, recuperation, and other activities [7–9].

The construction of ecological civilization is the cornerstone of the development of ecotourism and the sum of the material and spiritual achievements made by the managers of tourism areas to follow the law of harmonious development between man and nature and promote the development of society, economy, and culture [10–12]. It is an ecotourism cultural ethics form with the basic purpose of harmonious coexistence, all-round development, and sustainable prosperity between man and nature and between man and man. It will play an important role in the long-term development of ecotourism areas in the future [13–15]. Ecotourism in scenic spots is not only to meet the growing needs of the public for high-quality ecological recreation, but also an important way to enhance the scenic spot's own capacity-building, expand the source of protection funds, promote sustainable development, increase community

economic income, and drive economic development [16, 17]. In order to carry out ecotourism in scenic spots, the primary task is to evaluate the ecotourism resources in scenic spots. From the perspective of reasonable development, utilization, and protection of ecotourism resources in scenic spots, we can comprehensively evaluate and identify the value of ecotourism resources and their external development conditions in a certain area. The evaluation of ecotourism resources in scenic spots is a more in-depth research work based on resource investigation [18, 19]. It is also the premise of the development of ecotourism resources.

Due to the diversity, regionality, seasonality, and other characteristics of tourism resources, in order to better tap the characteristics of various tourism resources, further enhance the attraction of tourism resources, and protect them while reusing them, it is necessary to make scientific and reasonable planning of tourism resources to realize the sustainable utilization of tourism resources, the effective development of tourism destinations, and the three benefits of tourism industry [20–22]. Tourism planning refers to the full excavation and protection of tourism resources and the rational planning and layout of tourism destinations based on the scientific evaluation of tourism resources; the characteristics of tourism resources and the natural, social, and economic environment of tourism destinations; and the use of planning ideas [23–25]. The basis of ecological activities is the development of ecotourism resources, and the premise of development is the planning of ecotourism resources. As a subordinate classification of tourism resources, ecotourism resources belong to natural ecological environment tourism resources. In addition to the characteristics of the above tourism resources, ecotourism resources are vulnerable and nonrenewable [26, 27]. In addition to traditional tourism planning, the planning of ecotourism resources should be guided by the principles and methods of ecology.

In recent years, with the rapid development of tourism and the arrival of the era of global tourism, more small towns have joined the tourism industry [28]. A series of problems such as environmental pollution, resource destruction, and chaotic development of small towns in the development of tourism have become increasingly prominent, which has led to the decline of economic benefits, the downturn of social benefits, the degradation of the ecological environment, and other adverse consequences of tourism destinations and even forced the closure of tourism destinations. The reason is that, in addition to effective planning and management of tourism destinations, it is more important to take the path of sustainable development. At the same time, many scholars are focusing more on ecotourism. From the existing research direction of ecotourism, most of the research focuses on the development mode of ecotourism, existing problems, and countermeasures. Many studies classify the characteristics of ecotourism resources, but most of them integrate and reorganize the existing materials and resources, mostly focusing on the introduction of ecotourism-related situations [29, 30]. There is relatively little literature evaluating ecotourism from the perspective of practical statistical data. The analytic hierarchy process (AHP) is one of the most commonly used methods for tourism resource evaluation at

present, through comprehensively considering the factors affecting the evaluation results in the early stage and constructing the evaluation model of the interaction of indicators at all levels in the medium term to structure and organize complex problems and then put forward the optimal scheme.

Therefore, based on the research results of domestic and foreign scholars on ecotourism, this paper creatively uses AHP to build a comprehensive evaluation model and evaluation index system of ecotourism. Taking the Lishan scenic spot in Xi'an, Shaanxi province, as an example, this paper investigates and evaluates the ecotourism and historical and cultural resource elements, environmental characteristics, and development conditions in this area; finds out their improvements through weight analysis; provides scientific improvement suggestions for them; and provides a scientific basis for the development, construction, and management of scenic spots.

2. Problems in the Development of Ecotourism Resources

2.1. Lack of Scientific Planning. Ecotourism is different from traditional tourism and has strict requirements for environmental protection. The development of ecotourism in the nature reserve is carried out without destroying the natural environment. In the development process, we should not destroy the natural development law of the reserve and the local social order and should maintain ecological, sustainable development. During the ecotourism development of the Minjiang source reserve, there was no in-depth study on the ecosystem of the reserve, the development of scientific research and monitoring level was slow, the possible environmental impact and environmental carrying capacity were not evaluated enough, and there was a lack of scientific basis and technical means. In many areas, the development of ecotourism is in a disorderly state, and there are no detailed investigation and planning of scenic spot routes, resource assessment, and environmental monitoring and protection, which hinders the development of ecotourism.

2.2. Inconvenient Transportation. Qinling nature reserve is located in the Qinling Mountains, and the road is long and difficult to travel. The traffic construction of many reserves is insufficient. There are only a few forest roads and pedestrian trails, and vehicles cannot pass through. As a result, much beautiful scenery is seriously affected by the poor traffic, and even some places cannot be reached by manpower, wasting tourism resources. The original scenic spot is shown in Figure 1.

2.3. Imperfect Service Facilities and Institutions. After years of development, although some nature reserves have established professional ecotourism organizations, they are only limited to famous scenic spots, and there are no special service institutions in most nature reserves. The number of service facilities and places in Minjiangyuan nature reserve is small, which cannot meet the needs of tourists, causing great inconvenience to them and affecting the visit to the scenic spot. At the same time, the shortage of service facilities has



FIGURE 1: Natural scenery of Qinling Mountains.



FIGURE 2: Geographical location of Qinling Mountains.

also affected the economic income of the scenic spot. The maintenance of the scenic spot lacks funds, which is not conducive to the sustainable development of the ecology.

2.4. The Investment Mechanism Is Not Smooth. The financial budget has not been included by the government in the development funds of ecotourism development in the nature reserve. The nature reserve lacks a stable source of funds and operation management, the management personnel are unreasonable, and the management personnel of the nature reserve are too few to manage and maintain the nature reserve in an all-round way. At the same time, the reserve has a lack of operating capacity, poor economic benefits, and a lack of start-up funds for the construction of scenic spots and transportation and communication.

3. Overview of the Study Area

Qinling Mountains are east-west mountains across central China, starting from southern Gansu in the west, passing through southern Shaanxi to western Henan. The main body is located at the junction of Southern Shaanxi province and Northern Sichuan province. They are east-west, about 1,500 km long, 150 km wide from north to south, and mostly

1,500–2,500 m above sea level. It is the watershed between the tributaries of the Yellow River and the Yangtze River, Jialing River, and Han River. Qinling Mountain–Huaihe River is an important north-south dividing line in China's geography, and Qinling Mountains are also honored as the dragon vein of the Chinese civilization. Qinling Mountains are rich in mountain and forest tourism resources, determined by the unique geographical location and distinctive characteristics of the Qinling Mountains. In the middle of China's territory, Qinling Mountains is the highest mountain in the East since then, and it is also the only mountain in the east-west direction. In the eyes of geographers, Qinling Mountains are the dividing line between the south and the north and the watershed of the Yangtze River and the Yellow River. In the eyes of zoologists, the Qinling Mountains are divided into the Palaearctic and the Oriental realms, where two distinct animals meet and merge. In the eyes of climatologists, the Qinling Mountains are the transitional zone between the northern subtropical zone and the warm temperate zone. In the eyes of writers, the Qinling Mountains and the Yellow River have become the father mountain and mother river of the Chinese nation. The geographical location of the Qinling Mountains is shown in Figure 2.

There has been a saying of seventy-two valleys in the Qinling Mountains since ancient times. Seventy-two valleys in

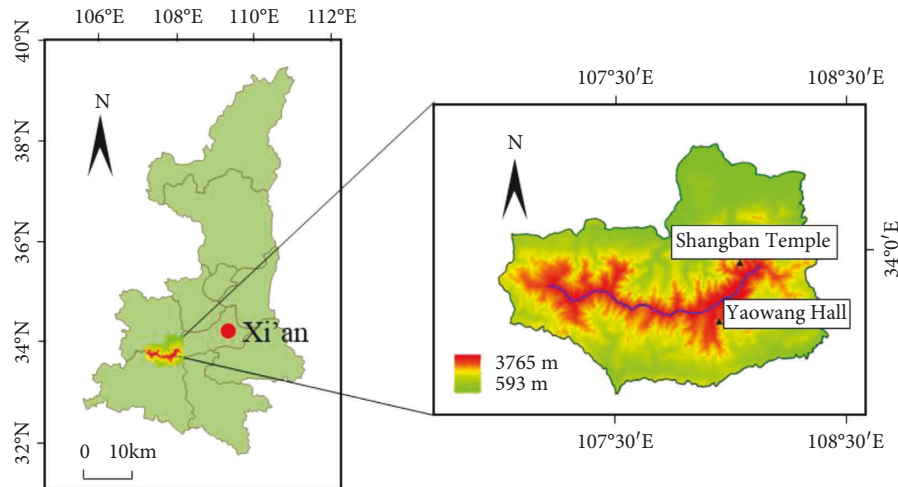


FIGURE 3: Taibai Mountain.

the Qinling Mountains refer to the north slope of the Qinling Mountains, starting from Tongguan in the East and ending at the larger Valley in Baoji in the West. Most of the rivers originate from the watershed, and there have been relatively long Sichuan roads and small roads since ancient times. The most famous ones are LAN Guan Road, Ziwu Road, Luotang Road, and Chencang Road. As for the smaller valleys and gullies, there are as many as hundreds, not counting this. The highest peak of the Qinling Mountains is mount Taibai, with a height of 3,763.2 m. It is the first peak in the eastern half of the Chinese Mainland (known as the top of the peaks). Currently, the second peak of the Qinling Mountains in Shaanxi is known as “Aoshan” or “West Taibai” for short, with a height of 3,740 m, as shown in Figure 3.

There are obvious differences in the natural landscape between the north and south slopes of the Qinling Mountains. The northern slope of the Yellow River Basin is a warm temperate coniferous and broad-leaved mixed forest and deciduous broad-leaved forest zone. Due to long-term agricultural development, most of them are secondary forests. The floristic elements and animal species in Qinling Mountains have obvious transitional, hybrid, and complex diversity. Among the wild animals, there are precious species such as giant panda, golden monkey, antelope, and birds such as Crested Ibis and black stork, which are national first-class protected objects. Among them, giant panda, golden monkey, antelope, and Crested Ibis are collectively known as the “four treasures of the Qinling Mountains,” as shown in Figure 4.

Developing ecotourism and ecological civilization construction in Qinling Mountains is a new task. It benefits from the early construction and development of tourism areas. In turn, it can better protect and improve the existing ecological landscape and further promote the development of scenic spots and the harmonious coexistence of man and nature.

4. Evaluation of Ecotourism Resources

4.1. Selection of Evaluation Methods. AHP is a practical decision-making method proposed by Sati, a famous mathematician, in the 20th century. It can evaluate the

expanded influence factors, is multilevel and multiobjective, and can overcome the deviation caused by the inability to quantify the relevant influence factors in the previous decision-making process. Based on the principles of simplicity, science, systematicness, and operability, the evaluation system of ecotourism resources is established. Through the AHP, the evaluation index system structure of the subtarget, project, and index levels is constructed (Figure 5), the index weight is determined in combination with field investigation and expert scoring, and a multi-index comprehensive evaluation model of ecotourism resources is established to analyze and evaluate ecotourism resources. Finally, the empirical application analysis of the established evaluation model is carried out to realize the evaluation and analysis of ecotourism resources.

4.2. Evaluation Index Selection and Weight Calculation.

According to the characteristics of ecotourism areas, an evaluation model system is established to evaluate ecotourism resource. Based on consulting numerous documents, consulting relevant ecoenvironmental experts, and conducting on-the-spot investigation and evidence collection of ecotourism areas, including Qinling Mountains, the agricultural ecotourism resource evaluation (a) is taken as the overall target level. According to the content of the system, it is divided into three subtarget layers: resources (B_1), ecological environment (B_2), and development conditions (B_3), further dividing the tourism resource subsystem into three project layers and dividing the ecological environment system into two project layers. Moreover, the development condition system was divided into three project layers. Finally, the project level is subdivided into 22 indicator levels, as shown in Table 1.

According to the selected evaluation indicators of Qinling Mountain tourism resources, the evaluation index system is shown in Figure 6. AHP is used to evaluate the ecotourism resources in Qinling Mountains. According to the objective reality and subjective judgment, combined with expert opinions and objective judgment results, the hierarchical elements are compared and quantified, the weight value of

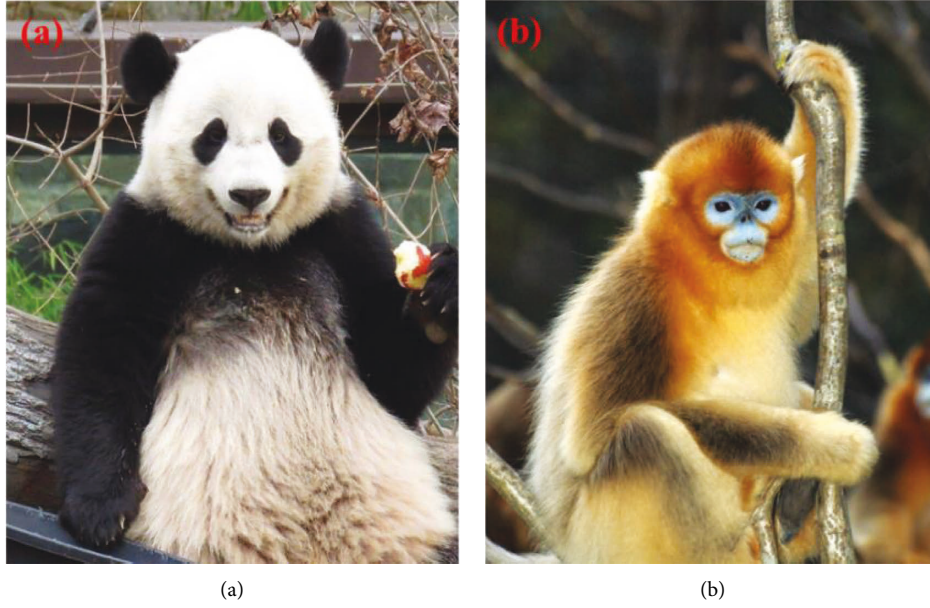


FIGURE 4: Rare animals in Qinling Mountains: (a) panda and (b) golden monkey.

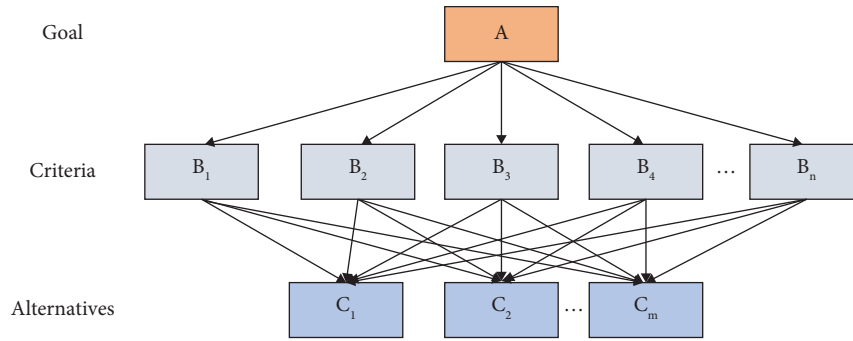


FIGURE 5: Structure of the analytic hierarchy process.

the importance of each level element is calculated, and the weight of all elements is sorted.

The importance scale of index a_i compared with index a_j : $A_{ij} = 1$ is equally important, $A_{ij} = 3$ is slightly important, $A_{ij} = 5$ is more important, $A_{ij} = 7$ is significantly important, $A_{ij} = 9$ is extremely important, $A_{ij} = 2, 4, 6, 8$ are the intermediate values of adjacent judgments, and $A_{ji} = 1/A_{ij}$ is the importance of index a_j compared with index a_i . The importance of each factor in the same layer is compared in two pairs according to the important scale value. The comprehensive weight value of each indicator is equal to the weight of an indicator at the indicator level relative to the indicator at the project level multiplied by the indicator weight at the project level. Take the average of the two feedback results from the questionnaire consultation scores of experts related to agricultural tourism, ecotourism, and tourism planning, and establish a judgment matrix as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2j} \\ \vdots & \vdots & \cdots & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} \end{bmatrix}. \quad (1)$$

Based on the constructed evaluation model, the influence degree of the factors listed at all levels in the evaluation model on the ecotourism area is determined. Through consulting relevant literature, it is found that there is a lack of research on the systematic evaluation of ecotourism resources with AHP as the main method. Considering that the quantitative assignment of various factors directly through human perception leads to analysis errors and does not have objective authenticity. The author tries to quantify by comparing two methods and constructing a judgment matrix to compare the importance of various levels of factors on the production of ecotourism areas.

Combined with the Delphi method, five experts in the field of tourism development and five experts in the field of ecology were invited to compare and score by face-to-face consultation and e-mail. The consistency of the results of the judgment matrix was tested by the following formula:

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^n \frac{(AW)_i}{W_i}, \quad (2)$$

$$CI = \frac{\lambda_{\max} - n}{n - 1}.$$

TABLE 1: Ecotourism evaluation index.

Target layer (A)	Subtarget layer (B)	Item layer (C)	Index layer (D)
Comprehensive evaluation of ecotourism resources (A)	Ecotourism and elements of historical and cultural resources (B ₁)	Humanistic characteristics (C ₁)	Historical and cultural values (D ₁)
			Scientific research potential value (D ₂)
		Tourism function and value (C ₂)	Popularity (D ₃)
			Entertainment and leisure (D ₄)
			Visual viewing (D ₅)
			Diversity of ecological elements (D ₆)
		Distribution of resource types (C ₃)	Uniqueness of ecological resources (D ₇)
			Scale degree (D ₈)
			Combination condition (D ₉)
		Ecological environment (C ₄)	Aggregation degree (D ₁₀)
	Environmental suitability (D ₁₁)		
	Ecological security guarantee level (D ₁₂)		
	Applicability of regulations (D ₁₃)		
	Environmental characteristics (B ₂)	Social and economic conditions (C ₅)	Safety guarantee level of tourist area (D ₁₄)
			Level of supporting facilities (D ₁₅)
		Regional location conditions (C ₆)	Basic tourism facilities (D ₁₆)
			Position (D ₁₇)
	Development conditions (B ₃)	Regional location conditions (C ₆)	Traffic conditions (D ₁₈)
			Interaction of tourism areas in the same region (D ₁₉)
		Source of passenger flow (C ₇)	Scale degree (D ₂₀)
			Source of passenger flow (D ₂₁)
		Tourist consumption capacity (D ₂₂)	

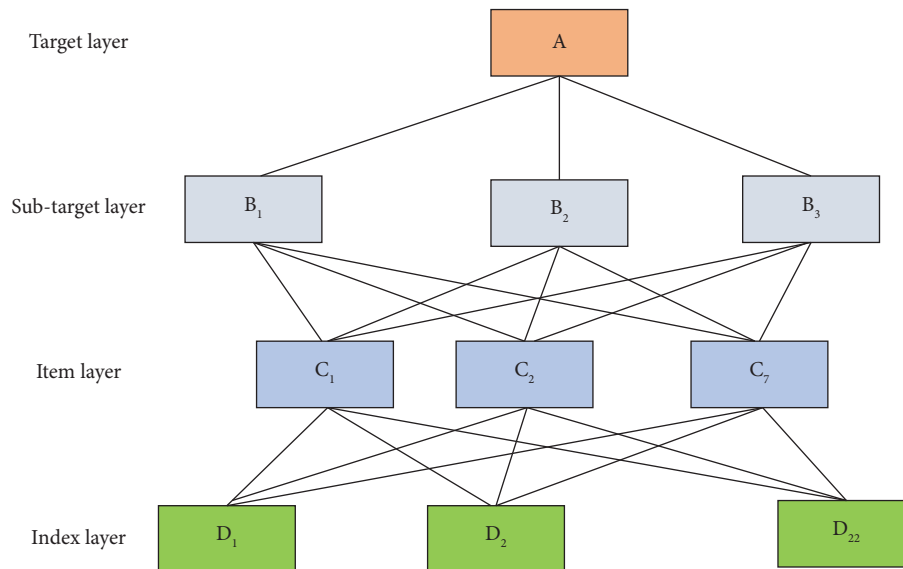


FIGURE 6: Evaluation index system of tourism resources in the Qinling Mountains.

Calculate the CI result, and check the average random consistency index RI value according to

$$CR = \frac{CI}{RI}. \quad (3)$$

CR is calculated. If $CR < 0.1$, the consistency is passed. If $CR > 0.1$, conduct multiple rounds of evaluation until the CR value is less than 0.1.

4.3. Evaluation Criterion. The constructed evaluation model is used to evaluate the tourism resource points in Qinling Mountains. The scale standard of the Likert scale is used to quantify each index. First, each factor is divided into five scales: good, good, general, poor, and poor, and each scale is assigned. Among them, “good” is 90–100 points, greater than or equal to 80 and less than 90 points is “good,” greater than or equal to 70 and less than 80 points is “general,” greater than or equal to 60 and less than 70 points is “poor,” and less than 60 points is the difference. After the weight of each index is calculated by AHP, the comprehensive score is calculated:

$$S = \sum_{i=1}^n d_i C_i, \quad (4)$$

where S is the comprehensive score, d_i is the evaluation factor score, and C_i is the index weight. S is divided into five grades, as shown in Table 2.

4.4. Evaluation Index Weight Calculation Results. According to the evaluation method in this paper, the weight of each evaluation index of Qinling ecotourism resource evaluation is obtained. After the consistency test, the evaluation results meet the requirements, and then the weight of each evaluation factor is obtained, as shown in Table 3.

4.5. Analysis of Evaluation Results. In the index layer, the weights of the interaction of tourism areas in the same region (D_{19}), the applicability of regulations (D_{13}), and entertainment and leisure (D_{18}) are 0.0691, 0.0672, and 0.0660, respectively. The index accounts for the top three, which has a high impact on the score of Qinling Mountain Ecotourism Resources to a certain extent. It shows that the problems related to these two factors greatly impact the ecotourism resources of the Qinling Mountains. Compared with other factors, we need to pay special attention to these two aspects when managing tourism resources.

In order to comprehensively evaluate the ecotourism resources of Qinling ecotourism scenic spot, through sorting out the data obtained from the questionnaire survey and field survey, the corresponding impact factors of each level in the evaluation model are valued and scored, and the weight of each index is calculated. Finally, the total comprehensive evaluation score of the Qinling ecotourism scenic spot is 92. Further explore the reasons for the high and low scores of various indicators, which are mainly reflected in the following aspects:

TABLE 2: Comprehensive scoring table.

Grade	Range of comprehensive scores
I	≥ 90
II	$89 \geq S \geq 80$
III	$79 \geq S \geq 70$
IV	$69 \geq S \geq 60$
V	$S \leq 59$

TABLE 3: Weight of various indexes in the evaluation mode.

Subtarget layer		Item layer		Index layer	
B_1	0.4276	C_1	0.1263	D_1	0.0542
				D_2	0.0421
				D_3	0.0300
				D_4	0.0660
	0.2853	C_2	0.1532	D_5	0.0331
				D_6	0.0452
				D_7	0.0089
				D_8	0.0321
	0.2871	C_3	0.0673	D_9	0.0152
				D_{10}	0.0020
				D_{11}	0.0523
				D_{12}	0.0364
	0.2853	C_4	0.1559	D_{13}	0.0672
				D_{14}	0.0442
				D_{15}	0.0246
				D_{16}	0.0306
	0.2871	C_5	0.1294	D_{17}	0.030
				D_{18}	0.0463
				D_{19}	0.0691
				D_{20}	0.0542
	0.2871	C_6	0.1154	D_{21}	0.0611
				D_{22}	0.0564

- (1) The natural ecological environment of Qinling Mountain Ecotourism Scenic Spot is good, but there are few elements of ecotourism and historical and cultural resources, indicating that although some scenic spots in Qinling Mountain have high historical and cultural value, other buildings in the scenic spot have been built in recent years, so their popularity is not high, and their influence is not enough.
- (2) Qinling Mountain Ecotourism Scenic Area has various plant species with scientific research value and the ability to carry out field teaching. At the same time, the diversity of species in the tourism area also brings better visual appreciation value and residents' leisure and entertainment value. However, there are still low species specificity and low aggregation in tourist areas.
- (3) Qinling ecotourism scenic spot is under the jurisdiction of the Xi'an Municipal Party committee and government. The municipal government attaches great importance to the development of service tourism. The social security situation of the city is good, and the transportation planning and construction are also gradually improving. Therefore,

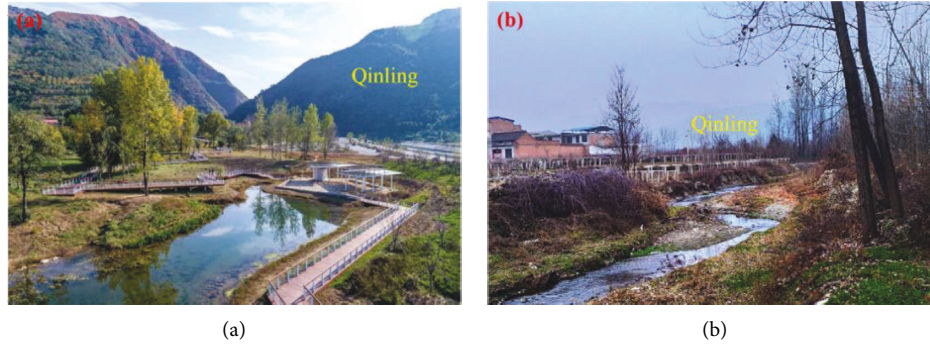


FIGURE 7: Scenic spots after development and investment: (a) Gengyu and (b) Tianyu.

the comprehensive evaluation of its tourism development conditions scores high. It shows that transportation has little impact on the tourism resources of the Qinling Mountains.

- (4) The tourist flow in the tourist area comes from a wide range of sources, but mainly from coastal provinces. Their consumption ability is very high, and their education level is also very high.

5. Suggestions for the Development of Tourism Resources in the Qinling Mountains

5.1. Strengthening the Construction of Infrastructure Services. The protection of ecotourism resources in each Yukou spot should be arranged as a whole, and scientific and reasonable ecological function areas should be defined. In particular, the protection of Yukou scenic spots that are restricted or prohibited by the government should be strengthened, such as the Heihe River and Jiuyu, and measures should be taken to regulate and restore the ecology as soon as possible. For scenic spots that the government encourages and focusing on development, we should increase investment in development, such as Gengyu and Tianyu (as shown in Figure 7). We should improve infrastructure services as soon as possible through reasonable layout planning. By strengthening and improving the hardware, we can improve the cultural connotation of Yukou scenic spots and improve the grade of scenic spots. The premise is not to destroy the ecology, give priority to nature, and never engage in predatory development and blind construction.

5.2. Landscape Restoration. Protective development requires the protection of the landscape of each valley to make it have natural integrity. First, according to the needs of the main valley landscape along the northern foot of the Qinling Mountains in Zhouzhi County, representative temples along the way and on the top of the mountain should be built, which can be used as both tourist landscapes and rest facilities. Secondly, according to the landscape needs and visual experience, the renovation of the environmental facilities of the existing villages should be strengthened. In addition to providing buildings for tourists to rest and lodge, campsites should also be opened. When developing these

valleys, the volume, form, color, style, and materials of the buildings should be strictly controlled to make them coordinate with the natural environment.

5.3. Ecological Construction. In areas where conditions permit engaging in agricultural production, we should fully introduce and use high and new technology to develop efficient agriculture. In areas with poor farming and living conditions, we should return farmland to forests and develop economic forests, specialty fruits, and ecological agriculture. In areas without farming conditions and with extremely poor living conditions, we should give full play to the catalytic role of the tourism economy, let some residents move out, and encourage some qualified mountain people to participate in the tourism service industry of the scenic spot to form a unique economic structure of the scenic spot.

In the process of protective development of scenic spots, human existence destroys the natural environment. However, human existence and the accumulation of human activities have become an integral part of the cultural environment of scenic spots. They are people in the environment. At the same time, due to human existence, the environment will increase “popularity” and sense of security. A certain number of residents should be retained to change the traditional way of production and life and better integrate into the environment. This kind of on-site relocation based on cultural and environmental protection is called ecological migration. The goal of ecological migration is to staff residents, service production, scenic spots of folk houses, enterprise management, and ecological scenic spots.

5.4. Brand Publicity and Construction. In the process of protective development of major Yukou, we should make full use of various media (traditional and new media) for advertising, use the Internet e-commerce platform to strengthen the publicity from multiple perspectives, and cooperate with tourism intermediaries and tourism channels to attract more attention from the society by designing various seasonal tourism projects to establish scenic spot brands and boutique brands, as shown in Figure 8. For example, various tourism activities can be used to drive the popularity of tourist spots, and activities such as “Zhouzhi special snack Festival,” “Rape Flower Festival,” “Lavender Flower Festival,” “New Year blessing,” and “China Kiwi theme park” can be carried out. We

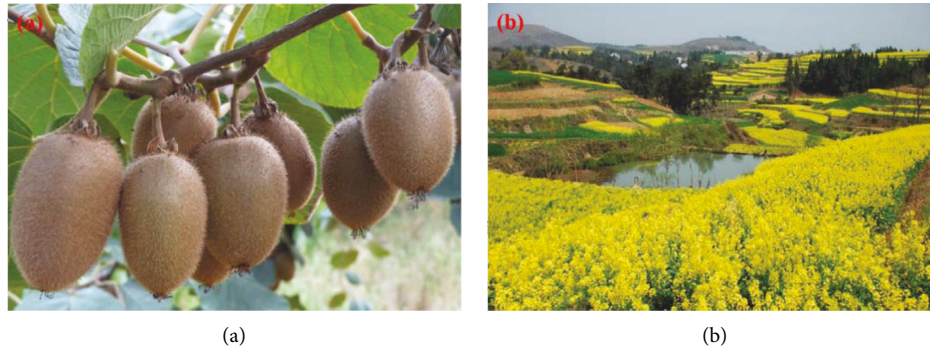


FIGURE 8: Qinling featured products: (a) kiwifruit and (b) cole flowers.

can also make use of Yukou's unique landscape characteristics, strange and beautiful natural scenery, long history and culture, and other tourism resources to create brand slogans and advertising language for tourist spots; attract tourists' interest in sightseeing and play; and then drive tourism growth to form a unique tourism competitive advantage.

6. Conclusions

This paper constructs the evaluation index system of ecotourism resources based on the AHP method. Through the case analysis of the Qinling ecotourism scenic spot, the results are consistent with the actual situation, which shows that this method has high reliability and can be applied to the comprehensive evaluation of ecotourism resources. The research results can provide a reference for the follow-up in-depth development of this tourist area, as well as the development of other tourist areas. In addition, the research method adopted in this paper can also provide a reference for other tourism resource evaluation cases. The main conclusions are as follows:

- (1) The top three evaluation index weights are the interaction of tourism areas in the same region (D_{19}), the applicability of regulations (D_{13}), and entertainment and leisure (D_{18}). The weight values of the three indicators are 0.0691, 0.0672, and 0.0660, respectively.
- (2) In the process of developing ecotourism, we need to pay special attention to the local history and culture and deeply tap into the local historical and cultural values. We take the functions of history and culture, scientific research and education, and tourism value as the characteristics of ecotourism areas into the subjective evaluation system.
- (3) We focus on the role of traffic conditions and other factors in the overall development of ecotourism because it is the basic condition to ensure that consumers choose to travel. Therefore, the local government needs to further improve the construction of infrastructure and supporting facilities in the tourist area, improve traffic conditions, such as increasing the number of parking spaces and rest stations in the tourist area, strengthen the management of merchants in the scenic area, and deal with the problem of high consumption in the scenic area raised by consumers in a timely manner.

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 there are no conflicts of interest.

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Research Article

The Important Function and Training of Sensitive Quality in Basketball Method Research

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Basketball is a skill-oriented group sport, which has been popularized and developed in China. However, the research on physical fitness training of basketball in China mostly focused on strength quality and speed quality, and less research was done on sensitive quality. Based on this, this paper aims to explore the important role of agility in basketball and put forward reasonable and scientific training suggestions in order to enrich the content of basketball training, complete the training system and to improve the level of basketball players as a whole.

1. Introduction

With the continuous improvement of China's comprehensive national strength, China's sports industry has also ushered in a golden period of development, and China has gradually improved sports power by leaps and bounds [1, 2]. However, with the retirement of a generation of sports athletes, there happened a fault in China's sports talents, and it is particularly important to vigorously develop the training of China's sports reserve talents. In order to improve the overall quality of Chinese sports athletes, cultural education is the main form, and sports training is supplemented to help Chinese reserve athletes to enhance their comprehensive quality. Basketball, as one of the most popular sports in my country, benefits from the long development history of basketball and the influence of world-class events such as the NBA league in the United States.

In recent years, China has continuously deepened its investment in basketball project research and funds, venues, etc., and China's basketball skills and tactics have achieved considerable results. In competitive basketball projects, high-level individual training programs, and team cooperation tactics designation and related theoretical research, China's basketball skills and tactics have achieved

considerable results. All are close to and some of them have reached the level of world-class echelons, but compared with the world's first-class basketball teams such as Europe and the United States, China still has many deficiencies in basketball competition, such as the congenital "deficiencies" caused by genetic differences, and the current situation on the basketball court [3]. In China, basketball players generally have problems such as insufficient adaptability, lack of rapid mobility, and unsmooth connection between personal strength and reflexes and special skills.

To develop the ability of basketball reserve players in these areas, we should first start from the young people. The young people are in the golden stage of rapid physical and mental development. They are extremely sensitive to the relevant quality training and consolidate their foundation in basketball so as to improve the current Chinese basketball players [4] and problems during exercise. However, teenagers are in a critical period of cultural education, and relevant basketball training can only be carried out in an amateur way so as to avoid the adverse effects of basketball-related training on teenagers' academics. Therefore, amateur basketball training is very important for the improvement of young basketball players' skills and personal quality.

In a word, basketball is a collective sport with the characteristics of confrontation, competition, fun, viewing, and commerciality. Basketball has the characteristics of strong physical confrontation, which requires that in basketball competition, during training, teaching, and other activities, participants and training personnel need to have qualities such as good speed, strength, and basketball skills and tactics. Sensitive quality is a combination of strength quality, speed quality, flexibility quality, and other qualities [5–9]. The agility of the body develops rapidly in adolescence, and the development of the agility of the human body gradually slows down in adulthood, and it continues to decrease with the increase of age. The high-speed movement, direction change, speed change, and other complex movements of basketball require a certain level of sensitivity as a support of athletic ability. Because the agile qualities of basketball players need to be exercised through more content and methods, the interestingness of the training content can better stimulate students' interest in basketball. The rich training content will provide the possibility to improve the agility of athletes and will also provide a more scientific training method for the cultivation of outstanding sports talents and promote the rapid development of basketball.

In many current academic researches and training reports, many coaches usually reflect that in our past training, we had a low level of cognition on the training of agility, and the training method was not systematic. How to further improve the agile quality of basketball players, make them more adaptable to the modern fast pace, and meet the requirements of modern basketball competitions has become a problem worthy of exploration by basketball experts and scholars.

2. Summary of Sensitive Qualities

2.1. Definition of Sensitive Qualities. The word “sensitive” is literally interpreted, and it can be divided into two parts such as “ling” and “sensitive,” where “ling” refers to flexible and changeable, and “sensitive” refers to agility. In the field of physical education, agile quality refers to the ability of a limb in a specific sports scene to feel stimuli and to quickly change direction or change actions as needed. According to the combination of sensitive quality and special purpose, it can be divided into general sensitive quality and special sensitive quality [10]. General sensitive quality refers to the ability to adapt to the external environment when completing various complex actions. The test method is the T-shaped running test (Figure 1) and Nebraska sensitivity test (Figure 2); special sensitivity quality refers to the ability to adapt to changes in the external environment in close contact with professional technology according to the needs of the special project, and the corresponding test method is the dribbling and running test, as shown in Figure 3. The author believes that the agile quality refers to the force of the body to make corresponding spatial and temporal action adjustments when the external conditions change during the exercise process.

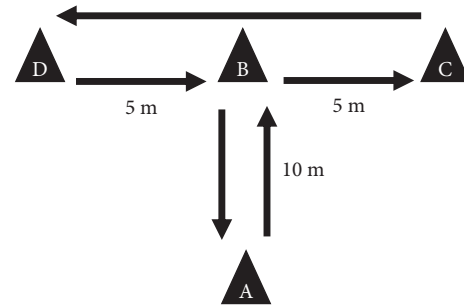


FIGURE 1: T-shaped running test diagram.

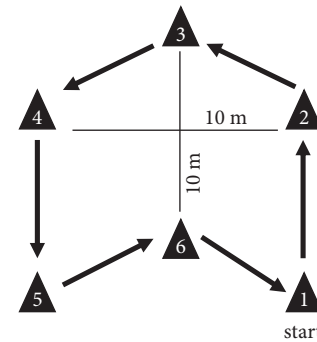


FIGURE 2: Sensitivity test icon of Nebraska.

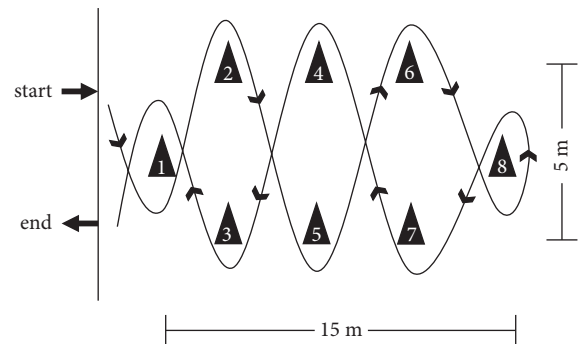


FIGURE 3: Dribble run test diagram.

2.2. Sensitive Quality Components. The level of athlete's agility is inseparable from the athlete's own strength, explosiveness, speed, and coordination, and it is also affected by the speed of the athlete's reaction speed and the mastery of their own special sports skills. The training of agility is closely related to the daily life of athletes, and sports and competitions.

The manifestation of speed quality in sensitive quality is mainly reflected in two aspects such as responsiveness and multidirectional speed [11–13]. The reaction speed depends on the ability of the neural reflex system, and the proficiency of technical movements and the multidirectional speed, etc., mainly depends on the coordination of the body, sex, strength control in different directions, joint flexibility, rapid change of direction of lower extremity muscles, and muscle

contraction ability. The main manifestation of strength quality in agile quality is the exertion of rapid strength [14]. The strength of rapid strength is inseparably related to muscle fiber type, muscle fiber cross-sectional area, and motor unit recruitment. It can be seen that the sensitivity quality is closely related to the nervous system, body coordination, muscle fibers, joint flexibility, muscle contraction ability, and many other aspects [15].

2.3. Current Research Status of Sensitive Quality. Sensitivity is one of the core components of an athlete's physical fitness and is often used as a measure of an athlete's performance in some fields.

An important reference for rapid response capabilities in a scenario or project, at present, is a general and common recognition for the importance of sensitive quality at home and abroad, and we are constantly trying to explore the final effect of sensitive quality training in different sports.

Scholar Sun [16] believes that agile quality can effectively measure an athlete's ability to quickly respond and deal with changes in complex and changeable situations such as quickly learning new actions or action combinations to deal with deliberate targeting by opponents. In complex collective sports competitions, the change in the field has strong randomness and inevitability, and agile quality training can significantly improve the ability of athletes to "brake quickly" and help overcome the enemy to win.

Scholar Li [17] found that agile quality is an important component of physical quality, and its training effect runs through the whole process of fluctuation of strength quality, coordination quality, endurance quality, and other qualities rather than being limited to the "fast" quality. They influence each other and the improvement of other qualities will lead to the improvement of agile qualities, and the latter will also reduce decision-making and additional coping costs, thereby improving the effectiveness of other qualities training. Under the modern multidimensional training system, the importance of agile quality training is self-evident.

Su [18] believed that agility is an extremely comprehensive and complex measure. "Sensitivity" not only includes physical factors such as explosive power and endurance but also includes psychological stress resistance.

Psychological factors included power, reaction power, and decision-making power. In sports, more emphasis is placed on the four stages of judging exercise power, reaction speed, reaction time, and seeking balance. At the same time, general agile qualities and special agility qualities are involved to characterize their commonality and individuality in the project. On the whole, the influencing factors can be roughly distributed in three aspects: the external environment, physiological factors, and psychological factors. Paying attention to these factors is of great significance for improving high-quality and efficient training programs for sensitive qualities.

Wang Jing and Wang Lei [19, 20] believed that for the precious adolescent stage, sensitive quality training should run through the growth of young athletes. According to the physical and mental development of adolescents at different

stages, timely and targeted replacement of training content and guidance programs, included adopting principles or methods such as first easy and then difficult, first general and then professional, and adding fun activities during training, stimulate athletes' enthusiasm for training, and fully tap their sports potential.

3. The Role of Agility in Basketball

Throughout the world of basketball, every superstar has a physical agility that is different from ordinary people. Foreign scholar Hoskins once made a famous remark: "Sensitivity is the soul of basketball skills." This sentence is not a general statement, but has been accepted by more and more athletes, officials, and even the world. They have begun to pursue and promote the development of the entire basketball game towards the core concept of optimism, convenience, and sensitivity. It is worth mentioning that based on the ever-changing pace of basketball itself and the unpredictable emergencies on the field, it undoubtedly implies the importance of sensitive quality to basketball. A basketball player with excellent and sensitive quality will not be stupid. Stand and wait until the emergency occurs until the end, but after observing the reaction of the audience, make the most effective judgment in the shortest time, such as stealing fast break one-stop, as well as on-the-spot arrangement and play of the lore ball.

Basketball is a sport with tight offensive and defensive rhythms, high intensity, and intense confrontation [21, 22]. In order to achieve their own tactical goals or intentions, players on both sides need to adopt different techniques and tactics according to their different situations. Tactics are divided into offensive tactics and defensive tactics. Sensitive qualities are of great significance to the achievement of defensive and offensive technical and tactical goals [23].

3.1. The Function of Sensitive Qualities in Basketball Offensive Techniques and Tactics. In basketball, the attacker often moves the ball flexibly, breaks through quickly with the ball, has a certain degree of acceleration and direction change, and makes an emergency stop, so as to achieve the purpose of attacking [24]. In the whole process, basketball players' dribbling rhythm, accelerating change of direction, or making emergency stop shots play an important role in their agility. When the attacker runs without the ball, the athlete needs to make a quick response to the situation on the field so as to make a judgment, carry out the next action, carry out pick-and-roll, card position, etc. In addition to solid basketball dribbling skills, a player with the ball should also make an accurate judgment on the situation on the court so as to choose to pass, break, or shoot [25–29]. In the process of breaking through with the ball, the athlete is required to have good speed, coordination, and coordination. Sexuality and strength quality are all indispensable comprehensive factors in sensitive quality. Passing requires the ball-handling player to have good reaction speed and control ability in terms of strength, quality, and body direction. Shooting requires athletes not only to have excellent shooting ability

but also a good connection to the dribbling rhythm and quick stop and start. It can be seen that the sensitive quality has a huge supporting effect on basketball offensive techniques and tactics.

3.2. The Function of Sensitive Qualities in Basketball Defense Techniques and Tactics. The role of agility in basketball is not only reflected in basketball offensive techniques and tactics but also in defensive techniques and tactics. For defensive players, the response they need to make not only includes the situation on the field but also predicts the actions of the offensive players so as to take appropriate and reasonable defensive actions, such as timely switching or supplementary defense, man-to-man defensive tactics, and defense or positional defense. During the entire defensive process, athletes are required to have better reaction speed, flexible footwork, coordination of limbs, and the ability to accelerate quickly so as to achieve the purpose of interfering and preventing the attacker. In the process of defense, the foot movement of the defending player is extremely important, not only to respond to the action of the offensive player but also to adjust the footwork and body position in time to avoid dislocation or fouls [30]. Flexible footwork and good body control ability require athletes to have good coordination and quick reaction ability and carry out daily defensive movement exercises based on this so as to ensure that they can give full play to their defensive ability on the field. It can be seen that the important role of agile quality in defensive techniques and tactics is not less than that in offensive techniques and tactics.

4. The Rational Basis of Sensitive Quality Training

4.1. Physiological Basis. Under the influence of the nervous system, central system, and other control and command systems, human muscles continuously contract, stretch, etc., and the body shows different movement postures or movement states. Sensitive quality is one of the main physical qualities with strong comprehensiveness and high degree of complexity. In addition to the basic central nervous system control, its physiological connotation requires higher coordination of various parts and systems of the body. Too much emphasis on muscle strength will lead to tension and stiffness in the body, and too much emphasis on reaction and movement speed will lead to a lack of strength in movements, resulting in lower movement quality or defects in movement structure [31, 32]. Therefore, the training of sensitive qualities should meet the physiological basis of speed and strength as the premise, and the basic conditions should be followed by the formulation of the training content plan, and then the training should be carried out.

4.2. Basics of Training. Since the rapid development of sensitive qualities is in the adolescent stage, the training basis should be based on the human growth stage as the main reference for the division of the training plan. Sensitive

quality plays an important role in the development and progress of sports skills and technologies in many sports. There are huge differences in the physical quality requirements of different sports. Therefore, the training of sensitive qualities should be based on all-round development and then enhance targeted exercises. Studies [33] have shown that the development of human agility in adulthood is slow and almost stagnant, which is not conducive to the development of agility in the later stage, and the training effect is poor. It can be seen that the development of sensitive quality should also be based on active training during the sensitive period of body development. In addition, there is a close connection between agile quality and many physical qualities. In the training process, the development and training of other physical qualities should be closely combined to improve agile quality in all-round development.

5. Basketball Special Sensitivity Training Principles

5.1. Sustainability Principle. The formulation of the training plan should meet the three conditions such as phase, periodicity, and integrity. The training of agile qualities in basketball has higher requirements for the scientificity and systematicness of the training plan. Therefore, to formulate a basketball-specific training plan for sensitive qualities, it is necessary to have complete and long-term systematic conditions. Divide a complete large-cycle training plan into multiple small stages, and make each stage have strong continuity, correlation, and operability, and at the same time, the principles of periodic training, interval training, systematic training.

The training principles are combined into a whole and integrated into the sustainable training plan principles with high continuity, strong scientificity, and strong practice [34]. This will promote the complete and efficient implementation of the entire training program, improve the sustainable development of the training program, improve athletes' ideological awareness of perseverance and persistent pursuit, guide athletes to establish long-term goals with the help of training results at various stages, deepen the depth of basketball students and athletes' understanding of the training plan, improve the enthusiasm of basketball players to actively participate in sensitive quality training, and correct their training attitude, thereby improving the resilience of athletes to participate in long-term training.

5.2. Holistic Principle. Sensitive quality is not the only one among the many qualities of the human body, but there are various qualities of the human body which play an important core role in different sports. Sensitive quality plays an important supporting role in high-explosive, fast-moving, and comprehensive basketball, and various complex and high-level basketball techniques and skills require the active participation of sensitive quality [35]. However, in terms of basketball as a whole, speed quality, strength quality, body shape, etc. are also very important for basketball. In addition to basic qualities, factors such as basketball awareness, ball

quotient, and adaptability are equally important to the development of basketball players' special sports level. Under the combined influence of many factors, other related factors are also needed to be taken into account in the formulation of basketball agility training plan, including the special required qualities of basketball and special sports skills training. Improve the comprehensiveness and integrity of the training plan, and avoid the phenomenon of physical fitness decline of athletes due to long-term single training. Therefore, the basketball-specific agility training plan focuses on agile quality and is based on quality training and special techniques and tactics.

5.3. Pertinence Principle. The pertinence of basketball sensitive quality training is mainly reflected in two aspects, one is quality pertinence, and the other is project pertinence. Sensitive quality is a comprehensive reflection of multiple qualities. When formulating agile quality training plan, the individual physical quality differences of participating athletes should be considered, and a highly targeted training plan should be formulated according to specific differences, and also make up for the shortcomings of basketball players' physical quality, improve the overall quality of basketball players, and lay a solid foundation for the improvement of sensitive quality. Project pertinence means that the formulation of the training plan, the use of means, and the characteristics of training load must meet the requirements of basketball. The sensitivity and quality training of basketball special aspects is mainly reflected in the training methods and methods in the training plan, for example, in the training process, adding basketball high-level dribbling practice and faking action practice or tactical movement practice. While improving the specificity of the training plan, the application value and practical value of the training plan should be improved in the view of development of basketball skills, the level of basketball competition, and the level of sports skills of athletes.

6. Basketball Agility Training Methods

6.1. Rope Ladder Training. Rope ladder practice, as the name suggests, refers to a derivative of rope skipping. Athletes jump twice at a time when skipping rope. This is also a standard test content for talent selection and testing of basketball players. Rope ladder exercises are mainly dynamic exercises that exercise the muscles of the four limbs of athletes as the main exercise target. Rope ladder exercises need to rely on the cooperation of the muscles of the athletes' lower limbs, and can also exercise the degree of coordination of the athletes' hands and feet, thereby improving the athlete's lower limb strength and lower limb sensitivity. In only 30 seconds of rope ladder exercises, the athlete's arm muscles, leg muscles, waist and abdominal muscles, and other muscle groups work together to improve the athlete's coordination ability. A major feature of rope ladder training is that it does not require the athletes to run continuously on the basketball court but only requires the athletes to complete the running action of the lower limbs during the

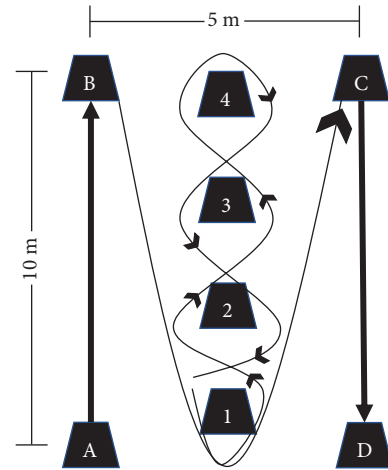


FIGURE 4: Illinois run test icon.

continuous rope skipping movement, which can fully reflect the athlete's original lower limbs, and the sensitivity and speed of the quality.

Rope ladders are commonly used tools in agility training not only in basketball but also in tennis, football, volleyball, badminton, and other sports. The rope ladder can make the whole training process more interesting and can greatly improve the training enthusiasm of basketball players [36, 37]. The rope ladder training method has a good promotion effect on the balance, foot speed, and lower limb strength of basketball players' agile qualities. The purpose of using rope ladders for agility training is to develop the ability of basketball players to move quickly and increase speed of footwork, for example, using rope ladders to do left and right single-leg hops, step jumps, small steps, back kicks, and cross hip movements.

6.2. Orienteering Fixed Obstacle Course. Orienteering running is mainly to develop athlete's ability to quickly turn, body control, and speed quality. Often a few logo buckets can complete the deployment of the training ground, and common ones include T-shaped running, cross running, meter running, Illinois running (Figure 4), and Nebraska running. In the training process, the basketball players not only can run without the ball but also can integrate basketball techniques in the running process, such as dribbling, dribbling, and turning so as to improve the pertinence of training and then improve the technical level of basketball players.

6.3. Small Ball Training. The small ball training method is more common in the training of NBA basketball players. Within the range of 5 ~ 10 m from left to right (adjusted according to the actual situation of the athlete's level), the athlete performs fast movement exercises, and the trainers throw small balls from time to time during the practice [38]. The basketball player catches the small ball within the moving range. This method is mainly to develop the basketball player's quick reaction ability and body control

ability. In addition, small ball practice can also be added during the dribbling practice. For example, during the dribbling process, the sparring team throws the small ball from time to time, and the basketball player catches the small ball while continuing to dribble.

6.4. Back Run Training. Back run, according to two markers, starts from one point (starting point), runs to the other marker (ending point) according to a certain distance as required, and turns around immediately after touching the marker with your feet or hands (no need to go around the marker). Objects run back to the starting point, continue to turn around and run to the end point, repeat in a loop, and do several back and forth between the start point and the end point according to the requirements of the exercise. The key to the reentry run is the reentry technique, and the quality of the reentry technique has a greater impact on the final result. The technical essentials of turning back (take the right foot touching the line or the right hand touching the marker as an example) are that when running fast to the end, usually 2 to 3 meters before the end, slightly reduce the running speed, lower the center of gravity, run to the end, face sideways, finish line or marker, squat with left lower extremity, extend right lower extremity to finish line (or slightly ahead) to brake and prepare for kick off, press down the upper body, touch the line with the foot (or touch the marker with the hand) After the object, the upper body turned to the forward direction, the right foot quickly kicked off the ground, and continued to run forward quickly.

As shown in Figure 5, reentry running is mainly used to develop the speed quality of athletes and the ability to stop and start quickly. Reentry running is involved in basketball training in universities, and middle and primary schools in China and even in the daily training of professional basketball teams. This method has obvious effects. It has many advantages such as strong feasibility and low site requirements. The more common methods include “6 × 6 m” reentry, half-court “third-line” reentry, and full-court “four-line” reentry. This training method can also be used in a developmental manner. For example, when the basketball player runs to a specific position, he does not return immediately. The sparring staff can pass the ball, and the basketball player can practice catching and jumping, thereby improving the basketball player’s reaction ability during the running process with the jump shot technique [39].

7. Training Notes

7.1. Grasp a Reasonable Exercise Load. When carrying out basketball-related sensitivity training, it is necessary to pay attention to the exercise load limit that can be endured by participants of different ages and sports levels and carry out training activities in a targeted manner so as to avoid athletes getting bored due to excessive load intensity [40]. Psychological and fatigued physical state is important to ensure that athletes are in good physical condition and have a high attitude when participating in training.

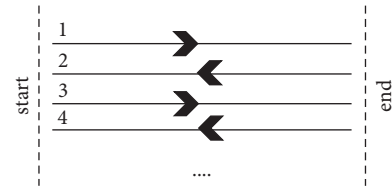


FIGURE 5: Schematic diagram of the return run.

7.2. Actively Changing Training Methods. During the training activities, pay attention to the physical adaptation of the athletes, and the training methods should be updated regularly to avoid the mental boredom of the athletes due to the single training method. Coaches should actively adopt different training methods to continuously stimulate new athletes so as to improve athletes’ enthusiasm for training and improve training effects.

7.3. The Training Content Is Gradually Deepened. In the training process, the selection of training content should be from simple to complex and from easy to difficult. Training methods with high difficulty or high load intensity should be placed in the middle and late stages of the training phase, which can effectively improve athletes’ enthusiasm and interest in training, as well as their enthusiasm for participation, and improve athletes’ sense of achievement. For example, in the training content of orienteering running, a relatively low-difficulty reentry run can be used in the initial stage, and in the later stage, T-shaped running, cross running, and meter running can be carried out gradually [41].

7.4. Combining the Technical Characteristics of Different Athletes. Basketball is a collective sport. According to the role of different players, it can be roughly divided into inside players and outside players. A study [42] has shown that high-level men’s basketball outside players are more affected by special qualities than inside players. High-level basketball inside players should increase the proportion of special speed and sensitivity training and special strength training in special training. It can be seen that in basketball, the training of sensitive qualities should be carried out differently according to the technical characteristics of different athletes, and “training” should be carried out according to their aptitude, so as to improve the pertinence, make the training effect more obvious, and comprehensively improve the level of athletes.

7.5. Comprehensive Development of Comprehensive Quality. The special physical fitness training of basketball players should follow the concept of “overall quality concept.” In terms of method selection and training load arrangement, it should meet the development characteristics of modern basketball with high intensity, confrontation, and variability [43]. Therefore, in the process of basketball sensitive quality training, we should pay attention to the combination with other physical fitness training, improve the connection

between each quality training, and promote the all-round development of basketball players.

7.6. Pay Attention to the Psychological Construction of Athletes. During the whole training process, coaches should pay close attention to the psychological changes of athletes, and grasp the psychological conditions of athletes at different stages in a timely manner. Ideas enhance confidence, improve their sense of satisfaction, give certain affirmations, encourage athletes to set different goals for different stages in the training process, and help them overcome the “bottle-neck” period of training.

8. Epilogue

When an athlete has excellent agility, it can naturally adapt to the training of the core strength of the body. To be more precise, the neurons and brain in the body can respond faster than ordinary people. This is why some sports are very strict in the selection of athletes and must require athletes to have innate agility.

Sensitive quality plays a vital role in basketball. In daily basketball training activities, it should be combined with other physical fitness exercises to develop sensitive quality, increase the emphasis on the training of sensitive quality, and adopt scientific and systematic training methods to develop targeted development and sensitive qualities of basketball players at different stages and levels.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

DNA Sequence Specificity Prediction Algorithm Based on Artificial Intelligence

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DNA sequence specificity refers to the ability of DNA sequences to bind specific proteins. These proteins play a central role in gene regulation such as transcription and alternative splicing. Obtaining DNA sequence specificity is very important for establishing the regulatory model of the biological system and identifying pathogenic variants. Motifs are sequence patterns shared by fragments of DNA sequences that bind to specific proteins. At present, some motif mining algorithms have been proposed, which perform well under the condition of given motif length. This research is based on deep learning. As for the description of motif level, this paper constructs an AI based method to predict the length of the motif. The experimental results show that the prediction accuracy on the test set is more than 90%.

1. Introduction

DNA sequence specificity refers to the ability of DNA sequences to bind specific proteins [1]. These specific proteins, also known as a transcription factor (TF), play a central role in gene regulation such as transcription and alternative splicing [2]. The segment in the DNA sequence that binds to transcription factors is called the transcription factor binding site. The same transcription factor often binds to multiple sites in the sequence. These binding sites are conservative to some extent. It is generally recognized that they share the same sequence pattern, which is called a motif [3]. Finding this sequence pattern in a given DNA sequence set is called motif discovery [4]. Obtaining DNA sequence specificity is very important for establishing the regulatory model of the biological system and identifying pathogenic variants [5]. DNA sequence specificity is closely related to transcription factor binding sites. Studying DNA sequence specificity can help understand the process of DNA transcription and then establish a more complete regulatory model of biological systems. In addition, researchers can explain and identify the variation of disease by studying the

specificity of DNA sequence and the relationship between specific diseases or determine the discovery of disease or disease trend in the early stage of disease through sequence level research, which is also of far-reaching significance to the medical industry.

With the development of chromatin immunoprediction sequencing (chip SEQ) and other technologies, it is becoming more and more important to use computational methods to study the specificity of DNA sequences. It takes a lot of manpower, material, and financial resources to study the specificity of DNA sequence by using biochemical experimental methods. Nowadays, the sample size of data related to biological information.

DNA sequence specificity is usually characterized at the motif level, and position weight matrix (PWM) is a representation of motifs. The elements in the matrix describe the frequency of the four bases at each position. The mode of motif level characterization is easy to explain and supports the rapid scanning of binding sites on the genome scale. Based on this description, existing studies mainly detect DNA sequence specificity through motif discovery. At present, many motif mining algorithms have been proposed.

Given the length of the motif, these methods can effectively mine the motif. With the application of deep learning in some sequence problems [6–9], this study uses deep learning to study the specificity of DNA sequence.

2. Related Work

2.1. Phantom Representation. At present, the two most commonly used modes of phantom representation are consensus [10] and PWM. For highly conserved sequence sites, a consensus has good expression ability. For low conservative sequence sites, more nonpreferred character information is ignored, resulting in poor expression of consistent sequences. PWM has more flexible expression ability than consensus and can well express low conserved sequence sites. In addition, there are other ways to represent the motif. For example, IUPAC code [11], which is an improved motif representation method based on consistent sequence, contains 15 coding characters in total. IUPAC representation is more accurate than consistent sequence. In addition to expressing the most frequent characters in a column of aligned motif instances, it can also express the proportion relationship of multiple characters in some cases. In addition, the motif representation methods of consensus and PWM assume that each base position of the motif is independent of each other. In view of this situation, researchers have modeled on the basis of PWM, and the relevant models include the hidden Markov model, Bayesian network, and generalized PWM. A sequence logo [12] is a graphical representation of DNA motifs, which is composed of several columns. Each column is a stack of one or several bases. Weblog provides an interface to generate sequence logos. Users can enter a set of phantom instances to get the corresponding sequence logos.

2.2. DNA Sequence Specificity Prediction. The prediction of DNA sequence specificity at the motif level is motif discovery. Phantom discovery is a complex biological computing problem, which is often simplified when solving. A typical simplified version is the implanted motif search (PMS) problem [13].

In reality, not every sequence in a given sequence set must contain motif instances. Therefore, the definition of the PMS problem is not applicable to the actual situation. Based on this consideration, in addition to the existing parameters of PMS, researchers often introduce a parameter quorum, whose value range is any real number from 0 to 1, which represents the ratio of the number of sequences containing motif instances to the number of all sequences. This kind of PMS problem with parameter q is called qpms problem [14].

According to whether all the motifs that meet the input parameter constraints can be found, the qpms motif discovery algorithm can be divided into accurate qpms algorithm and approximate qpms algorithm. The basic idea is to search all candidate sets of motifs in the solution space of the motif, and use the first mock examination scoring function to obtain the highest scoring motif. Motif discovery is a NP hard problem. An exhaustive search of all possible situations

will bring considerable time and space overhead. Time performance is an important index to evaluate the quality of accurate algorithms. In the past decade, many precise qpms algorithms have been proposed [15, 16]. Accurate algorithms based on sample pattern driving, such as pmsprune [17], stemfinder [18], travsttr [19], and qpms9, include two stages: sample driving and pattern driving. Precise algorithms based on suffix trees, such as weed [20] and fmotif [21], establish suffix tree indexes of input sequences to accelerate the verification of candidate motifs. Approximate algorithms, such as pairmotif+ [22] and qpms10 [23]. For example, pairmotif+ selects some l-mer pairs in the input sequence so that at least half of the motif instance pairs are included. Then, filter out the l-mer pairs with low weight, so that the remaining l-mer pairs contain at least one phantom instance pair. Finally, an approximation strategy is used to reduce the computational verification of candidate motifs, so that the algorithm can complete the motif discovery task in one hour.

Although there are many effective qpms algorithms, they are not effective in the discovery of motifs in real DNA sequence data. In order to deal with these problems, the algorithm does not rely on the calculation of some parameters. For example, meme [24] uses the strategy of expectation maximization to refine the motif and makes the initial motif achieve local optimization through the iterative update of step e and step M . Gibbs sampling [25] first selects part of the initial sequence to generate the initial motif, then update the initial sequence in the iterative update process through Gibbs sampling and select the updated final motif according to the score. In addition to refinement, the quality of the initial motif is also important.

The above-given algorithm is time-consuming when dealing with large data sets. Among them, the search space of qpms algorithm increases rapidly with the increase of data scale. Based on the iterative optimization algorithm, the number of initial motifs and the amount of calculation of refinement of initial motifs increase with the increase of data size. For example, samselect [26], meme chip [27], and micsa [28], select a part of the sequence from the entire data set for motif discovery, which will greatly reduce the running time, but it is difficult to identify the motif with a weak signal. Pairmotifchip [29] mining and merging similar substring pairs from the input sequence to get the motif. Its running time is mainly spent on mining similar substring pairs, which increases in square order with the increase of data size. In addition, there are algorithms based on word frequency statistics [30], such as prosampler, apms [31], and mces [32].

2.3. DNA Sequence Specificity Prediction Method at Sequence Level. In addition to the motif level, DNA sequence specificity is also characterized at the sequence level, and the most effective method is based on deep learning. In 2015, alipanahi et al. First proposed a deep learning model called deepbind for sequence level DNA sequence specificity prediction. In the same year, Zhou et al. Proposed more convolution layers and pooling layers, further proving the feasibility of applying deep learning to sequence level DNA

sequence specificity prediction. On this basis, the subsequent research has done a series of improvements, mainly including model-based improvement, data-based improvement, and improvement based on adding auxiliary features.

Sequence specificity prediction requires local continuous features learned by CNN, but it also requires global features of the sequence. The results showed that danq was more accurate than deepsea in predicting DNA sequence specificity. Lanchantin et al. Proposed the continental/highway MLP framework in 2016. The model has three convolution layers, each layer has 128 convolution cores with a length of 5, and finally connects five layers of highway MLP, of which each layer has 32 neurons. The model replaces the full connection layer with highway MLP. The results show that the prediction accuracy of the network model using the highway is higher. Chen et al. Added the kernel method on the basis of CNN to make the training speed of the model faster and more accurate. This method uses the homogeneous Gaussian dot product kernel to replace the traditional convolution kernel. Although the time to calculate the homogeneous Gaussian dot product kernel is increased, the training time of the convolution kernel is also reduced. Salekin et al. Proposed deepsnr in 2018. The model adds deconvnet layer after the convolution layer and pooling layer, which is an effective means to realize feature visualization in deep learning. This enables deepsnr not only to predict the specificity of DNA sequence, but also to output the probability that each base in the sequence belongs to the motif, and then to more accurately locate the position of the motif in the sequence. With the development of natural language processing, improved models based on attention mechanism have also been proposed. In 2019, deepgrn was proposed. This model established a model for DNA sequence specificity prediction and achieved better performance. On this basis, in 2020, researchers proposed network models based on attention mechanisms such as tbinet and deepett.

The improvement method based on data is described as follows: Zhang et al. Proposed the model hocnn based on high-order coding in 2018. The model encodes adjacent bases as one element. One hot coding based on a single base will make all data particularly independent, but in the DNA sequence, adjacent bases have an interactive effect, which is not completely independent. Zhang et al. Changed the previous coding method and adopted the data coding method of high-order coding considering the interaction and interaction of adjacent bases. It was proved that the high-order coding method was superior to the traditional method. However, because the learnable parameters of hocnn increased exponentially, its performance deteriorated with the increase of high-order degree. The results show that using high-order coding within a reasonable range will indeed improve the accuracy of the model. Zhang et al. Proposed to increase the original training data through some strategic means on the basis of the original training data unchanged in 2018. The first strategy is to introduce DNA antistrand data to participate in training, and its label is consistent with the original data. Through this means, the amount of data can be doubled; the second strategy is to add the surrounding information of the DNA sequence. For

example, the original 101 long DNA sequence is expanded left and right in the genome to obtain a 151 long sequence, and then it is divided into three 101 long DNA sequences from the left, middle and right. In this way, the amount of data is expanded to three times the original. The results show that using these two strategies will make the model achieve better prediction accuracy than the original data.

The improved method based on additional information features is described as follows: Jing et al. In reality, the expression of some genes is related to their cellular characteristics, so it is of practical significance to add these characteristics. In addition, Quang et al. Accelerated the motif discovery algorithm based on expectation maximization-yamda by combining the deep learning library and GPU in 2018. Zhang et al. Proposed wscnn.

Existing methods do not utilize cofactor information of specific TF. In biological systems, specific TFs often participate in the regulation together with nonspecific TFs. These nonspecific TFs are called cofactors, and their binding sites with DNA sequences are called cofactor binding sites. When the specific TF expression signal is weak, the introduction of the information of these cofactor binding sites is expected to further improve the accuracy of the model. In addition, the existing methods do not consider that the implicit expression of the same base in different DNA sequences may be different. Usually, fixed coding is used to encode DNA sequences. The use of dynamic coding is expected to make the model more realistic, so as to further improve the accuracy of the model.

2.4. AI Technology. Today, AI is used in almost all industries, providing technical advantages for all companies that integrate AI on a large scale. According to McKinsey, compared with other analysis technologies, AI is likely to create \$600billion in retail value and bring 50% incremental value to the banking industry. In transportation and logistics, potential revenue increased by 89%.

2.4.1. Application of AI in Medical Industry. The latest trend in utilizing AI healthcare systems is for every recent scenario. In recent years, it is necessary to develop such a system, which can transform classic diagnostic tools through AI based diagnosis, so as to have a better future. In addition, AI based assistive systems are also very useful for doctors who have a shortage of doctors in emergencies (such as the covid-19 pandemic). The AI based system has been trained on millions of data points collected from the electronic health records of millions of patients, and this AI based system can better diagnose the long history of patients than doctors. For example, mfine CO is one of them. It provides services for medical staff, laboratory technicians, and doctors of systems with AI functions. The platform can easily connect you with hundreds of doctors nearby. More than 700000 users have trusted mfine to become a family doctor on the road, especially in nonemergency situations. The image or visual content contains a lot of information to identify the application of instance = AI, which involves the algorithm training of these data. In the healthcare sector,

these types of data were collected to analyze radiologic reports for retinal scans. Computer vision - an AI based tool for diagnosing diseases such as cancer (India finds more than 1 million cases of cancer every year, but the country has only about 2000 pathologists with oncology experience) can get results faster and cheaper. For example, qure AI is one of the healthcare start-ups that can provide medical imaging services based on AI algorithms. It is based on the deep learning technology that uses millions of images (such as X-ray, MRI, and CT scanning) for training. AI cannot replace doctors, but it can certainly provide important help for doctors and medical staff.

2.4.2. Application of AI in Aviation Industry. Recently, many start-ups have put forward dynamic ideas for the aviation industry. AI based software can extract thousands of procurement management information from the aviation manufacturing industry. The software simplifies procurement and establishes a plan for assembling the final product. Another AI based startup will extract PDF documents and all unreadable old text files (such as aircraft manuals) and display them in readable format for new digital technologies. Stelae technologies stelae's technology can be inserted into any on premises and cloud solution to extract documents. These also include defense aircraft modules stored 20 years ago. Asia aerospace is a robotics and AI company dedicated to developing UAV based solutions to provide viable intelligence from aviation data. Their capabilities and intellectual property rights in the entire UAV technology stack (including hardware, software, and analysis) enable them to build in-depth customized aerial remote sensing tools.

2.4.3. Application of AI in Business. AI has changed the assembly line of the manufacturing industry through automation. In the early days, these tasks were performed by humans, mainly repetitive tasks. Analysis tools and CRM (Customer Relationship Management) platforms are now supported by AI algorithms such as machine learning and deep learning algorithms to provide faster, more reliable, and better services. Nowadays, it is common for chat robots to provide customer service for e-commerce companies on websites. The automation of these service industries has led to the work problems of academic and consulting institutions. AI plays an important role in it, which promotes the development of the robot industry. Usually, robots are preprogrammed to perform some repetitive tasks, but now, intelligent robots are created by combining AI algorithms, which can perform tasks based on previous experience without explicit programming.

2.4.4. Application of AI in Travel and Transportation. AI has higher and higher requirements for the tourism industry. AI can complete all kinds of work related to travel, such as arranging travel to recommending hotels, flights, and the best routes to customers. The tourism industry is using AI driven chat robots, which can interact with customers like people to achieve a better and faster response.

2.4.5. Application of AI in Autonomous Vehicle. Recently, the automotive industry has changed the way of using AI autonomous vehicle. For example, Tesla launched the car status supported by the virtual assistant teslabot, which is a Facebook Messenger chat robot for Tesla owners. It provides services such as unlocking, positioning your car in the parking space, and keyless driving, which makes it one of the best cars ever. At present, all industries are committed to developing an autonomous vehicle, which can make your journey safer. These cars collect a large amount of data through the sensors used in the car, such as the visual data of the surrounding environment, which are processed and served in real time. An autonomous vehicle is equipped with advanced tools to collect information, including long-range radar, camera, and lidar.

2.4.6. Application of Artificial Intelligence in Education. Through artificial intelligence technology, significant changes have taken place in the education sector. For example, great changes have taken place in the interaction between teachers and students. Teaching methods and automatic scoring system can give educators more time to carry out other research work. On the other hand, students can learn in their own way and have rich resources. Chat robots can act as teaching assistants to communicate with students so that instructors have more time. AI in the future can be used as students' personal virtual tutors, which can be easily accessed anytime, anywhere.

2.4.7. Application of Artificial Intelligence in Agriculture. Since the beginning of the industrial revolution in the 19th century, the agricultural sector has been using technology. In the 21st century, the agricultural sector has taken a step forward through digitization, automation, predictive analysis, and crop monitoring. For example, the Tamil Nadu e-government Department has developed a mobile application that can scan crop images and identify diseases and provide solutions at farmers' fingertips (including disease names, pests for specific diseases).

2.4.8. Application of Artificial Intelligence in Game Industry. As early as 1949, artificial intelligence (AI) entered the game industry. It is a chess game in which a chess player plays chess against a computer. AI can be used for game purposes. AI machines can play strategic games such as chess. On machines, machines need to consider a large number of possible places. AI is deployed to build simulation similar to reality, such as human beings such as unpredictable things and human beings such as emotional things.

2.4.9. Application of Artificial Intelligence in Social Media. Technology in the 21st century has changed the human social interaction in the AI era. Various platforms have changed society through the purposes of everyone who uses this platform every day, from individuals to enterprises. But have you ever thought about how this platform works with multiple users at the same time? The general answer is AI or AI. Most of your feeds on this platform are affected by AI.

3. Method

Motif discovery is helpful to find out the sequence fragments with biological significance in DNA sequence and plays an important role in the study of gene expression regulation. At present, a large number of motif discovery algorithms have emerged, which mainly determine the length of the motif through the following three methods: the length of the motif is specified by the user before the discovery of the motif. The fragments with high information content are cut out from the extension matrix found by the motif, and the length of the motif is determined according to this. These methods to determine the length of the phantom have some shortcomings, such as difficult to determine the threshold, time-consuming, and inaccurate.

3.1. Basic Ideas. This section takes the ATF3 motif as an example to show its corresponding training sample. The sites of the ATF3 motif in the DNA sequence were extended to both sides, and the extension site set P of the ATF3 motif was obtained. Take V as a training sample of ATF3, and take the length of ATF3 as a label.

$$M_{ij} = \frac{\text{occ}(P, i, j)}{\sum_{x \in \sigma} \text{occ}(P, x, j)}, \quad (1)$$

$$V_j = \sum_{i \in \sigma} M_{ij} \ln \frac{M_{ij}}{b_i}.$$

This paper makes the machine learning model automatically extract and learn the characteristics of high relative entropy fragments in the relative entropy vector.

3.2. Overall Framework of the Model. The overall framework of predicting phantom length is shown in Figure 1, including sample data construction, prediction model construction, and prediction model application.

3.3. Sample Data Construction. In this paper, the PWM of human transcription factor binding sites was obtained in the Jaspas database, and the corresponding chip SEQ data set was obtained in encode database. The training samples need to be constructed from the fragment of the phantom. If the motif discovery algorithm finds a motif fragment, then this fragment is often a fragment with high relative entropy. In addition, when constructing samples, the length k of the high relative entropy fragment should not be too different from the real motif length L , otherwise many sites located by this fragment may not be real motif sites, thus affecting the quality of the constructed samples. Therefore, the samples are constructed by intercepting the segments with high relative entropy and large length in the real phantom PWM. Specifically, given the length L of a real phantom, its range is generally 8 to 21, and the range of interception length k is determined by the following formula:

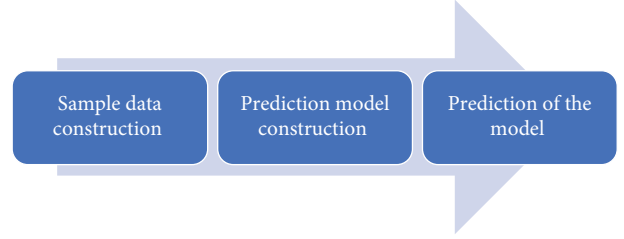


FIGURE 1: Overall prediction process of the model.

$$k \in \begin{cases} [l-3, l], & l \geq 11, \\ [8, l], & 8 \leq l < 11. \end{cases} \quad (2)$$

Some of the appearance sites of motif fragments were screened instead of all the appearance sites to construct samples. PWM detection tool moods is used to locate the occurrence site of the whole motif or motif fragment in DNA sequence data set D . It is found that many loci in p -do not fall into P . If the samples are directly constructed with all sites in P -, the quality of the samples may be relatively low, that is, the complete phantom information may be missing in the constructed relative entropy vector v .

For the obtained real motifs and chip SEQ data sets, the number of chip SEQ data sets corresponding to motifs of different lengths is not uniform, especially since some motifs do not find the corresponding chip SEQ data sets.

3.4. Prediction Model Construction. Figure 2 is a schematic diagram of a common neural network. CNN uses convolution to check different channels for convolution and finally fuses the convoluted results. The matrix is defined as follows:

$$f(M_{\text{input}}) = \text{net}(\text{pool}(\text{conv}(M_{\text{input}}))). \quad (3)$$

The reason why ReLu is selected here is that it is simple to realize and has fast convergence speed. Use maximum pooling for sampling, and set the size of the pooling window to 4. The activation function is defined as follows:

$$\text{ReLU}(x) = \max\{0, x\}. \quad (4)$$

The reconstructed vector is fully connected with 14 neurons in the output layer, and the parameter is 1280×14 weights and the same number of paranoid items. The dropout operation is performed during full connection, and some hidden layer neurons are randomly discarded during training, which can effectively prevent the model from overfitting. The value of dropout is set to 0.25. The softmax function is defined as follows:

$$\text{Softmax}(z_i) = \frac{e^{z_i}}{\sum_{j=1}^{14} e^{z_j}}. \quad (5)$$

The cross entropy function is used as follows:

$$H_{y'}(y) = - \sum_{i=0}^{14} y_i \log(y_i). \quad (6)$$

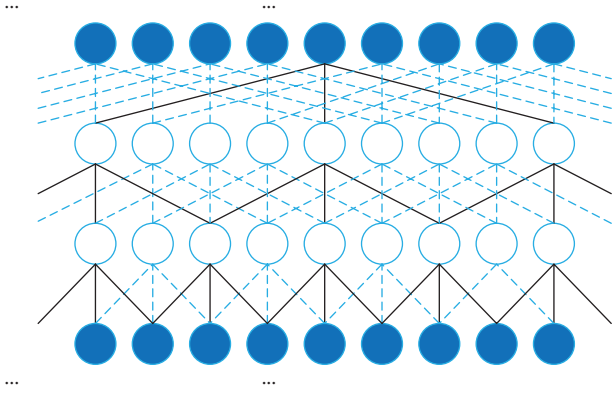


FIGURE 2: Schematic diagram of neural network.

In the training phase of the model, set 30 epoch iterations (one epoch is the process of training all training samples once), and the batchsize (the number of samples selected for one training) is 500.

4. Experiment

4.1. Experimental Setting. PWM of 280 human models were collected in Jaspard database. The length of these PWM ranges from 8 to 21. The number of PWM corresponding to each PWM length is 20. Among the 280 PWM collected, 74 PWM can obtain their corresponding chip SEQ data in encode database. For the other 206 PWM, simulated DNA sequence data sets are generated for them, respectively. During the experiment, the model was implemented on a Windows environment with a single CPU of 2.4 GHz and 16 GB memory. MPC is defined as follows:

$$mPC = \frac{\text{len}_{\text{overlap}}(m_p, m_k)}{l + l' \text{len}_{\text{overlap}}(m_p, m_k)}. \quad (7)$$

4.2. Model Validation. Cross validation method is used to verify the model. In order to avoid the samples generated by the same PWM appearing in the training set and the verification set at the same time, the sample set is divided according to PWM. For each discount data, train a model according to the other 10% discount data, use this model to predict the discount samples that do not participate in the training, and calculate its prediction accuracy.

Select 20 PWM with tags 18-21 corresponding to different transcription factors (TFs). For each PWM, the fragments with the highest relative entropy whose difference from the original length is no more than 10 are intercepted, and the prediction samples are generated from them.

We analyze the prediction accuracy of motiflen under different length segments of the real phantom. It can be found that the greater the difference between the fragment

length and the length of the real phantom, the lower the average prediction accuracy.

4.3. Optimize Existing Motif Discovery Algorithms. Motiflen can not only optimize the motifs found by the existing motif discovery algorithm but also optimize their time performance. Next, take the meme chip as an example to introduce the optimization method and optimization effect of motif.

First, motiflen can be used to optimize the motifs found by existing motif discovery algorithms. Meme chip, a well-known motif discovery algorithm, is taken as an example for discussion. In the experiment, the meme chip mining length interval was set to be 8 to 21, and the first 3000 sequences in the DNA sequence data set were taken for motif discovery. Meme chip was run on 74 sets of real data sets for phantom discovery, and the PWM found under 40 sets of real data sets was selected, which met the overlap with the published PWM. Then, from these found PWM, a prediction sample is generated, a new PWM length is predicted with motiflen, and a new PWM is obtained. This shows that by optimizing the results of the meme chip, motiflen can get a module length closer to the real PWM.

Secondly, motiflen can be used to improve the time performance of existing motif discovery algorithms. For meme chip, the time consumption of mining mode with fixed motif length is significantly less than that of mining mode with set motif length interval. In this way, motiflen is used to optimize the results of the mining mode of fixed module length in meme chip, and this method is used to replace the mining mode of setting the module length interval, so as to improve the time performance of the algorithm. In the experiment, the length of the meme chip mining module is fixed to 11 for module discovery, and then the PWM with the length of 11 is used to generate prediction samples, and a new PWM is obtained with motif. Because the running time of motiflen can be ignored, the acceleration ratio of the running time is taken as the ratio of the running time of the meme chip with a fixed length of 11 and the running time of the meme chip with a set length range of 8 to 21. We analyzed the results on eight PWM. It can be found that the optimized PWM obtained by motiflen is closer to the published PWM than the fixed length 11 PWM found by meme chip. Moreover, motiflen's correction of the PWM found by the meme chip can not only correct the shorter one to the longer one. When the PWM found by the meme chip is longer than the actual PWM, the model still has the repair function for it. On this basis, motiflen has increased the running time of meme chip by more than 2 times. In addition, the same strategy is used to optimize fmotif algorithm, which is an accurate motif discovery algorithm suitable for large data sets of DNA sequences, and it costs a lot of time. It can be found that the acceleration ratio of motiflen to fmotif can reach more than 100.

5. Conclusion

In reality, the length of the motif is unknown when it is discovered. Based on the shortcomings of the existing module length determination algorithm, this chapter proposes a set of overall solutions to predict the module length with supervised deep learning. Firstly, the motiflen model is verified, and the accuracy of motif length prediction of motiflen on the test set is more than 90%. Experiments show that in the collected DNA sequence data, the longer the length of the real phantom corresponding to the predicted sample, the higher the average prediction accuracy of motiflen. This is because the MPC index has a preference for samples with larger labels under the same absolute error. Select 20 TFs with labels ranging from 18 to 21, intercept fragments with a difference of no more than 10 from the original length according to the relative entropy, generate samples and input them to the motif. The results show that the greater the difference between the length of the motif and the real phantom, the lower the average prediction accuracy of the fragment, but the higher the complementation ability of the motif. Later, we will consider using feature reconstruction and data enhancement methods to iteratively optimize the results to make the results better.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.


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Research Article

Breast Cancer Identification Using Machine Learning

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Breast cancer is a cancer disease that seriously threatens women's health and occupies the first place in female cancer mortality. At present, the incidence rate of breast cancer in China is the first in the world and is on the rise. In view of the serious harm of breast cancer to life and health, researchers and institutions are making unremitting efforts to find a perfect diagnosis and treatment plan. With the improvement of computer performance and machine learning levels, intelligent algorithms have been able to replace human behavior and judgment in some fields. The traditional breast cancer diagnosis process requires medical experts to observe patient data repeatedly. In this case, the algorithm technology is used to quickly feedback a high probability reference result to doctors, which is particularly important to increase the diagnosis efficiency and reduce the burden of doctors. In order to improve the accuracy of existing breast cancer recognition methods, this paper proposes and implements a scheme based on a whale optimization algorithm to iteratively adjust the key parameters of the support vector machine to improve the accuracy of breast cancer recognition. In order to verify the performance of the WOA-SVM algorithm, this paper uses the Wisconsin breast cancer data in the UCI database for performance verification experiments. Experiments show that the WOA-SVM model has higher recognition accuracy than the traditional breast cancer recognition model.

1. Introduction

Breast cancer is the most common cancer and the leading cause of death in women. Around 1.4 million people worldwide are diagnosed with breast cancer every year. About 500000 people died of the disease, of which China accounted for 12.2% of the newly diagnosed cases and 9.6% of the deaths. Breast cancer not only destroys the bodies of patients but also seriously affects the image, psychology, and family relations of female patients [1–5]. In terms of the geographical distribution of the prevalence, the incidence rate of breast cancer in urban areas is significantly higher than that in rural areas. However, because the medical and health conditions and mental health levels of urban patients are better than those in rural areas, the mortality of urban patients is lower than that of rural patients. At present, the incidence rate of female breast cancer in most countries and regions is on the rise, especially in regions with low

incidence rates of early breast cancer such as Asia, Africa, and South America. Therefore, the situation of breast cancer in the world is not optimistic.

The causes of breast cancer are complex, mainly focusing on sex hormone disorders, genetic factors, and viral infection. The incidence rate of breast cancer decreased significantly in women who had undergone ovariectomy, which confirmed that estrogen and lutein were directly related to the incidence of breast cancer. For the family with a history of breast cancer, especially for women with early menarche and dense breast glands, the prevalence rate will also increase significantly. It mainly focuses on the ageing process, unhealthy living habits, and genetic factors. In biological experiments, it has been proved that the virus causes cancer. When the virus enters the breast gland, it will induce a series of pathological changes in the organs and eventually convert to breast cancer. In addition, the pollution deposited by the Earth's

environment with the development of society has also eroded human beings. Relevant studies have confirmed that in areas with serious industrial pollution, the incidence rate of breast cancer will be significantly higher than that in other areas.

The diagnostic process of breast cancer is divided into pathological diagnosis and imaging diagnosis. The pathological diagnosis of breast cancer relies on the reference of cell morphology. First, the cells of the breast mass are extracted by a fine needle, and the size, thickness, uniformity, and other data of the cells are counted in detail. Finally, the newly obtained data are classified according to the characteristics of the previous data. The imaging diagnosis methods of breast cancer are mainly divided into mammography, PET, MRI, CT, and ultrasound [6–11]. These methods have their own unique theories and tools to provide doctors with the diseased organs of patients which are invisible to the naked eye. Among them, breast ultrasound has a good resolution for soft tissue, can clearly show the layers between the thymus and the chest wall, and can accurately identify millimeter-level tumors. It is a non-radioactive way and has been a routine item for the detection of breast cancer.

In the past half century, computer technology has brought a great driving force to social progress. With the change of times, computer technology has also scattered a wide range of research directions. As a star concept, artificial intelligence has become the direction of various technologies. Using machines to completely replace artificial is not only a beautiful demand but also a visible future. As an important category of artificial intelligence, machine learning technology can automate the process of data processing and use specific mathematical models to describe the data completely. Today, in the medical field, computer-aided diagnosis based on machine learning technology has been specifically implemented for various diseases [12–17]. Whether it is to use algorithms to classify and judge a large number of data or to predict new data based on past data, the existing algorithm models have achieved reliable results and have also been recognized and trusted by the majority of pathologists.

Although individual breast cancer can be judged in advance by miRNA sequence detection technology, breast cancer is a chronic cancer with no obvious early symptoms. Once the abnormality is detected, it is likely to be in the middle and late stages. Using machine learning technology to make accurate judgments can carry out targeted early diagnosis and treatment for patients. In order to improve the accuracy of existing breast cancer recognition methods, this paper proposes and implements a scheme based on a whale optimization algorithm to iteratively adjust the key parameters of the support vector machine to improve the accuracy of breast cancer recognition. In order to verify the performance of the WOA-SVM algorithm, this paper uses Wisconsin breast cancer data in the UCI database for performance verification experiments. Experiments show that the WOA-SVM model has higher recognition accuracy than the traditional breast cancer recognition model.

2. Related Work

2.1. Diagnostic Techniques for Breast Cancer. There are many research studies on machine learning technology in the intelligent diagnosis of breast cancer. The clinical data for breast cancer will be collected according to the patient's disease degree and period, including the patient's age, tumor cell morphology data, physical condition before and after the disease, survival time, and other aspects. Through these collected real data, various algorithm models are used to test and analyze. The researchers proposed using the sigmoid kernel support vector machine method for the auxiliary diagnosis of breast cancer. Under the 5-fold cross-validation, the average accuracy reached 96.24%, but this method ignored the further improvement of the results by accurate parameter optimization. Researchers use particle swarm optimization algorithms to optimize SVM parameters. The model has been applied to breast cancer data and achieved 97.28% high precision. It is proven that the optimization algorithm can significantly improve the SVM classification ability and has a certain practical value. Alickovic et al. [18] used a classification model based on the normalized multilayer perceptron neural network to classify the Wisconsin breast cancer (original) data set, used 80% of the data as a training set and 20% of data as a test set, and obtained 99.27% accuracy. Khadija et al. [19] used the Naive Bayes and support vector machine algorithms for the Wisconsin breast cancer diagnosis data set and used a 10-fold cross-validation method to detect the results. Among them, the Naive Bayes algorithm obtained 95.65% recognition accuracy, which is better than that of the support vector machine algorithm. The researchers used the support vector machine feature elimination algorithm to process the triple-negative breast cancer data set and then used the decision tree algorithm to test the classification, and the accuracy reached 97.8%. Polat et al. [20] proposed using least squares support vector machine (LS-SVM) to classify breast cancer data and achieved high accuracy. However, the accuracy results will vary greatly under different verification methods. Watkins et al. [21] proposed an immune-inspired supervised learning algorithm and applied it to the breast cancer data sample donated by Dr. William Wolberg of Wisconsin University Hospital in the United States. Through 10-fold cross-validation, the recognition rate reached 97%. At present, there may be some inaccuracies in the diagnostic research on clinical data using machine learning technology, but this is largely due to the limitations of data acquisition accuracy, computer hardware level, algorithm level, etc; these problems will be completely solved with the passage of time.

Compared with the number of studies on clinical data of breast cancer, there are relatively few studies on ultrasound images of breast cancer. Because ultrasonic images are often high noise images, modeling recognition or doctor judgment will produce high error values. Compared with other medical imaging methods, ultrasound images are cheap, noninvasive, and painless, and have high diagnostic feedback efficiency, so they are also widely welcomed and applied. Therefore, it is necessary to develop vigorously. According to the difference in geometric features between

benign and malignant tumors in ultrasound breast tumor images, the researchers developed a diagnostic scheme. The final experimental accuracy was 72.90%. In addition, the ultrasound images of breast nodules can be used for experiments using the USNet model. The AUC values of benign nodules, malignant nodules, and normal glands are 93.67%, 94.34%, and 99.68% respectively. In addition, researchers used the AlexNet network model to recognize the ultrasound images of breast nodules provided by Beijing Friendship Hospital. Using the verification method of 80% of the training set and 10% of the verification set and test set, after being processed by the ACE algorithm group, 93.25% of the AUC value was obtained. Uniyal et al. [22] also introduced the gray level cooccurrence matrix into the feature extraction of ultrasonic RF signals, which further improved the accuracy of the feature description of breast lesions. The AUC value of the support vector machine classifier reached 86%. In addition, the researchers used a hierarchical binary tree SVM classifier to classify breast ultrasound RF data. In the process, the Shearlet transform was used to extract the multiscale and multidirectional features of breast ultrasound RF signals. Second, a multiscale directional binary pattern (MDBP) was used to reduce the data dimension without losing feature information. The experimental results showed that the AUC value was 78.40% and the accuracy reached 89.29%.

2.2. Machine Learning. Machine learning is the inevitable outcome of social development, and also the inevitable outcome of the development of artificial intelligence research to a certain extent. From the 1950s to 1970s, the research study on machine learning technology was conducted in the “reasoning period.” People at that time had realized that as long as the machine was endowed with logical reasoning ability, the machine would have wisdom. The original imagination is still so directional now. The representative products of this period mainly include A. Newell logic theorist program and later “general problem solving program” [23]. In the mid-1970s, researchers gradually felt that artificial intelligence could not be realized only by making machines have reasoning ability, but also by making machines have knowledge. During this period, many expert systems for solving practical problems appeared, with gratifying results. However, the expert system soon reached the bottleneck period, and some researchers thought that the way out for artificial intelligence was to let machines learn knowledge by themselves. In the 1980s, a decision tree was born, which directly simulated the human judgment process. Today, a decision tree is a commonly used machine learning technology. In 1986, the BP algorithm was also born, which laid the foundation for the hot in-depth learning at that time. In the mid-1990s, “statistical learning” was born, and its representative technology is the famous support vector machine. Its own algorithm and various derived kernel techniques are still widely used in almost all research fields. In the 21st century, there has been an upsurge in in-depth learning. The so-called in-depth learning refers to neural networks with more complex topology and more layers. At

present, the application scenarios of in-depth learning are very rich, and in various competitions, in-depth learning has also made many outstanding performances.

Today, machine learning technology has been used in all aspects of life, such as weather forecast, stock trend, medical identification, etc. In addition, Gaode, Baidu Maps and other navigation platforms can recommend the best route according to the real-time traffic conditions, current location, and destination. In the 2012 US. election, there was an excellent machine learning data analysis team in the Obama camp, which conducted a three-dimensional analysis of various intelligence data, guided Obama to make timely and accurate election campaigns, and made a very important technical foreshadowing for the final election [24]. In the man-machine confrontation go game held in March 2016, AlphaGo [25] designed by the deep mind team based on reinforcement learning, also defeated lishiyu, the best chess player at that time, with a score of 4 : 1, which had a great shaking effect in the world, and also attracted great attention from all walks of life to machine learning technology. The auto drive system based on in-depth learning developed by Tesla is also becoming more and more perfect and will finally realize the situation of unmanned driving one day. The self-service shopping device that uses facial recognition to check out has been deployed nationwide by the Alipay team of Alibaba, which has reduced the waiting period of shopping queues, made it easy to use, and achieved a good response. In the field of machine learning, there are many excellent institutions dedicated to special research, including Stanford Research Institute, Google Lab, Aridamo Institute, etc. these organizations have done a lot of practical research, which has greatly promoted the extension and development of the field of science and technology.

2.3. Intelligent Medical Technology. At present, machine learning has been applied in many fields, such as data modeling, image analysis, natural language processing, audio recognition, social network filtering, and so on. The level of machine learning in the medical field is directly related to people’s life safety, so it is the key direction of intelligent technology development. In the middle of the 20th century, Ledley [26] first proposed applying the algorithm model to the medical scheme and using computers for auxiliary diagnosis. The concept of “intelligent medical care” was formally put forward in 2008. IBM took the lead in launching a medical wearable device that integrates Internet of things technology and artificial intelligence technology and achieved a good response. For the research and development of medicine, artificial intelligence technology can create a simulation environment based on the existing medical textbooks, patient medical records, treatment plans, and other huge amounts of data, from which the optimal composition ratio can be mined, greatly reducing the research and development threshold and cycle [27].

Machine learning-assisted diagnosis has the most important application in the medical field. According to statistics, more than 57 million cases in China are misdiagnosed

to varying degrees every year, and the misdiagnosis rate is as high as 27%. In the future, with the improvement of machine learning level, the accuracy of patient data recognition and imaging diagnosis will be higher and higher, which will effectively reduce misdiagnosis and improve diagnosis efficiency, reduce the occurrence of various medical disputes, and provide high-quality medical services for the public. Intelligent medical technology has greatly eased the pressure on patients' treatment. With various public opinion surveys, medical staff and nonmedical staff have very high support and expectations for intelligent medical technology. At present, many departments need to work together in some disease fields, so the integration of intelligent medicine is an important goal.

The essence of intelligent diagnosis and treatment is to apply intelligent technology to the patient's course and treatment cycle, intelligently analyze some real-time test reports of the patient, and feed back the test results and treatment plans recommended by the machine. While intelligent medical technology requires hardware adaptation, of course, it cannot be separated from the support of data. Although we are now in the era of data sharing and there are some public data sets for researchers to study and analyze, institutions such as hospitals and medical research institutes have more data sets with a large number of samples. These data sets are more high-quality, but they cannot be provided to the outside world for various reasons. If all medical data sets can be interoperable, the current level of intelligent medicine will be greatly improved.

3. Proposed Breast Cancer Recognition Algorithm

3.1. Whale Optimization Algorithm. The whale optimization algorithm (WOA) is a new group optimization algorithm developed by Mirjalili et al. [28] in 2016 to establish a mathematical model by imitating the hunting behavior of humpback whales. Whales are considered to be the largest mammals in the world. In the whale brain, there are spindle cells similar to those in humans. These cells are responsible for judgment and social behavior. Therefore, they are also highly intelligent creatures. The humpback whale preys ingeniously. First, it swims upward in a spiral posture from a depth of 15 meters from the sea surface, spits out bubbles of different sizes, and makes all bubbles reach the water surface at the same time, forming a cylindrical and tubular bubble net, which narrows the range of activity of the prey and forces it towards the center of the bubble net. Then, it opens its big mouth almost vertically in the bubble net and swallows all the prey in the net.

WOA has the characteristics of a simple principle, few parameter settings, and strong optimization performance. It has been proved that WOA is superior to the traditional meta heuristic algorithm in both search accuracy and convergence rate in the extreme value optimization of standard test functions. The following describes three methods of WOA location update: surround prey, bubble attack, and random search.

- (1) The stage of encircling prey. In the initial stage of predation, the whale will observe the approximate location of the prey and then surround the prey group. In the WOA algorithm, it is assumed that the problem solution or problem variable to be optimized is the location of the optimal whale. After the best prey position is defined, other whale individuals will approach this position and gradually surround the food. In contrast, in the WOA algorithm, the distance between the individual and the optimal whale needs to be calculated first:

$$\vec{D} = |\vec{C}\vec{X}^*(t) - \vec{X}(t)|, \quad (1)$$

where t is the current iteration number. $\vec{X}^*(t)$ is the individual position of the t -generation whale, which will be continuously revised with each iteration. The swing factor is defined as follows:

$$\vec{C} = 2\vec{r}. \quad (2)$$

The individual position in the whale group will be updated according to the best individual position, and the expression is as follows:

$$\vec{X}(t+1) = \vec{X}^*(t) - \vec{A}\vec{D}, \quad (3)$$

where \vec{A} is the convergence factor, which is defined as follows:

$$\vec{A} = 2\vec{a}\vec{r} - \vec{a}, \quad (4)$$

where r is a random number between 0 and 1.

- (2) Bubble attack phase. In this order, according to the behavior of the humpback whale to spit out bubbles for predation, two strategies, contraction and spiral update, are designed to achieve the purpose of local optimization of the algorithm. In the process of shrinking and encircling mechanisms, the whale group shrinks and encircles. When a is less than 1, the whale will approach the whale with the best current position. The process of spiral position updating is to calculate the distance between the individual humpback whale and the current optimal whale, and then shrink the swimming in a spiral way. In the process of food search, the mathematical model of spiral contraction mode is as follows:

$$\begin{aligned} \vec{X}(t+1) &= \vec{D}' e^{bl} \cos(2\pi l) + \vec{X}^*(t), \\ \vec{D}' &= |\vec{X}^*(t) - \vec{X}(t)|, \end{aligned} \quad (5)$$

where \vec{D}' represents the distance vector between the individual and the currently optimal whale; L is a random number between 0 and 1; and B is a constant that limits the shape of the logarithmic spiral. In order to be able to both maintain contraction and swim to food along the spiral path.

- (3) Random search phase. Humpback whales capture prey by controlling the a vector to swim. When a is greater than 1, individual whales randomly search according to each other's positions, which can promote individual humpback whales to conduct global search and obtain the global optimal solution.

3.2. WOA-SVM Algorithm. At the beginning of the birth of each metaheuristic algorithm, the most intuitive performance is demonstrated through its extreme value optimization ability of the standard test function. Therefore, in the face of practical problems to be solved, WOA's fitness optimization is generally divided into the maximum problems and minimum problems. The biggest problem is that the classification accuracy is generally used as the fitness; for the minimum problem, the error rate is generally used as the fitness. In this paper, the misclassification rate of the SVM model in the sense of cross-validation is taken as the fitness value, and the two important parameters of SVM are iteratively optimized by the WOA algorithm to continuously improve the generalization accuracy of the SVM model.

Reasonable parameter setting is very important to improve the classification performance of SVM. In this paper, the WOA-SVM algorithm is used to recognize breast cancer data. The WOA-SVM algorithm first initializes the population, that is, initializes the population number and the individual search dimension. Since the parameters that have the greatest impact on the accuracy of the SVM model are the penalty factor C and the kernel function parameter g , the individual search dimension is set to 2. The data set used in this paper is relatively small, and the dimension of a single data sample is small. The initial position of the individual population can be set randomly, which will not affect the convergence speed and final accuracy of the algorithm.

In each iteration of the WOA algorithm, all individuals in the population will be updated according to their search results. Individuals beyond the search boundary will be reinitialized. For individuals that do not exceed the boundary, local optimization or global optimization will be performed according to the parameter setting conditions. When the iteration times of the whole algorithm model reach the set value or get perfect fitness results, the whole test process ends. The flowchart of the WOA-SVM algorithm for identifying breast cancer is shown in Figure 1.

4. Experiments

4.1. Experimental Setup

4.1.1. Experimental Environment and Parameter Setting. The experimental research platform and tools are Microsoft Windows10 and MATLAB r2018a. The LIBSVM toolbox is used for some functions of the research work. The Toolbox provides many application functions related to SVM models and their source codes, which make it convenient for users to conduct data research. In order to show the performance advantages of the WOA-SVM, BP neural network, traditional SVM, and PSO-SVM are selected as comparison methods. The BP model is established by using

the new function in the MATLAB neural network toolbox. The hidden layer is set to 10 neurons, the training times are set to 500, the learning rate is set to 0.01, and the default $1e-5$ is used as the training target value. Traditional SVM model parameter settings: $C=0.1$, $g=0.005$. The population size of PSO and WOA is set to 10 and the number of iterations is 100.

In this paper, the clinical data of breast cancer are studied by using the WBCD data set in UCI, which is taken from the nuclear features extracted from the fine needle of a breast mass. The data set contains 699 samples, each of which has 9 characteristic attributes and 1 category label. In the sample data inspection, it is found that 16 sample data are missing, and the samples with missing data have been eliminated. The resulting data set is shown in Table 1.

4.1.2. Experiment Verification Method Experiment. Two verification methods are adopted. The first verification method adopts the traditional set-aside method, which first divides the data set into two mutually exclusive sets, assuming that the two sets are s and t , respectively. Set s is used to train the algorithm model, and set t is used to test the generalization ability of the algorithm. In order to ensure the consistency of data category distribution, the training set and test set should be selected randomly from the middle proportion of the two categories, that is, assuming that 70% of the data samples are required as the training set; then, 70% of the samples from benign and malignant are randomly selected for model training, and the remaining samples are used for evaluation. The second verification method adopts 10-fold cross-validation. The data set is divided into 10 parts, on average, 9 of which are used as training data and 1 as test data in turn. In this paper, benign and malignant samples are divided into 10 equal parts respectively. Each time, one benign data sample and one malignant data sample are selected as the verification set, and the rest of the data samples are used as the test set for simulation experiments.

4.2. Performance Evaluation Index. The evaluation index is a quantitative index of the quality of the algorithm or parameters given by inputting the same data into different algorithm models or the same algorithm model with different parameters. In many evaluation indicators, most of them can only reflect part of the performance of the model. If the evaluation indicators are not used reasonably, the problems with the model itself will not be found, and even wrong conclusions will be drawn. Therefore, in the process of evaluating the performance of the algorithm model, it is often necessary to combine a variety of different indicators for comprehensive analysis.

Accuracy is the most direct and original indicator for evaluating model performance. It is defined as the percentage of samples correctly identified by the algorithm model within the total samples. The calculation formula is as follows:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \quad (6)$$

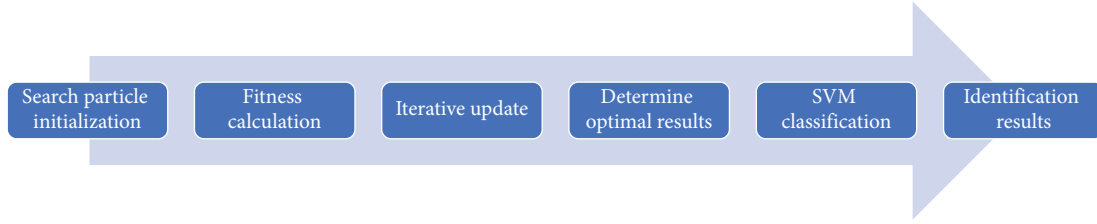


FIGURE 1: Flowchart of the recognition algorithm.

Precision refers to the proportion of samples that are predicted to be true and actually true in the total number of true samples. Its formula is as follows:

$$\text{Precision} = \frac{TP}{TP + FP} \quad (7)$$

Sensitivity refers to the ability of the model to correctly judge the data of malignant patients. The higher the sensitivity of the algorithm model, the lower the missed diagnosis rate of the model. The formula is as follows:

$$\text{Sensitivity} = \frac{TP}{TP + FN} \quad (8)$$

Specificity indicates the ability of the model to correctly judge nonpatients. The higher the specificity value, the lower the misdiagnosis rate of the representative model. The formula is as follows:

$$\text{Specificity} = \frac{TN}{TP + FP} \quad (9)$$

4.3. Experimental Result. It can be seen from Table 2 that WOA-SVM and PSO-SVM algorithms are significantly better than SVM and BP in terms of accuracy and benign/malignant accuracy of WBCD data sets. Compared with the SVM model with default parameters, the accuracy of the two optimization algorithms is improved by 5.34% and 5.82%, which shows that the value of key parameters has a great impact on the performance of the SVM model. When 70% of the training set samples are taken, the training results of the test set show that WOA-SVM is 0.48% higher than PSO-SVM in accuracy. Although PSO-SVM is 0.71% higher than WOA-SVM in benign diagnosis rate, the recognition rate of WOA-SVM for malignant samples has reached 100% perfect accuracy, 2.78% higher than PSO-SVM.

In order to more fully reflect the real performance of each algorithm for WBCD data set classification, the number of samples in the test set is increased, that is, the samples used for training are decreased step by step. Due to the reduction of learnable samples, the accuracy results of each algorithm also show a decreasing trend. The performance of the WOA-SVM algorithm in accuracy is still better than the other three algorithms, which further shows the effectiveness and stability of WOA-SVM.

The framework of using a group optimization algorithm to optimize SVM model parameters adopts the average accuracy of the model in the sense of 10-fold cross validation as the fitness value. When the model training is completed, the

TABLE 1: WBCD data set information table.

Data set name	WBCD
Number of samples	683
Benign	444
Malignant	239
Characteristic number	9
Category	2

TABLE 2: Comparison of simulation results of tumor recognition rate (select 70% of the training set).

Method	Accuracy	Benign diagnosis rate	Malignant diagnosis rate
WOA-SVM	99.02	98.51	100
PSO-SVM	98.54	99.25	97.22
SVM	93.20	96.27	87.50
BP	98.06	99.25	95.83

corresponding parameter values under the best fitness are transferred to the SVM model, and then tested in a corresponding way. Here, this paper directly derives the optimal fitness value, that is, the highest average accuracy value of the SVM model under 10-fold cross-validation, and transmits the corresponding sensitivity (SEN) and specificity (SPE). The results are shown in Table 3. Compared with the retention method, the accuracy of each algorithm model has significantly decreased in the accuracy results. The accuracy of the BP neural network model has decreased by 6.3% compared with the retention method of 70% training set and 30% test set, indicating that the BP model has poor overall control ability for the relatively rigorous validation method of 10-fold cross-validation. In the SVM without an optimization algorithm and only using default parameters, the accuracy value is still not ideal. The WOA-SVM algorithm has higher accuracy and sensitivity than PSO-SVM. Therefore, in the 10-fold cross validation mode, WOA-SVM is still the optimal model compared with the other three algorithms.

5. Conclusion

As one of the most common cancers, breast cancer has a high incidence in women, and the incidence rate is increasing year by year. For patients, if they can accurately judge their illness and timely take targeted treatment plans to follow-up treatment, the survival rate of patients will be significantly improved. In order to reduce the possibility of misdiagnosis or missed diagnosis when doctors judge the

TABLE 3: Comparison of recognition performance under ten-fold cross-validation.

Method	Accuracy	Benign diagnosis rate	Malignant diagnosis rate
WOA-SVM	97.50	99.54	94.19
PSO-SVM	97.21	98.42	95.39
SVM	91.91	94.79	87.35
BP	91.76	92.72	93.40

patient data or breast pathological images, in this paper, machine learning technology is used to recognize WBCD data set obtained from fine needle aspiration of breast mass. The new group optimization algorithm WOA is proposed to intelligently adjust the parameters of the SVM model, maximize the fitting ability of the SVM model to the WBCD data set, and optimize the recognition results. Then, the simulation test is carried out by using the set aside method and the 10-fold cross-validation method. The experimental results show that the performance of the WOA-SVM model is significantly better than the traditional breast cancer recognition model and has a practical value.

The data sets used in this paper are not from the Asian region. Due to the great differences in the physique of women from all continents, the research results have certain limitations in terms of reference significance for Asian women. In addition, all the recognition experiments in this paper are carried out using traditional machine learning algorithms. Although they have achieved good results, they do not use the current popular deep learning algorithms. In the future, they are ready to extend the knowledge system to the field of deep learning.

Data Availability

The data set can be accessed upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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Retraction

Retracted: Practical Thinking of Neo-Confucianism in Qing Dynasty from the Scope of Practice Based on Deep Learning

Mathematical Problems in Engineering

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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.

References

- [1] J. Deng and T. B. Chuan, "Practical Thinking of Neo-Confucianism in Qing Dynasty from the Scope of Practice Based on Deep Learning," *Mathematical Problems in Engineering*, vol. 2022, Article ID 8284696, 9 pages, 2022.

Research Article

Practical Thinking of Neo-Confucianism in Qing Dynasty from the Scope of Practice Based on Deep Learning

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As the mainstream of Confucianism, the Song and Ming philosophies played an irreplaceable role in the 800 years of history from the Song dynasty to the end of the Qing dynasty. The theoreticians were concerned with the principles of heaven, nature, and physics and especially with the principles of human nature, which changed in the Qing Dynasty to a practice-oriented way of thinking. However, the practical thinking of Qing dynasty Neo-Confucianism is difficult to apply to practice because of the obscure text and the limitations of the time period, so it is worth further discussing how to deconstruct and promote the learning of Qing dynasty practical thinking under the new technology. This paper systematically reviews the ideological origins and political practices of Qing dynasty Neo-Confucianism and proposes a knowledge-tracking model around deep learning technology, which not only provides a contemporary technological tool for deconstructing the practical thinking of Qing dynasty Neo-Confucianism but also provides an application path for the integration of technology and knowledge.

1. Introduction

The Qing Dynasty was an important watershed in the history of Chinese scholarship. The scholarly development of this period was not only a summary of two thousand years of traditional scholarship but also a precursor of modern scholarship. The history of Qing Dynasty scholarship has been a hot topic of research, and its understanding is constantly being updated. However, as far as the history of Qing studies is concerned, it has been questioned since the phrase “Qing Dynasty Neo-Confucianism is exhausted and there is no residue of it” [1], and it has come to a deadlock. In order to break this deadlock, it is necessary to conduct a systematic, comprehensive, and profound investigation of the way of thinking of Neo-Confucianism in the Qing dynasty.

From the viewpoint of the history of thought and scholarship, the focus of the Neo-Confucianism of reasoning was on the theoretical experience and practice of the state of mind and work, which developed to the extreme in the late Ming Dynasty. The early Qing scholar Huang Zongxi had

profound attainments in the science of reason, but he did not work as a scholar of reason, and his Confucianism only discerned the concepts of reason, mind, nature, etc. As an important school of traditional Confucianism, the science of reason was constantly socialized and played the role of the right and the left in the world, especially in the Qing Dynasty. Therefore, “writing theories with theories” was obviously incomplete, and even difficult to realize after the end of theories as a dominant form of theory. One important reason is that the work and the realm that belonged to the core of science could not be dealt with in detail from the perspective of academic history alone. Therefore, the study of the history of Qing Dynasty Neo-Confucianism must be integrated with the broader social life and culture in order to comprehensively and systematically interpret the changes and unique features of Qing Dynasty Neo-Confucianism at the concluding stage of traditional Chinese scholarship, in addition to having a firm grasp of the data [2]. It is only by combining the thinking of the history of ideas with the perspective of social and cultural history that the study of theories can be deepened.

In the practical application of Neo-Confucianism, the Qing scholars either promoted Cheng and Zhu or continued to adhere to Lu and Wang's philosophy of the mind, and all of them incorporated their practical ideas into their Neo-Confucianism and actively participated in the political practice of the Qing dynasty with the mission of restoring the broken social order and maintaining the long-term peace and stability of the country [3]. The emperors of the Qing dynasty also supported the famous scholars of science from the political point of view, ruled the country by science, and selected the contents of the thought and Neo-Confucianism of the famous scholars of science that were beneficial to the rule of the Qing dynasty. The political practice of the scholars was not only in line with the ideology of Neo-Confucianism for the benefit of the country and the people but also against it. There were complex social backgrounds and political factors behind this phenomenon, reflecting the contradiction between Confucian ideals and political reality. Importantly, the political practice of Qing dynasty Neo-Confucianism gave rise to practical thinking, which had a profound impact on later generations. However, along with the continuous development of society, the practical thinking of Qing Dynasty Neo-Confucianism has been gradually replaced by instrumental rationality and has been declining. Therefore, under the boom of artificial intelligence, how to effectively apply artificial intelligence technology to the simulation of practical thinking has become an important research issue.

This paper attempts to simulate practical thinking in Qing dynasty Neo-Confucianism using deep learning techniques and proposes a corresponding improved knowledge-tracking model in order to provide a channel for the contemporary dissemination and promotion of practical thinking in Qing dynasty Neo-Confucianism, as well as an application basis for the integration of technology and knowledge.

2. Literature Review

Because of the multiple aspects of Ming and Qing scholarship, the academic turn in Ming and Qing dynasties was a holistic turn in various intellectual disciplines such as scriptures, history, sons, and collections and was neither a linear evolution nor a narrow change from Song and Ming scholarship to Qing dynasty koanology or Neo-Confucianism, koanology, "respect for virtue," and "Daoist scholarship." The change is not a linear evolution, nor is it a narrow shift from Song and Ming dynasties to Qing dynasty koans, or science, koans, "respect for virtue," or "Taoism." Among them, although the science was in crisis, it was not hopeless, and the inclusive "early Qing new Neo-Confucianism" came into being and became the bridge between the mainstream of early Qing scholarship and the transformation of Ming and Qing scholarship, and the source of all schools of Qing scholarship. In other words, the academic transformation of the Ming and Qing dynasties was not a "one-step process" from science to koanology, as traditionally believed, but a "two-step process."

In the social crisis of the Ming and Qing dynasties, Song and Ming schools of thought were transformed into "early

Qing new Neo-Confucianism" and from "early Qing new Neo-Confucianism," Qing dynasty Neo-Confucianism, koanology, and Tongcheng school were transformed. Reflected in politics, the "early Qing Neo-Confucianism" also had a great impact on early Qing dynasty politics.

As a bridge to the academic turn of the Ming and Qing dynasties and the crystallization of the collective wisdom of the Qing scholarship, Qing Neo-Confucianism defended the basic values of Neo-Confucianism, faced the broad social reality, and sought a new way to unite the scholars and Sincize the foreigners. Wang Guowei's statement that "the early state learning was great" and Qian Mu's statement that "the new world of Neo-Confucian thought in the Qing dynasty" originated from the shaping of this Neo-Confucianism in the first place.

2.1. Neo-Confucianism in Qing Dynasty. Compared with Song and Ming Neo-Confucianism, Qing Neo-Confucianism changed in two major ways: firstly, it promoted a problem-oriented approach to learning and was committed to the inclusion of Cheng-Zhu Neo-Confucianism, Lu-Wang Xinxue, and other Neo-Confucian resources, with a focus on "righteousness" and abandonment and absorption, unlike the previous strict gateway. Secondly, the focus of practice is on solving realistic problems rather than being confined to metaphysical thinking or ethical dogma, moving from discursive lectures to kung fu theory and institutional criticism, taking kung fu theory and institutional criticism as the base, integrating inner sainthood and outer kingdom, developing theoretical innovation and moral practice at the same time, and taking metaphysical "reason" and metaphysical "reason" and metaphysical "reason" together. "It is for these two reasons that the Qing dynasty's philosophy was developed. It was for these two reasons that the leading figures of the Qing Neo-Confucianism were all academic and moral icons [4].

In terms of academic style, they were inclusive, and they accepted both literature and martial arts and used both chivalry and Confucianism. In the north, Sun Qifeng said, "Begin with the heroes and end with the sages." In the Ming Dynasty, during the Tianqi period, the eunuch Wei Zhongxian dictated power and disorderly government and ruthlessly cracked down on the ministers who impeached him for his sins, Zuo Guangdou, Wei Dazhong, and Zhou Shunchang were the first to be arrested. Although the rescue operation failed, Zuo, Wei, and Zhou died, but Sun Qifeng still saved their relatives. As Sun Qifeng, Lu Zheng, and Zhang Guozhong were in a hurry, "the righteousness of the people was high in the sea, and they were known as the 'three martyrs of Fangyang'." Sun Qifeng is familiar with the art of war, in the Ming and Qing dynasties, leading the people to fight against all sides of the attack, to ensure the peace of the party. In 1636, Huang taiji became emperor and at the same time sent troops to break through the Great Wall and approach Baoding, the surrounding cities fell one after another; but under Sun Qifeng's leadership, the people of Rongcheng rose up to resist and were saved. Therefore, the History of the Ming Dynasty directly positioned Sun Qifeng

as a “knightly warrior.” Wang Yuyou “studied the art of war under Sun Qifeng” and wrote “The Outline of Qiankun” and “The Thirteen Swords,” which were dedicated to the convergence of the new Confucianism, martial arts, and military science. The “Ontario” is the first work of military theory in the history of Chinese military books that discusses the principles of strategy from the perspective of the beginning soldier.” In this book, Wang Yu-you put forward the idea of “attracting force with the sword,” which had an important influence on the thought of Chinese swordplay. The Yan-Li school was based on Xia Feng’s northern school, which pushed the style of both literature and martial arts, chivalry, and Confucianism to the climax. As late as 1917, Mao Zedong, in his first published article, “Study of Sports,” praised Yan Yuan’s academic style of “both literature and martial arts.”

In the south, Huang Zongxi changed three times in his life: “first he was imprisoned as a party member, then he was referred to as a ranger, and finally he was toiled in the Confucian forest. In the early years of Chongzhen, Huang Zongxi avenged his father’s death by stabbing the eunuch Xu Xianchun with a cone in his sleeve, beating Cui Yingyuan in public, and plucking his beard to his father’s spirit. After the Qing army conquered Nanjing, the King of Lu supervised the country and recruited volunteer soldiers with the old East Foresters in an attempt to recover, and his troops were called “Huang’s Shizhong Battalion.” He also begged for a teacher in Japan, but after several hardships, he did not succeed. In the “Epitaph of Wang Zhengnan,” Huang Zongxi clarified for the first time in the history of Chinese martial arts, the “internal martial arts,” which are “to be calm and braked, the offender will fall down when he is attacked,” and the “external martial arts,” which are “famous for their courage and their ability to fight people.” The difference between the “internal martial arts” and the “external martial arts,” which are “famous for their courage and their ability to fight. Gu Yanwu, after the Qing army entered the country, served as the minister of military affairs in the Hongguang dynasty of the Southern Ming Dynasty, and wrote “Theory of Military System,” “Theory of Situation,” “Theory of Tian Gong,” and “Theory of Money Law.” After the Qing army sacked Nanjing, Gu Yanwu joined Wang Yongjo’s volunteer army and joined forces with Guizhuang and Wu Zhihui and Lu Zhiyu to solve the siege of Kunshan, but failed to do so. Gu Yanwu’s birth mother, He, lost her right arm to the Qing army, and his heir mother, Wang, died of hunger strike, ordering him not to serve the Qing for the rest of his life. He was not allowed to work for the Qing Dynasty for the rest of his life. Gu Yanwu visited the Ming Mausoleum six times and was framed by his enemies. Wang Fuzhi raised an army against the Qing Dynasty in Hengyang in the fifth year of the reign of Shunzhi and blocked the southward movement of the Qing army, but he was defeated and retreated to Zhaoqing.

In terms of attitude toward Song and Ming Neo-Confucianism, Qing Neo-Confucianism was committed to rebalancing the basic values of Neo-Confucianism with social reality, reconstructing the relationship between heaven and man, ritual, and human feelings, and the

relationship between Lu Wang Xinxue and Cheng Zhu Neo-Confucianism, and constructing a new consensus to unite more Han scholars. If we take a broader view, the Neo-Confucians of the Qing Dynasty, on the one hand, devoted themselves to the abandonment of Song and Ming Neo-Confucianism, and on the other hand, starting from the theme of the times, launched a powerful movement to return to the classics and reinterpret them. It was the continuous induction of this inclusive “New Confucianism” that led to a new period of expansion and peak of Han culture. Wang Fuzhi’s patriarch Zhang Zai, compatible with the late Ming Donglin party and Lao Zhuang, Buddhism some resources, “revised Cheng Zhu, opposed to Lu Wang,” historical philosophy opened up a new world. Huang Zongxi inherited from Wang Yangming and Liu Zongzhou, and opened up to Wan Sitong and Zhang Xuecheng, talking about “all qi in heaven and Earth,” focusing on qi theory, emphasizing the integration of history with scripture, and opening up the academic precedent of Zhejiang East in the Qing Dynasty. He also wrote the book “Ming Yi Zu Zhuan Lu,” criticizing the monarchy. Gu Yanwu “said that there is no other so-called new Confucianism in the past and present and that scripture is the new Confucianism. He also wrote “The Book of the Day” and “The Book of the Sick,” talking about “the rise and fall of the world is the responsibility of every man” and other doctrines” [5].

In terms of academic thinking, Neo-Confucianism in the Qing dynasty was a departure from the dogmatic approach of Neo-Confucianism in the late Ming dynasty and was based on the social situation and themes of the time. From the perspective of Chinese and Western history, the 17th century was a time of many crises. In the West, the economic situation, which had recovered and developed vigorously in the 15th and 16th centuries, suddenly fell into a trough in the 17th century and seemed to be returning to the 14th century. Spain and Italy were declining, France and Germany were struggling, and there was a return to slavery in Eastern Europe. Thus, in the second volume of his *Modern World System*, the famous modern Western scholar Wallerstein entitled the preface “The Crisis of the Seventeenth Century.” In China, the internal manifestation was the dramatic Ming and Qing dynasties. First, within the Ming Dynasty, political corruption and eunuch dictatorship led to peasant uprisings that swept across vast areas of Shaanxi, Shanxi, Henan, Hubei, and Sichuan. The Qing army then entered the country and used force as a backing to break the Southern Ming, the peasant army and then the three clans and other forces, and only after the Qing government recovered Taiwan in 1684 did it become stable; externally, the geographical environment around the Ming Dynasty deteriorated. In the north, Nurhachi established the Later Jin in 1616, captured Liaoshen in 1621, and then continued to move south to northern China; in the south, following the Portuguese occupation of Macau, the Dutch and English colonists arrived one after another, and the Dutch occupied Taiwan for 38 years (1626–1662). In short, economic decline, population decline, social unrest, and regime change became common phenomena in the East and West in the 17th century. Academics never existed in isolation, especially in

imperial China, where great social crises were often accompanied by dramatic academic shifts. The academic turn in the Ming and Qing dynasties was a reflection of the crisis in China in the 17th century. As the situation became more stable, the schools of “Qing Neo-Confucianism” were oriented toward the social problems themselves, which were induced by the crisis of the 17th century, and devoted themselves to solving the crisis of the 17th century with the idea of “New People’s Principles.” They criticized the monarchical dictatorship and constructed a series of reconstruction programs. Based on the idea that the world was public and the ruler and his subjects ruled together, they discussed “ruling the people” and “ruling the law,” the relationship between the scholar, the farmer, the businessman, the ruler, and the subject, and the relationship between the ruler and the people [6].

2.2. Political Practice of Neo-Confucianism in Qing Dynasty.

The idea of nationalism, the idea of discrimination between *yi* and *xia*, was on the rise. In the face of the Qing government’s brutal national oppression, the “Chinese/*Yi* distinction” also became one of the focal points of the new Confucianism. Among them, Wang Fuzhi was the most thorough, but it was Lv Luliang who had the most sensational impact in the Qing Dynasty. Lv Liuliang learned from Cheng Zhu, and strictly adhered to the tenet that “the distinction between China and *yi*” was superior to “the righteousness of rulers and subjects.” He believed that “the discernment between Chinese and foreigners” was the highest tenet of Confucianism, and that it was the place where Confucius made the “Spring and Autumn Annals,” which was “the great meaning of the small words.” He was not only unhappy with Guan Zhong’s death but also praised him for his benevolence and righteousness because he was able to save the Central Plains from being “overlapped by the left overlapping hair” by uniting all the lords. In the Yongzheng dynasty, Zeng Jing, a Confucian scholar from Hunan, was influenced by him to lobby Yue Zhongqi, the governor of Sichuan and Shaanxi, to rise up against the Qing Dynasty, and his deeds were exposed. The sons, grandsons, and disciples were either killed or beheaded or sent into slavery, the suffering was so severe that it was the first of the Qing Dynasty’s written prisons. Wang Fuzhi wrote “The Yellow Book” to sort out the history of the Han people. He argued that, although the predecessor of the Han Chinese may have been similar to the barbarians in the early years of civilization, there was a natural civilizational divide between the Chinese and the barbarians after the formation of the Han Chinese, and all peoples had to adhere to their places of origin and not mix with each other. At the same time, because of the civilizational divide between China and the barbarians, the morality of the two cannot be confused, and Han loyalty, filial piety, and benevolence cannot be applied to the barbarians. And, divided the water and fire.”

The relationship between Taoism and governance, in the face of the serious conflict between Manchu and Han in the Qing Dynasty but the reality of the gradual Sinicization of the Qing government, the new Confucianism of the Qing

Dynasty, on the one hand, insisted on the supremacy of Taoism but also paid attention to harmonizing the relationship with governance and even made concessions to the Qing government so that the conflict between the two did not intensify as in the late Ming Dynasty, on the other hand, united more Han scholars to promote the Sinicization of Manchus. The Qing dynasty is an era of China’s practical thinking, a prominent feature of this period of practical thinking is to focus on the outside king, focus on the world to apply. And, to be practical, in the imperial society, relying on the imperial power became the only way, for the so-called “king to do the way” is also. In the general trend of the Qing government’s rule, although the criticism of the monarchy and the idea of “*yi xia*” due to national oppression were prevalent, it was inevitable to bow down to the Qing government in order to be useful. The Qing dynasty banned the assembly and association of scholars, and the “Kechang Case,” “Tonghai Case,” “Zhangshen Case,” and “Crying Temple Case.” Although ministers such as Wei Diji, Wei Xiangshu, and Ye Fangli participated in the rescue, the academy basically took the lead. “To realize the “politics of the king,” it is most important to rely on the emperor. But on the other hand, the various schools of Neo-Confucianism in the Qing Dynasty, in order to accelerate the Hanization of the Qing Dynasty, contacted various forces and exerted various influences on the Qing government. For the sake of the country’s livelihood, they not only acquiesced to their disciples’ service to the Qing government but also interacted with Han officials who had surrendered to the Qing dynasty but had made real achievements in social and cultural development. For example, Sun Qifeng, although he personally led the villagers to resist the invasion of the Qing Dynasty in his early years, took the lead in consciously promoting the Hanization of the Manchus when the general situation had been settled, not only maintained good relations with the high officials and dignitaries of the Qing Dynasty and the second-tier ministers but also made positive comments on those people who had made achievements in promoting social and cultural development but were lacking in morality.

In terms of the main body and academic pattern, the Qing dynasty legacy group was the main body of the Qing dynasty Neo-Confucianism, and at one time Northern Qing dynasty Neo-Confucianism led the trend. The group of Qing dynasty relics was the leading figure of Qing dynasty scholarship and the main body of Qing dynasty Neo-Confucianism. On the one hand, although they were small in number, they had a high reputation, great fame, and profound skills, and each of them had established a doctrine, occupied the academic and moral high ground, and their disciples and disciples were all over the court and field and responded to all calls. Therefore, it is easy to understand how they could dominate the Qing scholarship and be drawn in by all parties. Tang Bin, for example, was one of Sun Qifeng’s famous disciples and an important Neo-Confucianist of the Qing Dynasty [7].

In short, the reconstruction of the academic landscape and leaders in the Qing Dynasty reflects the great changes in the regional academic landscape since the Qing Dynasty. In

the early Qing Dynasty, since the great changes in the Ming and Qing Dynasties first broke out in the north and gradually advanced from the north to the south, the new northern scholasticism emerged in the early Qing academic landscape and once led the trend, which was reflected in the leading figures, two of the three great Confucians of the early Qing Dynasty. Since the late Qing Dynasty, the academic landscape has undergone significant changes in step with social changes: from the Qian and Jia periods, intellectuals from the two lakes and Guangdong began to rise, and in modern times, echoing the already flourishing Jiangsu and Zhejiang regions, two major “talent belts” were formed, centered on Jiangsu and Zhejiang regions and along the Guangzhou-Changsha-Wuhan line. The “talent belt.” The strong intention of these two talent belts to construct regional culture and related schools of thought is deeply hidden behind the writing of modern Chinese history. In this process, Gu Yanwu, Huang Zongxi, and Wang Fuzhi, as academic icons and regional sages, received much attention from the intellectuals of Jiangsu, Zhejiang, and Hunan in modern times. The “Three Great Masters” of the Qing Dynasty were rooted in the themes of the times and the regional academic pattern and were the result of the combined effect of the above-mentioned historical and practical factors. Therefore, despite the fact that in modern times, the scholarly circles have also seen various references to the “Four Great Confucians of the late Ming Dynasty,” “Four Great Confucians of the Qing Dynasty,” and “Five Masters of the Qing Dynasty.” However, none of them could shake the status of the “Three Great Masters” of the Qing Dynasty.

However, along with the development of the times and society, although the practical thinking of Qing dynasty Neo-Confucianism is still significant in contemporary times as an abstract way of thinking, the decline of the overall doctrine has led to its practical thinking being gradually abandoned and replaced by instrumental rationality. The emergence of artificial intelligence technology and the continuous updating of deep learning algorithms provide a technical path for extracting the practical way of thinking; importantly, the learning model represented by knowledge tracking also provides a channel for promoting and learning the practical thinking of the Qing dynasty Neo-Confucianism.

3. Methodology

How to use deep learning technology to extract the practical way of thinking of Qing Dynasty Neo-Confucianism and provide technical support to learners in the form of knowledge tracking is the difficulty of the specific application of technology in Neo-Confucian thinking. Therefore, this paper tries to improve the knowledge tracking model.

In this paper, we propose a fused multi-feature knowledge tracking model SGRUR@MECF, which first uses the LightGBM algorithm to evaluate the importance of the features in the dataset, selects the features with high importance as input features and performs one-hot encoding and cross-coding of the correct and additional features of student responses. Since the cross-coding of multiple features leads to the high dimensionality of the input data, an

autoencoder is used to compress the cross-multiple features, and then the compressed features are input to the prediction model [8, 9].

The SGRUR@MECF model proposed in this paper is a knowledge tracking model incorporating multiple features, and its model framework is shown in Figure 1.

The SGRUR@MECF model framework consists of four components: data preprocessing, feature selection, multi-feature coding, and deep learning prediction [10]. In the data preprocessing stage, the metadata set is cleaned and organized to obtain a relatively complete data set. Finally, in the deep learning prediction stage, the compressed features are passed into the SGRUR model for student knowledge tracking and student performance prediction [11].

3.1. Multifeature Selection Algorithm. The framework of the student performance prediction model based on the LightGBM algorithm is shown in Figure 2.

First, input the features of the student response data, use the histogram algorithm to find the feature with the greatest gain, and determine the optimal splitting point of the decision tree based on this feature; use the Leafwise leaf growth strategy with depth limitation to generate the CART tree; then calculate the residual value of the CART tree, use the residual result of the previous tree as the training sample, train the next CART tree, and repeat the training; finally, the CART tree generated by each training is weighted and summed to obtain the final prediction model. The CART trees generated from each training session are weighted and summed to obtain the final prediction model [12]. The LightGBM algorithm measures the importance of a feature attribute based on the total number of times the feature is used as a segmentation point. The feature elements are sorted from largest to smallest according to the attribute importance, and the search starts from the full set of all features, and the features with the lowest importance are removed or not according to the accuracy of the results; all the features are traversed and the optimal feature subset is output [13].

Let there be d features before feature selection and j features left after feature selection, so feature selection can be calculated by equation (1)-(3).

$$F = \{T_i | i = 1, 2, \dots, d\}. \quad (1)$$

$$F_i = \text{LightGBM}(F). \quad (2)$$

$$\text{LightGBM}(F) = \{T_i | i = 1, 2, \dots, j\}. \quad (3)$$

After filtering the dataset features by the LightGBM algorithm, multiple features need to be encoded to compose the input data [14]. In this paper, the direct splicing method is used.

The direct stitching method is to encode the response data and the optimal feature subset in onehot and then form a new input vector by stitching [15] as shown in Figure 3.

The direct splicing method can be expressed by the following equation:

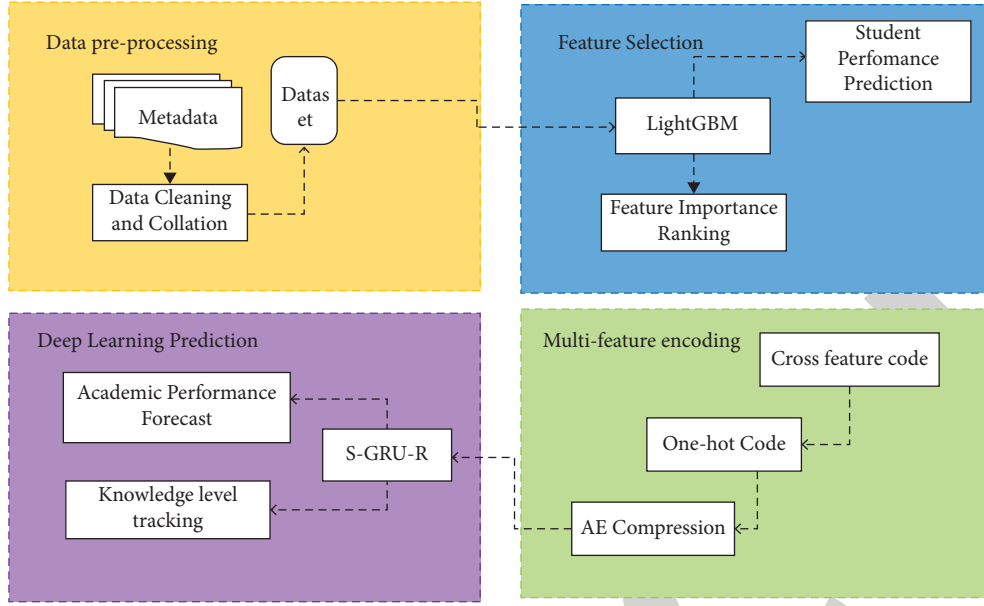


FIGURE 1: Framework for the SGRUR@MECF model.

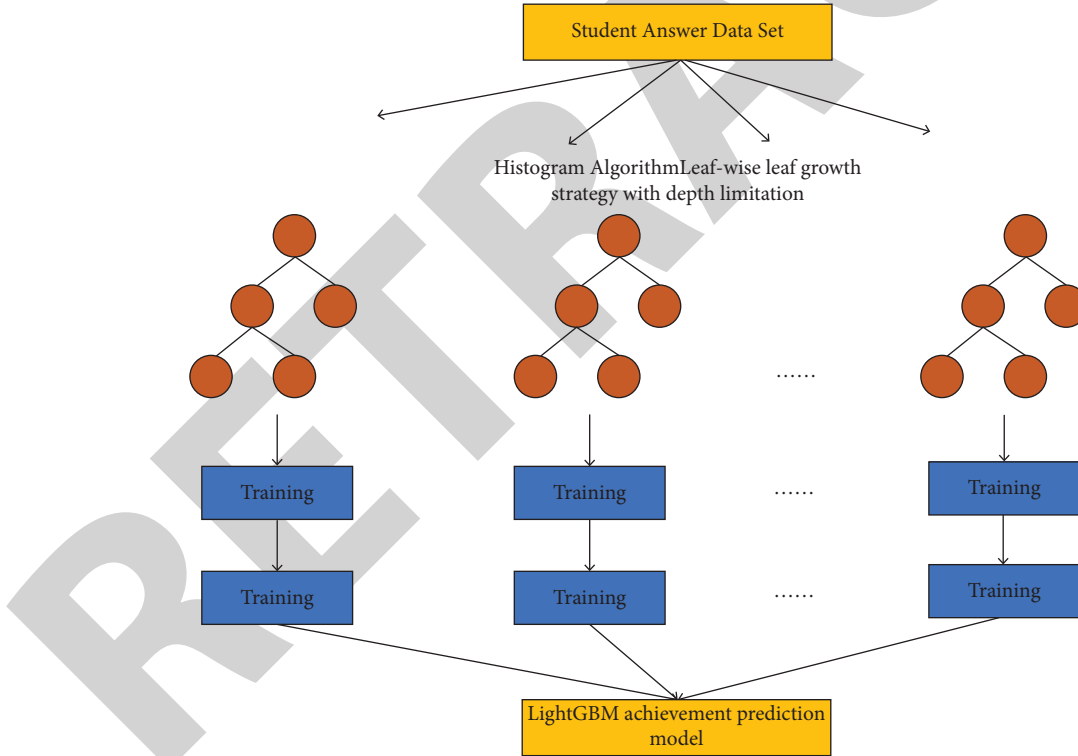


FIGURE 2: Framework for the LightGBM achievement prediction model.

$$x_t = O(C_t) \oplus O(F_t). \quad (4)$$

where C_t represents the student response data, F_t is the optimal subset of features selected by the LightGBM algorithm, and the function $O()$ represents the onehot encoding. The input x_t of the model can be obtained by the direct splicing method [16].

In addition, this paper modifies the direct splicing coding method for the practical thinking of Qing dynasty Neo-Confucianism, which can be expressed by equations (5)-(6).

$$C(s_t, c_t) = s_t + [\max(s) + 1] * c_t. \quad (5)$$

$$x_t = O(C(s_t, c_t)) \oplus O(C(F_t, c_t)) \oplus O(F_t). \quad (6)$$

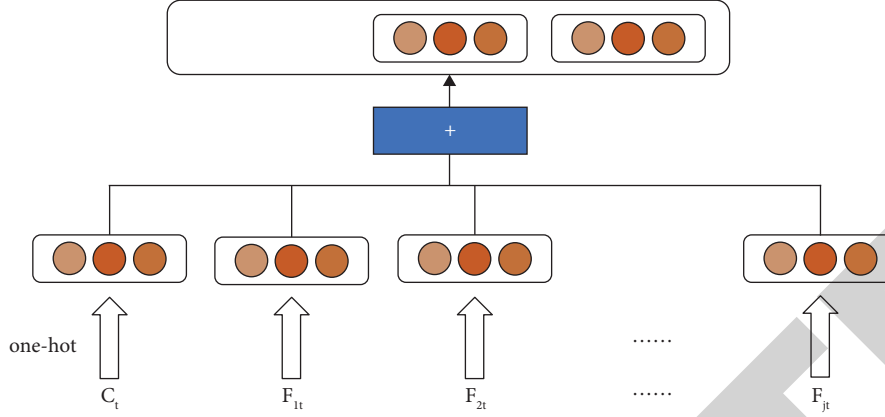


FIGURE 3: Direct connection multi-feature method.

where function $C()$ denotes the use of crossover features, function $O()$ denotes one-hot encoding, \oplus denotes vector splicing, s_t denotes the knowledge point ID, c_t denotes the response result of the corresponding question (1 denotes correct, 0 denotes incorrect), and F_t denotes the optimal feature subset selected by the LightGBM algorithm [17].

Furthermore, the coding results were passed into the prediction network for training based on the ideology of Qing Dynasty Neo-Confucianism, which was calculated as follows:

$$\begin{aligned} z_t &= E(x_t) = \sigma(Wx_t + b), \\ x'_t &= D(z_t) = \sigma(Wx_t + b). \end{aligned} \quad (7)$$

where x_t is the same as (6), function $E()$ denotes the encoding operation, and function $D()$ denotes the decoding operation. z_t denotes the learned latent variable, and the latent variable can be used as the input data [18].

3.2. Depth Prediction Model. The S-GRU-R is modeled based on the stacked GRU residual network, which is calculated as follows:

$$\begin{aligned} h_{1,t} &= f_{gru-1}(h_{1,1-t}, z_t), \\ h_{2,t} &= f_{gru-2}(h_{2,1-t}, h_{1,t}). \end{aligned} \quad (8)$$

$$k_t = \sigma(W_{kh}(h_{2,t} \oplus z_t) + b_k). \quad (9)$$

where z_t is the latent variable obtained by cross-coding and one-hot coding the student responses with the optimal subset of features, and then compressing them by the self-encoder, the dimensionality of which can be set by oneself [19]. If the multifeature coding method or multifeature cross-coding method is used, z_t is replaced by x_t in (9).

3.3. Model Optimization Function. Finally, the model is optimized with the following equation:

$$\begin{aligned} L = & - \sum_t (a_t \log k_{t+1}(q_t) + (1 - a_t) \log (1 - k_{t+1}(q_t))) \\ & - \sum_t (x_t \log x'_t + (1 - x_t) \log (1 - x'_t)). \end{aligned} \quad (10)$$

The whole formula is divided into two parts, the first part is the optimization function of the SGRUR model network, and the second part is the optimization function of the self-encoder, which also uses the cross-entropy loss function. x' is the reconstructed data generated by the self-encoder [20].

In conclusion, this paper presents an improved knowledge-tracking model, which is expected to provide technical support for the simulation and learning of technology in the practical mindset of Qing dynasty Neo-Confucianism. However, the model performance is still subject to further experimental validation.

4. Discussion and Results

In order to further validate the performance of the proposed model, experimental analysis of the performance of different models is carried out in this paper separately. In this experiment, LightGBM is used as a comparison experiment, and SGRUR@1, SGRUR@2, and SGRUR@3 are set as ablation experiments. The Riid dataset is divided 4:1 into training and test sets. The results are shown in Figure 4.

Another major task of knowledge tracking is to track students' knowledge acquisition levels. Figure 5 shows a visualization of the predictions from the SGRUR@MECF model for a randomly selected sample of data from the Riid validation set.

Finally, we conducted a three-store simulation of practical thinking in Qing dynasty Neo-Confucianism using a deep learning model and found that the improved model can dynamically simulate practical thinking patterns at more nodes, and the results are shown in Figures 6 and 7.

In conclusion, the knowledge tracking model proposed in this paper has obvious advantages over previous models both in terms of simulation performance and learning feedback mechanism.

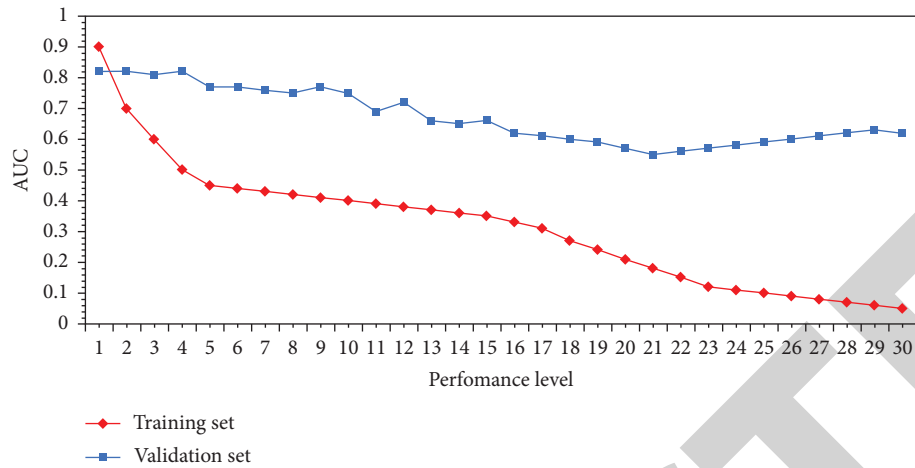


FIGURE 4: AUC values in different performance level.

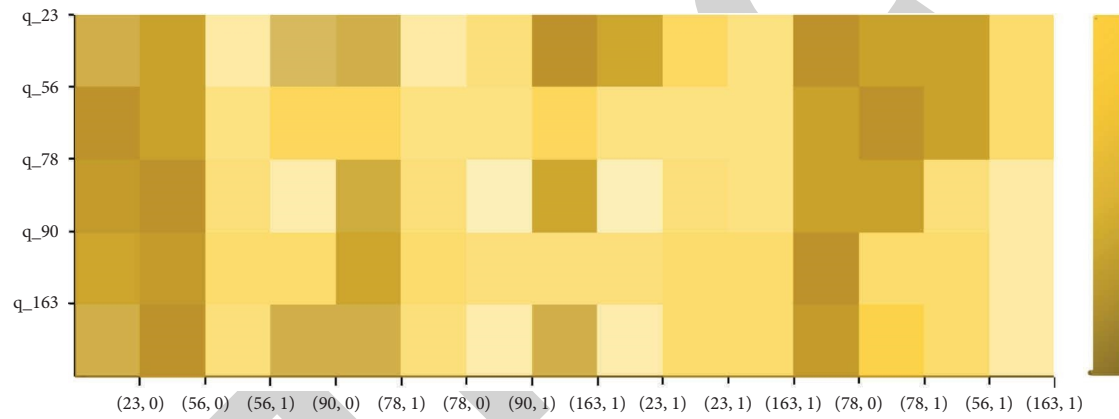


FIGURE 5: Visualization of knowledge level tracking results.

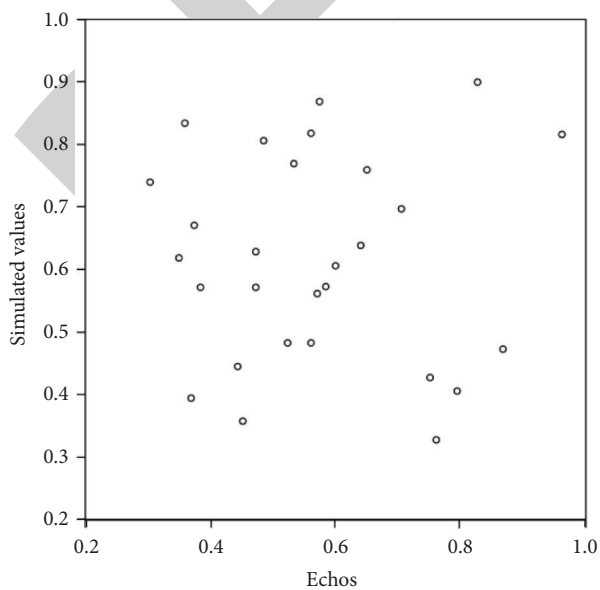


FIGURE 6: Traditional model.

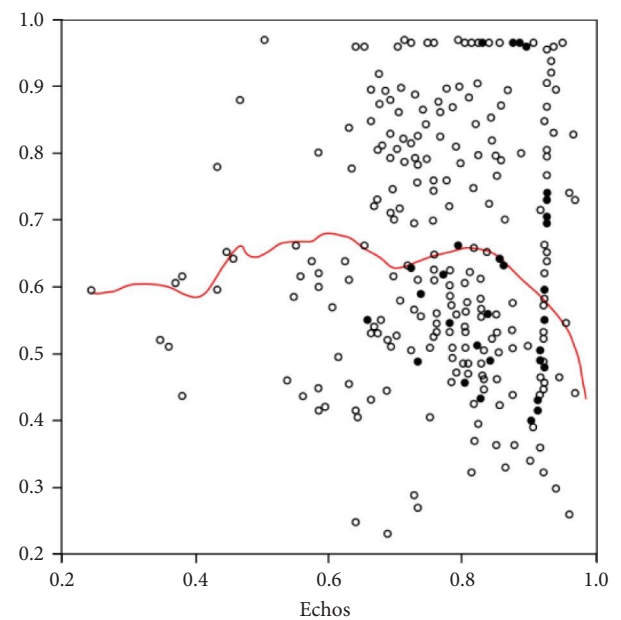


FIGURE 7: Improved model.

Retraction

Retracted: Design of Artificial Intelligence-Based English Network Teaching (AI-ENT) System

Mathematical Problems in Engineering

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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.

References

- [1] X. Liu and X. Huang, "Design of Artificial Intelligence-Based English Network Teaching (AI-ENT) System," *Mathematical Problems in Engineering*, vol. 2022, Article ID 1849430, 12 pages, 2022.

Research Article

Design of Artificial Intelligence-Based English Network Teaching (AI-ENT) System

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The English teaching network system uses the Internet to provide distance education. There are several challenges in teaching, including a lack of knowledge and expertise, expectations from students, lack of facilities, and unfavourable opinions about the process of English teaching and learning. In the era of information, education combines the advantages of both online and offline learning, including conventional and networked learning. The production of test pattern paper is an important part of the English teaching network since it helps students study independently. In this study, the artificial intelligence-based English network teaching (AI-ENT) method has been suggested to enhance the student's performance in distance education. There are strong indicators that the methods of teaching and learning and the teaching tools used by machine learning can be fundamentally altered by AI. With AI technology tools and teacher coaching, students can make significant progress in their English learning experiences. Artificial intelligence expert system thinking is reflected in this design. Teachers and students can improve their English proficiency by gaining access to relevant data from a wide range of sources. The system's test application reveals that it can assist students in increasing their learning efficiency and making learning information more relevant.

1. Introduction of English Teaching Network System

Online learning and the Internet's expansion of computer networks allow many different learning techniques and environments [1]. It is possible to teach English remotely using a self-directed learning technique [2]. The English network education system's design to boost learning efficiency and accuracy is integrated into the Internet mobile terminal [3, 4]. The best strategy is explored for designing an English network teaching system [5]. It has been a requirement for school students to take an English major because of the reform and liberalization of the educational system [6]. Artificial intelligence (AI) is a hard and innovative area [7]. The developing field of artificial intelligence is based on the integration of computer science, cybernetics, information theory, psychology, philosophy, linguistics, and other fields [8]. The primary goal of computer science is to

learn how to mimic and replicate human cognitive abilities [9]. Students started to employ computers in education due to the rise and development of artificial intelligence. Its inception and growth have made information technology and curricular integration more important [10]. Statistics and artificial intelligence provide a complete and clear combination of English and instructional web apps to achieve its data analysis goals. Before taking English classes, students should know their proficiency in the language. This will assist customers in selecting the ideal course for their needs and skill level, i.e., whether they are at an introductory, intermediate, or advanced level. Museum of Knowledge exclusively offers intermediate and high-level language training for businesses. Therefore, students will be aware that an entry-level course module is not available at the museum.

There has been a shift in the emphasis of today's society on the practical application of language quality [11]. Contradictions between this development and English teaching's

purpose are becoming more apparent [12]. School English tests and teaching methods emphasize exam-oriented education, which neglects the content of language use and its ultimate goal, therefore failing to better adapt to social progress and increase English competence in society [13]. Information processing and database creation are at the core of an English network education system [14]. Optimizing English teaching network information management and settlement, improving network information management and resource scheduling, and enhancing the system's compatibility with processing capabilities are some of the goals of the server device [15–17]. Distant education monitoring and learning control create English network teaching systems. Using artificial intelligence, learning programmes may now be personalized to each student's individual needs and interests. According to their level of expertise and learning pace, students get the most out of the educational experience. Through AI, it is possible to remove geographic limitations from schooling. With the use of artificial intelligence (AI), students from all over the world can access the best teachers, no matter where they are. Using this system, students can study the information points, levels, and safeguards that are part of an English test and examples of the offered format, notably the maintenance of the knowledge-based foundation, test maintenance in the password area. An online English teaching system incorporates an Internet architecture to provide online English teaching and recognition [18]. The teaching system's whole database remains centralized in the network architecture. A larger system load is required to ensure that the information in each database copy is consistent [19]. It is now possible to create a network-based teaching system for English as a second language because of the Internet's popularity among students and teachers alike [20]. The conventional method concentrates on essential skills, while the contemporary style focuses on broad concepts. Teaching tools such as lesson plans and practical skills, including learning and thinking, are the most popular. For the most part, educational standards are set by the government. A classroom, textbook, or anything else is no longer required in modern schooling. Student can simultaneously take courses from various colleges and universities online. Taking one class at a time restricts pupils' advancement in traditional schooling.

The artificial intelligence-based English network teaching (AI-ENT) method has developed skills and assessment systems. Schools and teachers can soon accomplish more than ever before with AI educational solutions as they become more developed. Teachers can have more time and flexibility to provide students with the knowledge and adaptability that only humans can deliver, thanks to AI-driven efficiency, personalization, and automation. The ideal vision for AI in education is that both teachers and machines work together to achieve the greatest possible outcomes for students. A new method of instruction known as the network teaching system is being applied using computers and the Internet in the virtual classroom. It offers a distinct edge over more conventional methods of instruction. An ideal network teaching system can completely replace the Internet teaching procedure.

The main contribution of this study is as follows:

- (i) Artificial intelligence-based English network teaching (AI-ENT) method has been recommended to improve the student's interaction.
- (ii) Mathematical modelling of proposed machine learning-assisted English education systems is becoming more supported by modern reforms and developments in English teaching.
- (iii) Explores how artificial intelligence (AI) is used in English classrooms to assist electronic learning.
- (iv) Enhances education quality and helps students learn English more efficiently by analyzing pedagogical approaches.

The rest of the (AI-ENT) technology research can be organized similarly. Section 2 describes the literature research. The new ideas that have been presented about and used in this study are briefly described in Section 3. Section 4 details the findings and conclusions based on the data. Last, in Section 5, the (AI-ENT) technology comes to a close with a thorough analysis of the findings.

2. Related Work of English Network Learning

The Internet has unquestionably revolutionized foreign language instruction, and English is no exception. Colleges and universities were increasingly using computer Internet technology (CIT) to improve their management efficiency and teaching quality, deepen the reform of English teaching mode, speed up the construction of college teaching management, create a better campus environment, and enhance the level of information management [21]. It was becoming more common for foreign language teachers to focus on computer-aided language instruction in a network context. The expansion of digital information network technology has allowed education to acquire experience, from current teaching methods to computer technology and communication technology. This study used an improved fuzzy hierarchical neural network system (IF-HNNS) to create an English language teaching system [22]. The quality of English-language instruction directly impacted the effectiveness of classroom instruction. The traditional teaching method had been transformed, and students had the freedom to study at their own pace and in their manner, thanks to the advent of interactive educational systems. Computer-aided learning with human-computer interaction techniques can enhance the educational and teaching cycle monitoring. In a network database, multiple entries or files belonging to members can be linked to records or files belonging to network administrators. It is possible to illustrate this paradigm with an upside-down tree, each branch connected to its owner. This includes logging in and out of tasks and jumping between different websites.

Conventional teaching approaches were used mostly in the home and academic English language classes. Students now had poor academic competency because they had a restricted academic vocabulary. It was the role of English instructors to assist students in developing their academic

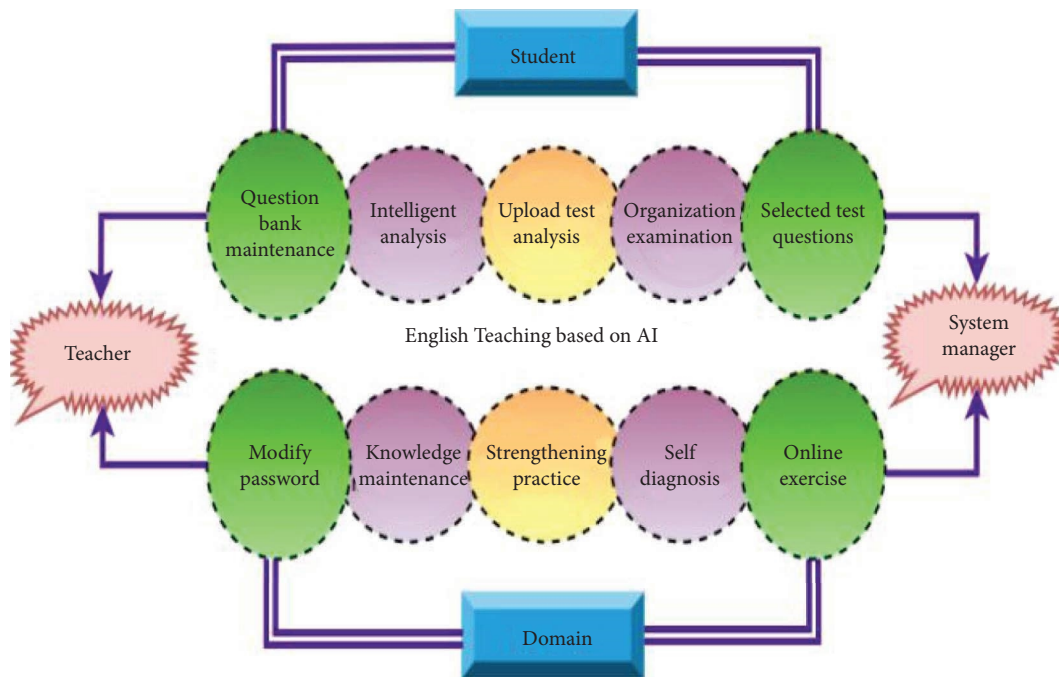


FIGURE 1: Design of a teaching system using AI.

language skills. Using the production-oriented approach (POA), this study constructs the teaching design for academic English and investigates successful methods for increasing students' academic English competency [23]. Teaching academic language skills under the auspices of POA theory is shown to be more in line with the foreign language teaching practice and more successful in stimulating student internal motivation, promoting task completion, and improving students' sense of acquisition. New teaching methods and creative apps need to be introduced to incorporate deep learning (DLA) environments into the learning environment and educational settings. A current technique was automating successful intellectual instruction using picture identification and deep learning. Image discovery was the basis of deep learning [24]. There was a brief introduction to image detection for ecological assessment. Learning centres and students alike can benefit from a personalized education system that provides resources adapted to their unique learning preferences, allowing for a smoother transition into a platform.

Scientific tools and approaches, such as multimedia technology (MMT), have improved studying a fresh teaching strategy [25]. Multimedia technology was widely thought to be an efficient method of teaching languages and enhancing students' linguistic ability. An important use of multimedia technology in English language instruction was for speakers of non-native languages. An in-depth examination of multimedia tools and technologies was presented in the research. At length, the pros and drawbacks of various multimedia tools and technologies are discussed. The artificial intelligence-based English network teaching (AI-ENT) method has overcome the existing model issues. This study has been suggested to increase the participation ratio,

interaction ratio, efficiency ratio, resource utilization analysis, and performance ratio.

3. Artificial Intelligence-Based English Network Teaching (AI-ENT) Method

Due to the close connection between culture and language, English teaching [21–30] encompasses all aspects of vocabulary acquisition and social learning. Artificial intelligence [31–40] has opened up new teaching options in higher education, and social approaches at college now have to keep up with the growing integration of information technology and chosen English teaching techniques. Artificial intelligence technologies can be employed in English teaching practices to encourage and increase education quality, and these technologies have both technical benefits and adjacent qualities geared to enhance teaching.

Figure 1 shows the design of a teaching system using AI. The module is a well-structured system that uses the Internet to build an integrated education system—several students, including subject matter experts, English instructors, students, and system administrators. When students log in, the system's operational authority frequently has distinct identities as a result. Admins refer to a group that does daily maintenance prearranged by system operators, such as user administration, test question bank management, and password changes.

The term expert in the field refers to English teachers who have had extensive experience in the classroom. This system can evaluate information points, levels, and protections that are part of an English test and examples of the supplied format, primarily maintenance of the knowledge-based foundation, test maintenance in the fixing passwords. Each teacher has access to the given courses and students,

and the lecturer refers to English teachers in general. The major authorities are in charge of organizing tests, uploading test data, and analyzing the designated student group's information points. The term student refers to regular students who can use their allotted login and password to access the system.

The teacher model is a framework for organizing, managing, and implementing the complete core of teaching activities in a school or educational setting. One of its main goals is to establish a framework for analyzing educational goals, teaching methods, and learning styles so that the approach can generate successful teaching at the level of the students. Teachers use the teacher model as a framework for managing all aspects of teaching in a school or educational context. As a result of artificial intelligence, learning programmes may now be tailored to each student's specific needs and interests. Students benefit from the educational experience when it is tailored to their degree of knowledge and speed of learning. Through AI, it is possible to remove geographic restrictions from education. Students worldwide can now have access to the world's greatest teachers because of artificial intelligence. Students can use this system to learn about the information points, levels, and protections that make up an English examination and instances of the offered structure, such as the maintenance of the knowledge-based foundation and the password area. After students have been assessed in the classroom, the student model serves as the basis for intelligence education by characterizing the structure in knowledge and intelligence and learning reasons and methods. The result is a combination of the student's aim and realistic skills, integration of student module learning, assessment of student's status, and development of a teaching strategy. Students are taught, monitored, evaluated, and guided by the teacher using the most effective manner.

The domain model incorporates a student knowledge base and a teacher expertise level. Students can learn about their academic progress, educational background, solved problems, and other relevant information in the student knowledge base. This information serves as a systematic framework for evaluating students, selecting education, organizing material, and resolving system issues. An important part of the diagnostic paradigm is identifying and rectifying student mistakes and defects in education using personal characteristics. Both students and teachers are considered in this paradigm. The student knowledge base is accessed to learn more about your academic achievement and educational background. An essential diagnostic component is identifying and fixing students' errors and instructional inadequacies. There should be a means for science teachers and their teaching to rely on local and worldwide resources, support systems, and networks to maximize their progress in science teaching and impact students' scientific understanding.

As an integral part of undergraduate English instruction, classroom evaluations play a vital role in the assessment of English and have sparked an interest in U_j teaching English using neural networks, which is defined as follows:

$$U_j = \prod_{m \in L} (z_m + \rho_L)^2 - \prod_{n \in S} (z_n + \rho_S)^2. \quad (1)$$

As shown in equation (1), a scheduling transmission channel model for English teaching resources is with $(z_m + \rho_L)$ input parameters and $(z_n + \rho_S)$ output parameters and m, n are the function of the transmission channel. Algorithms for machine learning learn from the data they are exposed to and adapt their performance accordingly. The "learning" aspect of machine learning refers to how these systems adapt their processing methods over time, just like people do. Supervised, semisupervised, unsupervised, and reinforcement learning are all forms of machine learning algorithms.

The input layer, output layer, and hidden layer form the basis of the machine learning algorithm. Layers are held together by a ρ adjustable weight. The $Y_j(k)$, $\sigma_j(k)$, and $x_i(k)$ subscripts signify the nodes of the input layer of the learning algorithm, respectively, whereas j, i denote the elements of the output layer of the network. The approximation error function H is defined as follows:

$$H = \frac{1}{2} \prod_{j=1}^L (Y_j(k) + \sigma_j(k))^2, \quad (2)$$

where $\sigma_j(k) = g(x_i(k), \rho)$.

As shown in equation (2), every network layer and ρ node function contribute to the g function's composition.

Thanks to machine learning and knowledge discovery, advances in information processing technologies have been made possible. Figure 2 shows the strategy of intelligent online English learning. It does a lot more than look at prior data and see any connections, and it does a thorough analysis to decide the best course of action, forecast future trends, and much more. Useful information such as legislation or higher-level data can be reliably mined from relevant database sets and used as a resource for extracting new knowledge using machine learning. College institutions' electronic archives are being accessed because of the rapid expansion of Internet information innovation, electrical science, and technological innovation. Students are no longer classified as excellent or terrible based on their performance on a test. The exceptional outcomes of the evaluation methods have played a critical and irreplaceable role throughout schooling. Data from a broad range of complicated information can be summarised and analyzed using AI systems. These systems can convert and extract data and uncover hidden conceptual norms and correlations relevant to the overall group condition. The Student Help Desk frequently recommends Firefox as the best browser for students. According to our educators' survey, this browser has the most consistency in its advancements and the most forgiving relationship of all the ones considered. The Student Help Desk normally recommends Firefox as the preferred online browser. Various elements that can be investigated extensively and comprehensively hide the evaluation findings and their underlying linkages, strengthening the process assessment system and allowing for an application

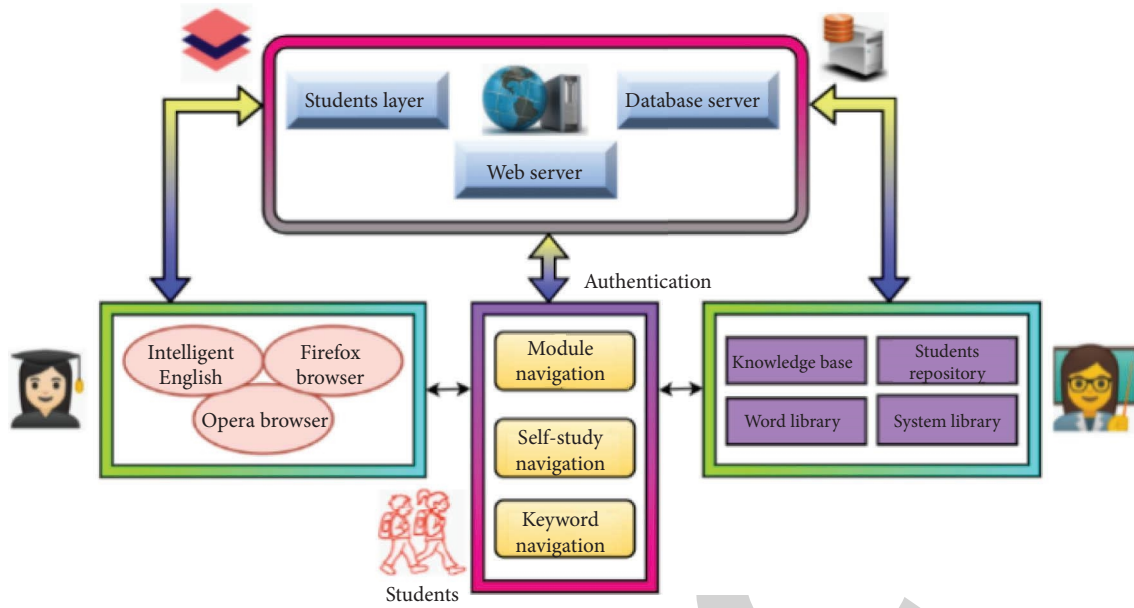


FIGURE 2: Strategy of intelligent online English learning.

procedure that is scientific and objective throughout the whole process assessment.

The purpose of using distributed databases in network learning systems is to make knowledge more accessible while collecting data more quickly. The most basic kind of network learning is knowledge databases, which are not necessarily formal instructions in the traditional sense. A knowledge database collects indexed explanations and helps with software issues, coupled with detailed instructions on certain tasks. Web page distribution system distributes web pages in response to students' requests for information. Storage, processing, and delivery are the main responsibilities of a web server, and hypertext transfer protocol (HTTP) is used for this kind of communication. The process of verifying a student's identity is known as authentication. The credential is usually in the form of a password, which is kept confidential and is only known by the individual using it and the computer system. A knowledge base is a collection of indexed explanations and instructions that can aid with software issues and specialized tasks. Students' needs for information are satisfied through a system for delivering web pages. The primary function of a web server is to store, process, and distribute websites to users. In addition to HTTP, web servers also offer SMTP (simple mail transfer protocol) and FTP (file transfer protocol), used for e-mail, file transfer, and storage purposes. Students with access to the Internet can access many media and other materials. Needs assessment, goal analysis, and performance assessment are all methods that instructional designers might utilize to uncover instructional issues. Cloze reading, cooperative learning, hands-on learning activities, scaffolding, group instruction, self-assessment, thematic education, and word wall are the most popular instructional tactics.

The Student Help Desk normally recommends Firefox as the best online browser for students. Teachers suggest it

because it has demonstrated the greatest consistency in its different upgrades compared to the other browsers on this list and has had the most forgiving relationship. Students returning to school should use Opera as their primary browser. Librarians use communication technology to give electronic reference services and instructional assistance to learners mainly linked to their institution's library through a computer network. They provide remote access to and electronic distribution of library materials. Researchers, students, and other academic personnel can store their papers in a web repository that is simple to maintain. Many intellectual repositories allow transparency around the content of each contribution to be selected. All teaching system data must be kept in a single location on the network. As a result, each database requires a bigger system load to ensure its integrity. Internet use by students and teachers alike makes it possible to create a network-based approach for teaching English as a second language. Teachers and robots should work together to ensure the best possible outcomes for students. The network system is a completely new teaching approach that utilizes computer and Internet technology in the virtual classroom. Because of this, it has a distinct advantage over traditional education. Ideally, a network teaching system can replace the existing teaching methods on the Internet.

Weights are used in proportion to the negative gradient direction estimate error H , which is the particular analysis to speed up the learning process, as given in the following equation:

$$\lim_{k \rightarrow \infty} H = \lim_{k \rightarrow \infty} \frac{1}{2} \sum_{j=1}^L \sum_{j=1}^L (Y_j(k) + \sigma_j(k))^2 = 0. \quad (3)$$

The core network receives information from instructional resource management. The English network teaching

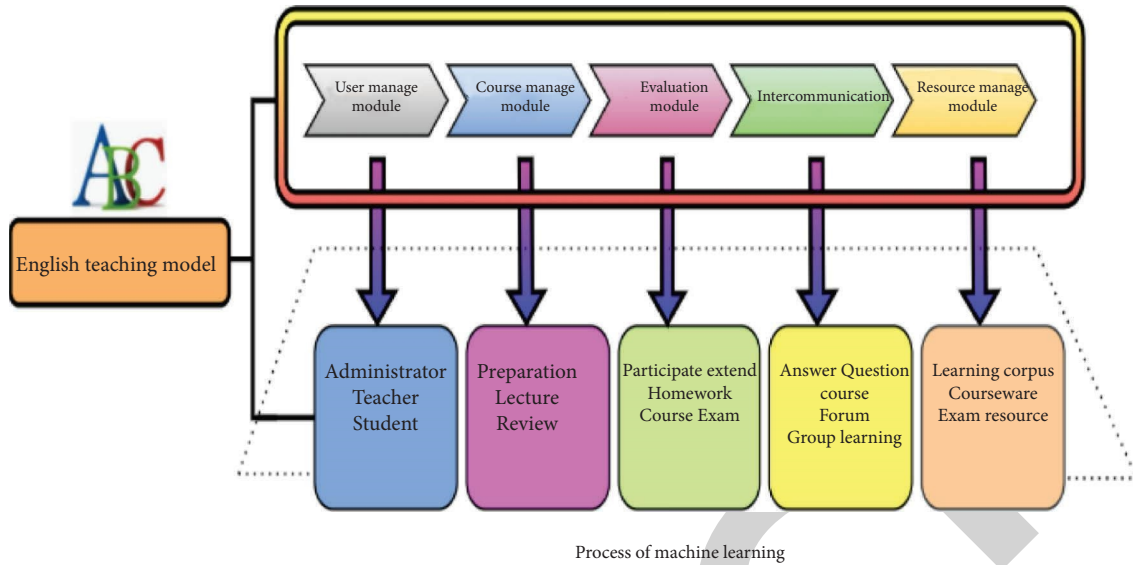


FIGURE 4: Process of machine learning in network education.

3.3. Step 3: AI Analysis. This method uses statistics and artificial knowledge to accomplish data analysis goals and gives a full and understandable integration of English and an educational web application. Utilizing these processes' classification, evaluation, prediction, association principle, and grouping can boost English learning.

3.4. Step 4: AI Application. This process can comprise constructing, using the classification, evaluation, prediction, and association principles.

Education administrators are in charge of setting policy and overseeing the daily operations of daycare facilities, preschools, schools, and postsecondary institutions of higher learning. Other institutions such as museums, enterprises, and job-training programs are supervised. Multiple records or files of members can be linked to the records or files of administrators in a network database. An upside-down tree with each member's information as a branch connecting to the tree's owner can be used to depict this paradigm. Trajectory behaviours include logging in, signing out, and jumping between online pages. In terms of behaviour, trajectory behaviours are the most general and fundamental. The behaviour of a student retrieving a certain sort of resource falls under the resource learning and trajectory behaviour categories. Trajectory behaviour differs from resource learning behaviour in that the former contains the search's fundamental content, while the latter comprises recovering the action. Both students' and teachers' knowledge is considered in the development of this method. Students can learn about their academic progress and educational history and overcome difficulties in their knowledge base. In this model, both students and teachers are taken into consideration. The student knowledge base is accessed to learn more about your academic achievements and educational background. Identifying and correcting students' mistakes and shortcomings are key diagnostic components. To maximize development in science teaching

and impact students' scientific understanding, science teachers and their teaching should rely on local and worldwide resources, support structures, and networks. Teachers use the teacher model as a framework for managing all aspects of teaching in a school or educational context.

Figure 4 shows the process of machine learning in network education. Teaching English is an approach that requires students to interact with others, exposing them to a variety of viewpoints. This personal factor differs greatly from the self-taught English language learning technique. Even if a teaching assistant and a modest amount of time are used in English classes, not all students can engage with one another and get responses. With the Internet and an effective English education module, these issues can be resolved.

In addition, students who have access to the Internet can see, read, and listen to media and other information online. The English teaching module includes various modules: user module management, course module management, assessment module, communications module, and resource management module. The purpose of the user management module is to verify a user's identification. In addition to providing information about the course, the administration module oversees the teaching process. The learning effect is being measured, and student model status is being updated due to the assessment module. Students can use the intercommunication module to obtain adaptive learning and engage in online study groups.

Several aspects make up this model's English education course: (1) students of online preparation get a solid grounding in the fundamentals of English language instruction. The content of the preparation can be generated via a suggested framework for students. (2) The teacher teaches English on a one-on-one basis, and a student profile suggestion framework can be used to build the content of the analysis. (3) AI examines the inefficiency of the English education system and considers a machine learning approach for English instruction.

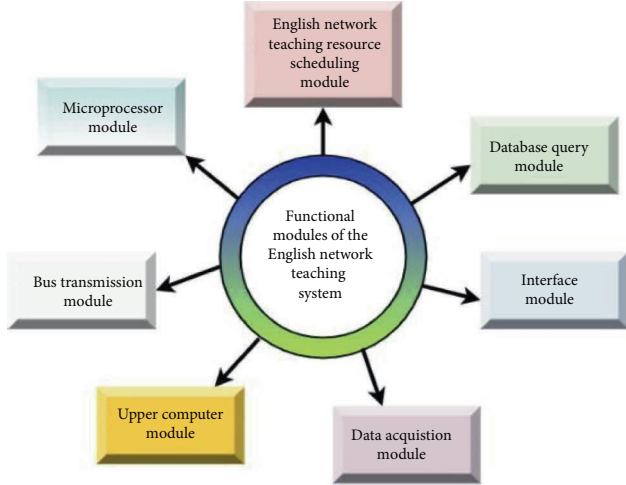


FIGURE 5: Operational component compositions of the English network education system.

Data similarity and conceptual depth are directly linked in English network teaching resource information Tjn retrieval, which is given by the following equation:

$$Tjn(u_1, u_2) = \frac{dep(u_1) - dep(u_2)}{|dep(u_1) + dep(u_2)|} \quad (6)$$

As shown in equation (6), u_1 and u_2 have conceptual depths $dep(u_1)$ and $dep(u_2)$, respectively.

Differentiated fusion $M + 1$ is performed considering the variations in the breakdown of information resources in English network instructional materials. English network teaching resources information is referred to as $CCS_{T(m)}$ distributed scheduling model, which is defined as follows:

$$CCS_{T(m)} = \sum_{m=0}^{M+1} T(m)c_{l,u,d}^*(m). \quad (7)$$

As shown in equation (7), m denotes a multiple regression statistical analysis and is used to examine the $c_{l,u,d}^*$ data statistics of English network teaching T resources.

English network teaching resource scheduling at the time has a BUH_Y slot allocation autocorrelation function, which is described as follows:

$$BUH_Y = \frac{1}{p \times q} \sum_{x=1}^q \sum_{y=1}^p H_Y(x, y). \quad (8)$$

As shown in equation (8), the grouping node (x, y) of English network transmission and scheduling is measured by H_Y and the time window width of time-division multiple addresses is measured by p and q .

Development of the system's functional components and interface has been completed. Figure 5 shows the operational component compositions of the English network education system. The most significant functional modules are the database, information processing, integrated control, human-computer interface, and back-end program loading. Online degrees and courses have emerged as a feasible option for students who want to continue working while

attending school in the last decade. A web-based method for teaching English is called the English teaching network. One of the most important modules in the English teaching network system is the automatic generation of test papers, which piques students' interest and encourages them to learn independently. It is now possible to combine education with cutting-edge information technology to construct an educational network teaching system because of the huge surge in Internet use. The English network teaching system's data output queuing technique is defined at the subscription layer. An intelligent platform can be controlled through cross-compilation and human-computer interface design. The data collection module gathers information about the original educational material. Massive data-collecting technology is used to upload English instructional materials. The interoperability of network teaching is improved with the use of radiofrequency technologies. Among the most critical elements are the database, information processing, integrated control, human-computer interface, and loading of back-end programmes. English network education system data output queuing techniques are defined at this subscription layer.

A network communication module is required to realize network information transfer and online communication functions. The Internet and 4G communication technologies are used for network communication. The material disseminated in each educational area is connected through the Internet. On the OpenStack cloud computing platform, an information sensor network is developed. The OpenStack cloud computing platform is used to build an information sensor network. The English network teaching system's network design incorporates object storage and data mining, a resource information service, and a remote call to offer feedback. Classroom design options are as varied as the courses and programmes intended to teach. Classrooms, laboratories, lecture halls, and other physical learning settings are not the sole components of a learning environment. Information about students' traits and educational goals will also be presented. Statistical and artificial intelligence methods are employed to analyze data, while English and instructional web apps are offered in full and easy combination. Multidimensional variables have the potential to improve your English communication skills.

As a function of web-based technology, the network architecture for the English network teaching system is created with object storage and data mining as well as a resource information service and a remote call for providing feedback on the educational experience's quality. It includes an information-gathering unit, a database of instructional resource information, a network application server, and an organizational structure. Interface access control enables QoS management and network security evaluation. The Internet of things is used to build the network adaption layer's middleware.

Modules in an online course usually include material and exercises arranged to provide students with a clear learning path. Without a microprocessor, students are unable to perform anything on the computer. The microprocessor performs various arithmetic and logical processes when

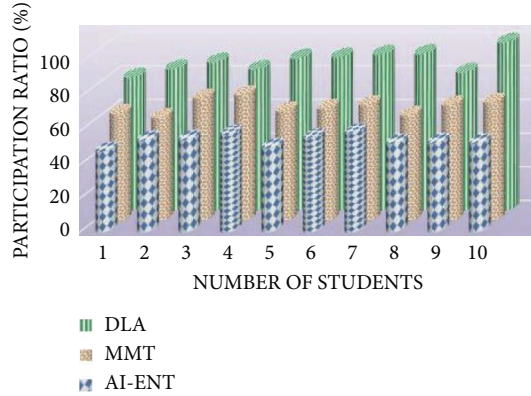


FIGURE 6: Participation ratio.

given input before outputting the desired results. Curriculum and student-level determine the exact content as well as activities. Still, most educational modules feature knowledge about a subject, emphasize student-centred learning, and conclude with a project that allows students to show their comprehension. Students use home computers to access online education, which is a sort of instructional teaching supplied over the Internet to them.

Online degrees and courses have increased in popularity over the past decade as a viable choice for a broad spectrum of nontraditional students, including those who wish to keep working while they go to school. Students can learn and research computers. Students can utilize the Internet to obtain relevant information for their projects and assignments. They can get assistance from other students by storing and organizing their research materials on computers. Most school buses utilize automatic gearboxes that can be manually shifted between gears. Transmitting is the act of teaching something to someone else by telling, demonstrating, and guiding them purposefully and consciously. The proposed method enhances the participation ratio, interaction ratio, efficiency ratio, resource utilization analysis, and performance ratio.

4. Numerical Outcome

Artificial intelligence (AI) advancements in school English teaching have fueled the school's present education reform and progress. Combining the advantages of traditional education with network teaching through online learning has become a crucial development guideline for information age education development. This study examines the usage and impact of artificial intelligence (AI) in English education and various teaching methods to help students learn more efficiently.

Figure 6 shows the participation ratio. Teachers and students can be more involved with this mobile technology, which improves teaching quality and quantity. Students' attitudes toward homework and its role in the educational process have been transformed with the distance English learning platform. Student login and passwords could only be obtained through an online learning network, requiring a registration request. They attended courses and completed

TABLE 1: Interaction ratio.

Number of students	DLA	MMT	AI-ENT
10	48	64	76.5
20	42.4	63.5	82
30	57	60	78.9
40	59.7	75	84
50	47	63	77
60	52	73.8	92
70	54	65.5	92.3
80	49.7	73	93
90	51	71	89.3
100	56	74	96.4

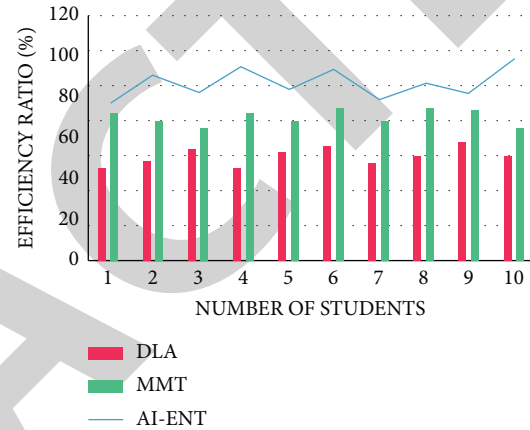


FIGURE 7: Efficiency ratio.

their assignments online, all while using smartphones. Enrollment rates are somewhat higher because more students turn up than miss class.

Compared to other methods, the proposed strategy is more effective (95.3%). Online English learning and mobile aspects are part of students' engagement in this course. Providing support, benefiting directly from the teaching, and implementing it into the classroom as an all-encompassing social and emotional environment are all part of the process.

Table 1 lists the interaction ratio. An important part of online education's usefulness and quality can be attributed to interaction. An online English education paradigm is to be delivered through the many available levels of contact. Students can discuss various topics in an open forum through social media while enrolled in an online English course. The quantitative data for this research have been gathered using an interaction and satisfaction survey.

Compared to MMT and DL's existing methods, the proposed method improves the interaction ratio by 96.4%. Students can utilize online discussion forums to get help with difficult course ideas if they find them difficult to grasp. The best way to convince people is to use language to participate. Using online forums to engage students and make them more eloquent helps students build communication skills that they can carry when they leave the classroom.

Figure 7 shows the efficiency ratio. Compared to DLA and MMT, the suggested AI-ENT system is more efficient for

TABLE 2: Resource utilization analysis.

Number of students	DLA	MMT	AI-ENT
10	61	61	79
20	72	72	84
30	68	68	88
40	78	78	83.7
50	75	75	90.3
60	62	62	91
70	79	79	92.7
80	71.8	71.8	93
90	85	85	82
100	76	76	97.2

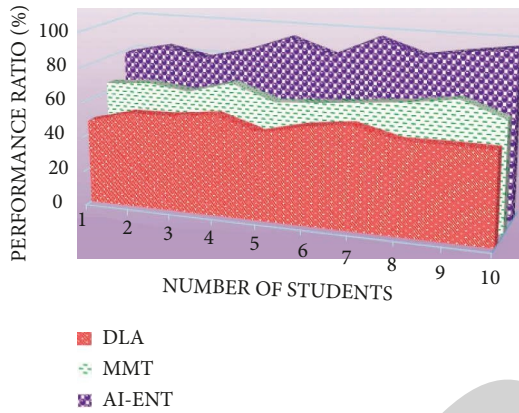


FIGURE 8: Performance ratio.

evaluation. Specifically, it is about the relevance and efficacy of student achievement in study groups and their role in increasing everyone's learning. This can be shown in several ways, including the construction and distribution of learning tools, assisting other students, managing online conversations, and substantially affecting groups. Therefore, it is argued that one can acquire social communication and good educational quality by contributing well to a whole learning community.

Table 2 lists the resource utilization analysis. The learning network includes essential learning environments, resources, and services to facilitate self-study and cooperative English learning. Complete use of educational materials refers to students' utilization of all educational resources. It reflects the state of the student and is linked to their online learning achievement. A 97.2% improvement over the current approach is achieved. In most cases, the more tools they use, the more invested they get, and the more they learn about the subject matter. Among the network learning platform's components are a learning site and software. Figure 8 shows the performance ratio.

Students' motivation and self-esteem are increased by online English learning because it encourages higher-level cognitive talents. Everyone can benefit from community activities that demonstrate the subject to expand learning opportunities and improve social and interpersonal skills. Academic performance is influenced by students' perceptions of the world around them, according to research. It had

been utilized more often by students with higher grades, whereas students with lower grades used the platform less frequently. AI-ENT outperforms existing MMT and DLA approaches in terms of performance ratio (98.3%). It is ensured that students are given high-quality tasks to evaluate their academic progress and identify areas, in which they need more assistance. Using this method, students can discover areas for improvement and work on them. Motivation and self-confidence boost students' desire to learn. The suggested method evaluated the participation ratio, interaction ratio, efficiency ratio, resource utilization analysis, and performance ratio.

5. Conclusion

The artificial intelligence-based English network teaching (AI-ENT) method has been transformed using wireless connections for distant learning. It can be included in the creation of a system for teaching English over a network. Multidimensional information points represent English memory and learning as a multidimensional variable in AI systems' expert knowledge. Machine learning algorithms are used in the learning process when the human brain's forgetting rule becomes apparent in analytical preparation. This creates a framework for students to develop their knowledge, provides expert support, and serves as the foundation for an online learning platform. The teaching module provides a set of interpretations to guide such methods and activities to allow for a wide range of teaching techniques and activities. A network teaching system for mobile distance learning and a network teaching system for mobile distance learning have been developed in the Internet mobile terminal. The experimental outcome of the proposed method boosts the participation ratio of 95.3%, interaction ratio of 96.4%, efficiency ratio of 98.8%, resource utilization analysis of 97.2%, and performance ratio of 98.3%.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Research on Design of Extensible Mobile Flood Control Wall in Underground

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The current natural environment is unpredictable with heavy rains and floods happening from time to time. In order to ensure the safety of underground workers, infrastructure, and rail transit, a mobile and expandable underground flood control wall was optimized and designed. The use of mortise-and-tenon structure splicing and modular extension design effectively increases the stability and useable area of the flood wall. The finite element analysis software was used to simulate and study the force of each component under combined loads, such as static water, dynamic water, and impact, to analyze the stability performance of the assembly such as anti-sliding, anti-tilting, and internal stress. The verification results show that when the designed and studied underground flood control wall equipment is fully deployed, the maximum stress is 220.762 MPa, and the maximum offset distance is 32.334 mm, which are all within the safe range. It provides innovative ideas for the optimization of the related flood control wall structure.

1. Introduction

In recent years, a short period of heavy rain has frequently caused waterlogging problems in cities and towns, especially in underground garages, subway, and other underground space entrances. The timely blocking of flood inflow can effectively avoid the crisis of human safety and the normal operation of rail transit. In addition to the rational design of the flood drainage pipe network, there is an urgent need for a device that is convenient, quick, and easy to install and has a good flood control effect to play an active role. The mobile flood control wall can not only be installed quickly during the flood season but also can be easily disassembled and folded for storage during the non-flood season. As a temporary flood control equipment to deal with sudden storms and floods, it is widely used at the entrances and exits of important underground spaces in cities and towns.

The first mobile flood wall in the world was installed in the urban area of Cologne, Germany in 1984, and then the same type of flood wall was put into use successively in places such as the Danube River in Austria, Baja, Hungary,

and Brado in the Czech Republic [1–3]. At the beginning of the 21st century, China begins to design and produce mobile flood control wall equipment. The new mobile flood control wall with aluminum alloy material instead of steel plate has been successfully put into use in Suzhou, Shanghai, Wuhan, and other places [4–6]. Many scholars at home and abroad have conducted a lot of research work on the structural design, material selection, and performance analysis of flood control walls [7–10]. Pan [11] designed an ecological flood control based on the full use of the basic functions of flood control projects. The wall is used for flood control and river treatment during flood season, which can effectively improve river pollution and protect the ecological environment on both sides of the bank. Xu et al. [12] used the elastic mechanics method to analyze and solve the problems of material selection and size design in order to better grasp the force and deformation of the mobile flood control wall during work, which played a guiding role in the flood control project. Ni et al. [13] elaborated on the application prospects and structural characteristics of light mobile flood control walls, combined with theoretical calculations and finite

element analysis techniques and focused on explaining the structural forces and failure modes of light mobile flood control walls. Zhang et al. [14] studied a new type of mobile flood control wall based on urban underground space entrances and exits. The stability and safety of flood control walls were analyzed through the material mechanics method, which provided a positive reference for urban underground space flood control. Getter et al. [15] used dynamic methods to carry out finite element simulations and analyzed the maximum impact load that the flood wall can withstand under dynamic conditions, providing additional guidance for static design schemes. In addition, the scientific research team and the company also applied for a number of patented technologies related to mobile flood control walls under the strong support of national policies [16–19] and manufactured various types of assemblies for use in flood control projects. However, most of the existing mobile flood control walls are made of aluminum alloy materials and have a single structure. There is still room for optimization in terms of overall structure design and material selection of key components such as main baffles, support rods, and beams.

According to the requirements of flood control at the entrances and exits of important underground spaces, considering the versatility of equipment and the convenience of installation and disassembly, this paper designs an expandable and mobile underground flood control wall. Corrosion-resistant and impact-resistant interstitial-free-steel materials are selected for key components such as the connecting column, rotating handle, and support rods to effectively increase the stability and impact resistance of the flood wall. The modular flood control wall is seamlessly spliced through the structural design of the connecting column, and the expansion of the flood control wall is controlled by rotating the handle, and the pressure is reduced by increasing the contact area during the flood control process. It can effectively alleviate the adverse effects of urban waterlogging on underground space projects.

2. Design Principle

The expandable and mobile underground flood control wall has well flood control and impact resistance. It is mainly composed of a retractable baffle, a plug-in support rod, a mortise-and-tenon structure connecting column, a rotating handle, a safety bolt, and pins. The design principle of the equipment is universal performance and easy installation and disassembly. The schematic diagram of the assembly is shown in Figure 1 below. The main stressed components are the baffle, support rods, and connecting column. When sudden storms and floods cause serious waterlogging problems in towns, the retractable baffle with support rods on the back is fixed to the entrance and exit of the underground space with pins, and the baffle and support rods are connected by plug-in connection with a tilt angle θ of 45 degrees to 105 degrees. If the waterlogging area is large, the baffle can be unfolded by the rotating handle; or the baffle can be spliced according to the modularity through the connecting column, and the different working methods of

the flood control wall can be determined according to the different intensity and scope of the waterlogging. The underground flood walls designed in this paper are all mechanical structures, which are convenient to assemble, disassemble, and maintain. They ensure that there is no risk of leakage during the process of blocking waterlogging and ensure that the maximum stress and offset distance are within a safe range when the flood wall is fully expanded.

3. Basis of Theoretical

3.1. Combined Load Analysis. This paper considers the effects of combined loads such as static water, dynamic water, and impact to calculate and analyze the bearing capacity of the expandable and mobile flood wall assembly. Static water load is the most common load state of flood control walls, as shown in Figure 2. The pressure of static water acts on the baffle of the flood wall, and the load of the baffle is transferred to the support rod. Therefore, the hydrostatic pressure q_1 can be calculated by the following:

$$q_1 = \rho ghL, \quad (1)$$

where, ρ is the density of water (if the content of suspended solids in the water is large, a larger water density can be selected appropriately), h is the water retaining height of the flood wall, L is the span length of the flood wall, and g is the acceleration of gravity.

When the flood control wall is fixed in the flowing water area, if the longitudinal direction of the flood control wall is not parallel to the direction of the water flow, the movement of the water will generate a dynamic water load on the baffle, as shown in Figure 3. Since the dynamic water load is caused by the impulse of water, according to the impulse, we get

$$\mathbf{F} \cdot \Delta t = m \cdot (v \sin \alpha). \quad (2)$$

Then the calculation (3) of the dynamic water load q_2 is as follows:

$$\begin{cases} q_2 h \Delta t = \rho (hLv \sin \alpha \Delta t) v \sin \alpha, \\ q_2 = \rho (v \sin \alpha)^2 L, \end{cases} \quad (3)$$

where, α represents the angle between the flood and the baffle, and v represents the water velocity.

When waterlogging disasters occur, the floods are often accompanied by drifting objects of different shapes. When they hit the flood wall, the impact load generated cannot be ignored. This article takes small drifting objects such as block and bicycle wheels as the main analysis objects and assumes that the drifting objects will not deform when impacted. Suppose the elastic stiffness of the baffle is C_F (N/m). According to the principle of conservation of energy, the kinetic energy of the drifting object is transformed into the strain energy of the assembly, which is obtained by the energy conservation formula:

$$\frac{1}{2} m (v \sin \alpha)^2 = \frac{1}{2} C_F \eta^2, \quad (4)$$

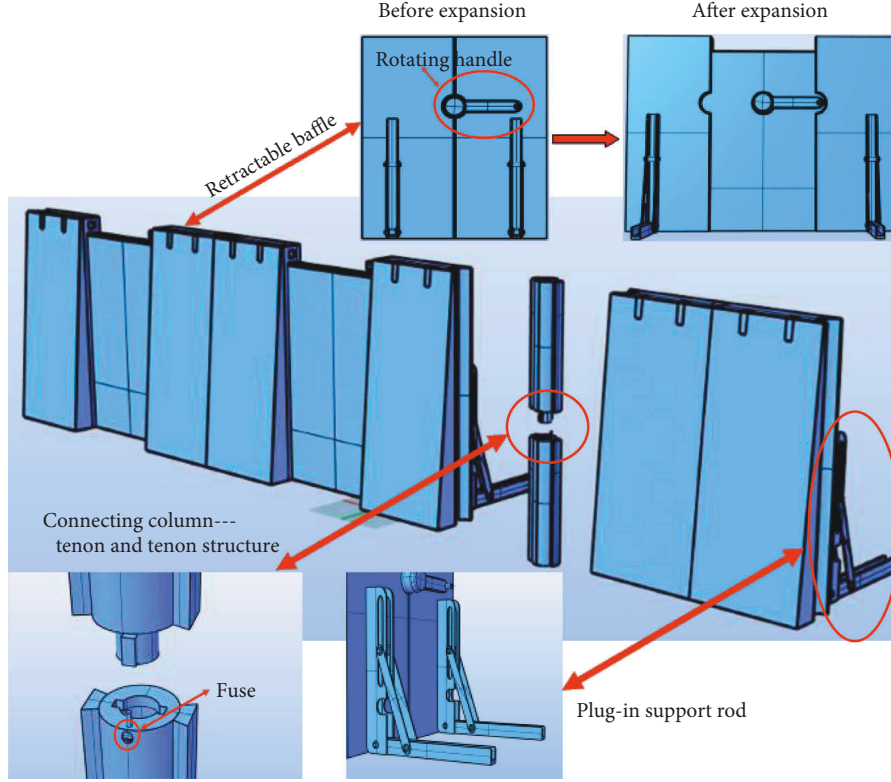


FIGURE 1: Design and assembly drawing of the expandable mobile underground flood control wall.

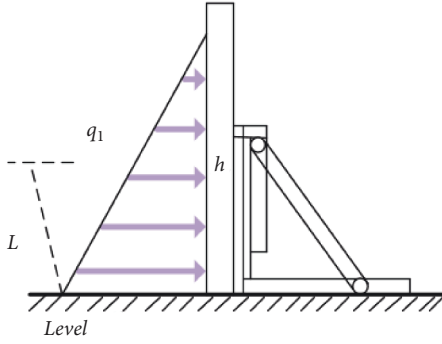


FIGURE 2: Diagram of the hydrostatic load.

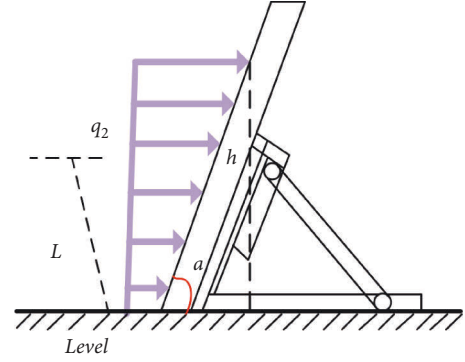


FIGURE 3: Diagram of the hydrodynamic load.

where, m is the mass of the drifting object, v is the speed of the drifting object (approximately equal to the water speed), α is the attack angle of the drifting object and the flood wall, and η is the structural deformation. The impact load can be expressed as (5), and the schematic diagram of the impact load is shown in Figure 4.

$$F = \eta C_F = v \sin \alpha \sqrt{m C_F}. \quad (5)$$

3.2. Stability Analysis. The design of an expandable mobile underground flood control wall in this paper focuses on safe flood prevention at the entrances and exits of underground spaces in cities and towns, and the inclination angle of the baffle is $45^\circ \leq \theta \leq 105^\circ$ under working conditions. The analysis of assembly stability [20, 21] mainly focuses on the

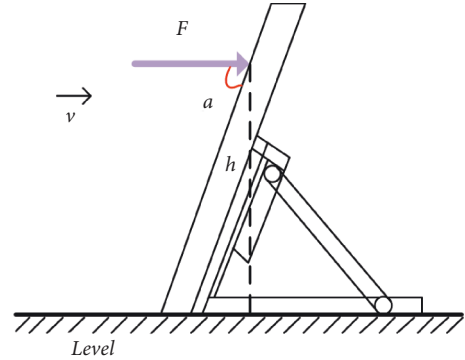


FIGURE 4: Diagram of the impact load.

calculation of anti-sliding stability, anti-tilting stability and base stress calculation of the baffle and support rod along the bottom of the foundation, as well as the calculation of the internal force of the connecting column. The formula for calculating the anti-sliding stability of the support rod of the flood control wall along the bottom of the foundation is as follows:

$$K_c = \frac{f \sum G_{rod}}{\sum L_{rod}}, \quad (6)$$

where, K_c represents the safety factor of anti-sliding stability along the base surface of the support rod, which must be less than 1.25 under the basic load combination; f represents the coefficient of friction between the base surface and the foundation, and the flood control wall is mostly in a cement layer. Take $f=0.45$, $\sum G_{rod}$ represents all the vertical loads acting on the support rod; $\sum L_{rod}$ represents all the lateral loads acting on the support rod. The formula for calculating the anti-tilting stability of the baffle of the flood control wall is as follows:

$$K_0 = \frac{\sum M_{baffle}}{\sum H_{baffle}}, \quad (7)$$

where K_0 represents the anti-tilting stability safety factor, and the basic load combination needs to be less than 1.50; $\sum M_{baffle}$ represents the vertical anti-tilting moment of the baffle; $\sum H_{baffle}$ represents the lateral anti-tilting moment of the baffle. The base stress calculation formula is as follows:

$$P_m = \frac{\sum G_{rod}}{S_{rod}} \pm \frac{\sum (M_{baffle} + H_{baffle})}{W_{baffle}}, \quad (8)$$

where P_m represents the maximum or minimum base stress of the support rod; $\sum G_{rod}$ represents all the loads acting on the support rods of the flood control wall perpendicular to the horizontal plane; $\sum (M_{baffle} + H_{baffle})$ represents the load acting on the flood control wall baffle. The sum of all moments above; S_{rod} represents the area of the base surface of the support rod; W_{baffle} represents the cross-sectional distance of the baffle mandrel. The schematic diagram of the force is shown in Figure 5.

In order to increase the working area of the flood control wall, two ways of modular splicing and rotating expansion are designed in this paper. When the connecting column and baffle are subjected to horizontal force, they are prone to bend and fracture to different degrees. Therefore, the gapless atomic steel material is selected for the key components such as the baffle and the connecting column, and the tenon-and-mortise structural connecting column is designed to effectively increase the stability and impact resistance of the flood control wall. When analyzing the internal force of the assembly during the flood control process, first determine the position of the dangerous section of the connecting column, as shown in Figure 6. Then calculate the maximum bending moment M_{max} and shear force F_{max} on the dangerous section according to the possible load combination.

Approximately calculated from the relevant formulas of material mechanics, the maximum normal stress of the dangerous section is

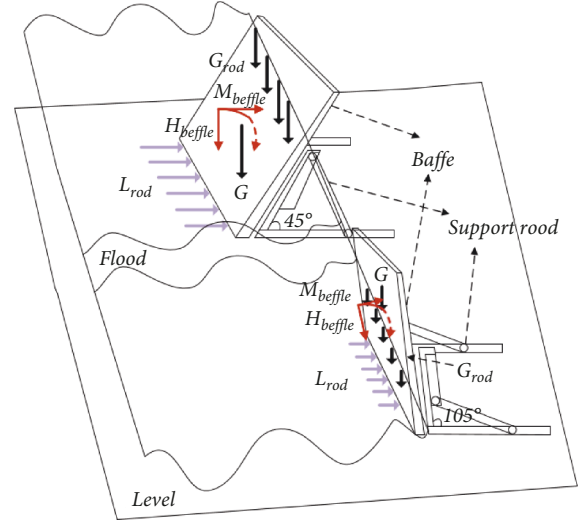


FIGURE 5: Schematic diagram of the force analysis-baffle and the support rod.

$$\phi_{max} = \frac{M_{max} y}{I_z}, \quad (9)$$

where, I_z is the moment of inertia of the dangerous section, and y is the ordinate of the normal stress point. The maximum shear stress of the dangerous section is

$$\varphi_{max} = \frac{F_{max} Q_z}{I_z b}, \quad (10)$$

where Q_z is the area moment of the area on the either side of the dangerous section from the neutral plane to the neutral plane, and b is the width of the horizontal slope. After obtaining the maximum normal stress and maximum shear stress on the dangerous section, you can refer to the following (11) for internal check.

$$\begin{cases} \frac{\phi_{max} k}{[\phi]} < 1, \\ \frac{\varphi_{max} k}{[\varphi]} < 1, \end{cases} \quad (11)$$

where k represents the safety factor, which is generally 0.58. $[\phi]$ represents the allowable normal stress, and $[\varphi]$ represents the allowable shear stress.

4. Experimental Verification and Discussion

During the modeling process, the selected materials and property parameters are shown in Table 1. The main baffle is made of 6005A-T6 aluminum alloy, and the connecting column, support rod, and rotating handle are made of IF alloy steel [22, 23].

The finite element analysis software Abaqus and HyperMesh & Hyperview are used for solution calculation and pre- and postprocessing. First consider the simulation experiment of the assembly in the hydrostatic state, and the experimental results are shown in Figure 7 below. When the

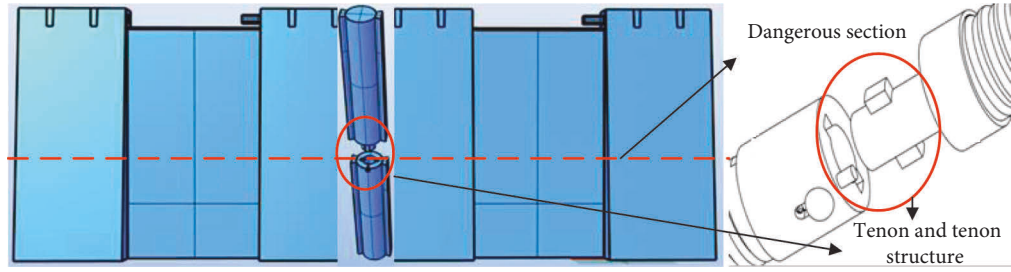


FIGURE 6: Schematic diagram of dangerous section-baffle and connecting.

TABLE 1: Material parameters.

Name	Elastic modulus (KN/mm ²)	Yield strength (Mpa)	Tensile strength (Mpa)	Poisson's ratio
6005A-T6	69	239	266	0.28
IF	225	443	390	0.33

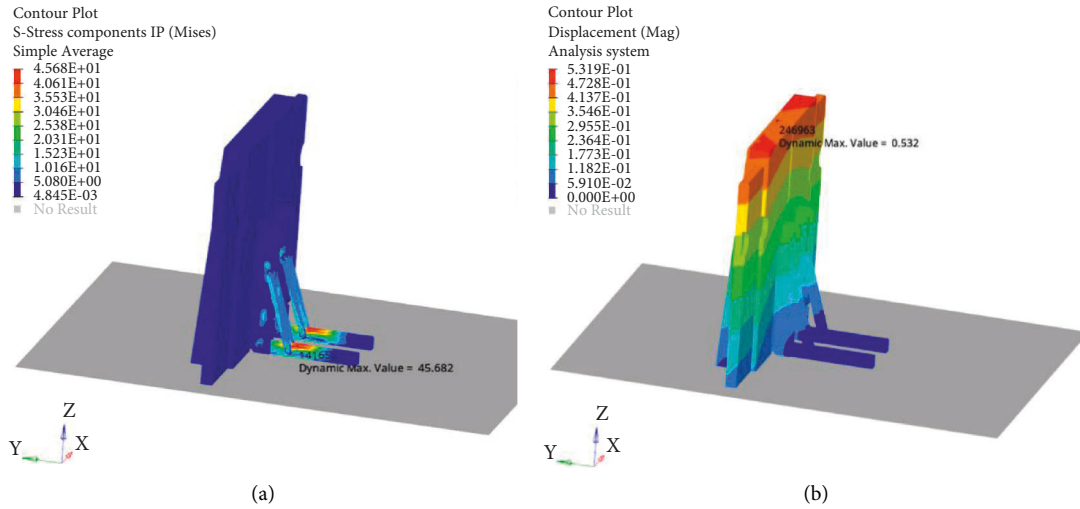


FIGURE 7: Analysis of hydrostatic load. (a) Maximum stress. (b) Assembly offset.

flood still contacts the entire baffle plane, the main force-bearing components are transmitted to the support rod. At this time, the maximum stress on the support rod is 45.682Mpa, and the displacement of the assembly in still water is 0.532 mm, which can effectively block the effect.

The assembly is vulnerable to the impact of objects of different shapes on the surface of the baffle in the dynamic state. At this time, it is necessary to focus on the impact of the impact load on the assembly. Assuming that the dynamic water speed is 3 m/s when the flood season comes, the arc-shaped block (8 Kg) driving the roadside impacts the flood control wall at the same speed.

When the block shown in Figure 8 impacts the flood control wall, the main force-bearing parts of the assembly are baffles, connecting columns, and support rods. The simulation experiment was carried out to analyze the maximum stress of each component of the flood control wall and the dangerous section under the combined load of dynamic water and impact. The experimental results are shown in Figure 9 below. The maximum stress at the fixed bracket of the support rod is 220.762 Mpa, the maximum

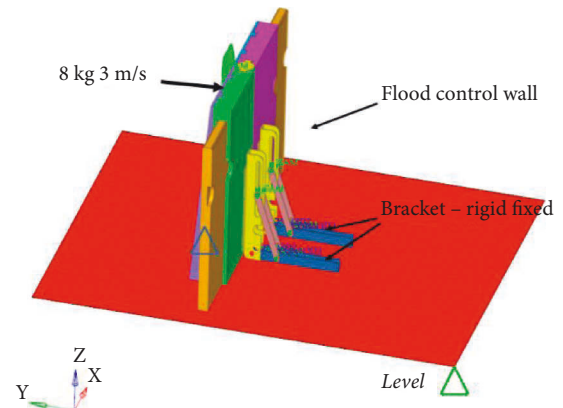


FIGURE 8: Simulation schematic.

stress at the mortise and the tenon joint of the connecting column is 56.919 Mpa, the maximum stress at the fully expanded state of the baffle is less than 23.970 Mpa, and the maximum offset distance of the assembly is 32.334 mm.

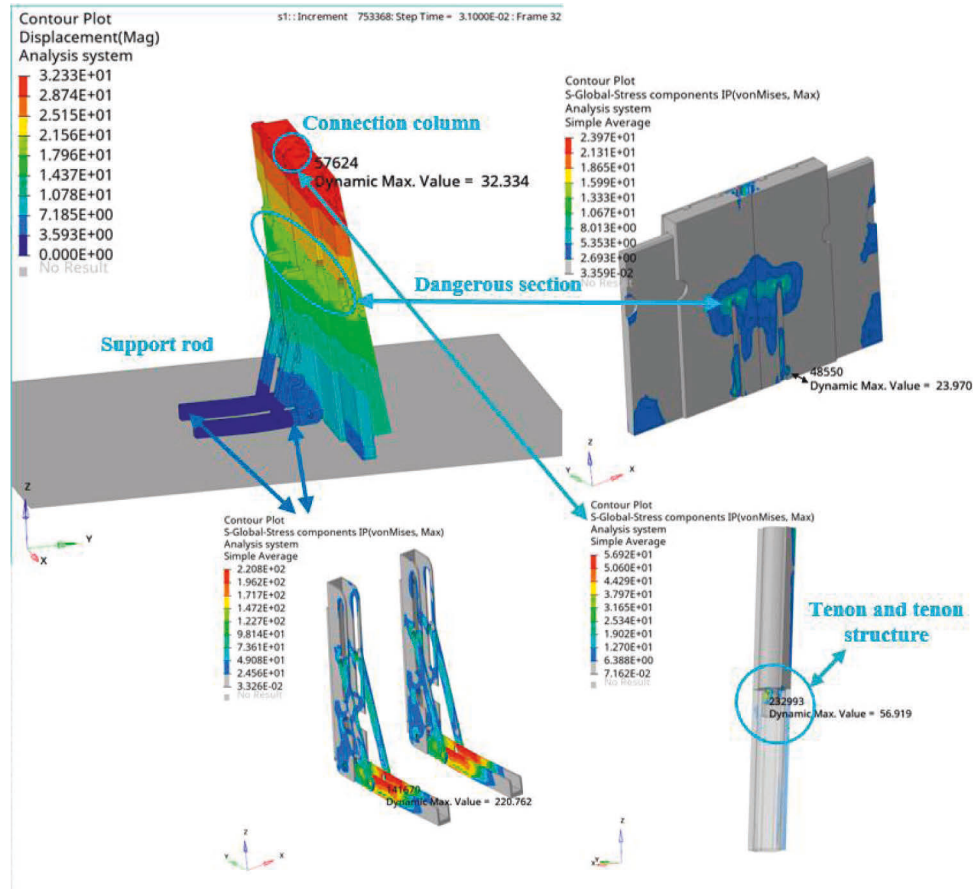


FIGURE 9: Analysis of the combined load.

TABLE 2: Simulation experiment data.

	Support bar (MPa)	Connection column (Mpa)	Baffle (Mpa)	Offset distance (mm)
Maximum	220.762	56.919	23.970	32.334
Security index	266.00	266.00	196.00	100.00

The simulation results show that the maximum bearing capacity of the extensible mobile flood control wall designed in this paper meets the allowable stress of the material under the combined loads of static water, dynamic water, and impact, and the safety is guaranteed, and it can be put into use when the flood season comes. The specific simulation data are shown in Table 2.

5. Conclusion

The expandable mobile underground flood control wall adopts mortise and tenon structure splicing and modular extension design. It is mainly used to protect the entrances and exits of important underground spaces in cities and towns during flood season. The finite element simulation experiment proves that it can be used under combined loads such as static water, dynamic water, and impact. Meet the safety performance requirements. Compared with traditional flood walls, it has the following advantages: (1) Modular and extended design, the size of the equipment can

be set independently according to the working environment. (2) Mechanized design to ensure that there is no risk of electric leakage and electric shock during flood prevention work, and maintenance is convenient. (3) The telescopic design of the mortise-and-tenon structure provides quick installation and operation, convenient disassembly and storage and greatly reduces labor intensity. (4) The selected material has good corrosion resistance and impact resistance and can be disassembled for the passage of people and vehicles in an emergency.

Data Availability

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

Conflicts of Interest

The authors declare that they have no known conflicts of interest.

Acknowledgments

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Research Article

Hybrid Japanese Language Teaching Aid System with Multi-Source Information Fusion Mapping

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Learning Japanese can enhance competitiveness in a globalized economy, and we address the problems of poor open-source Japanese language teaching, cumbersome teaching tasks, and a single teaching model. We propose a hybrid Japanese teaching aid system with multiple information fusion mapping, which can effectively improve the efficiency of Japanese teaching and reduce the tedious human teaching procedures. The system is divided into two branches of Japanese language recognition, namely, the Japanese text recognition branch and the Japanese voice sequence recognition branch. In the Japanese text recognition branch, we integrate attention mechanisms and long short-term memory networks as the basic network for Japanese character text recognition. In addition, we set up separate text feature recognition systems for Japanese computer writing and handwriting to prevent feature overlap problems. For Japanese voice sequence recognition, we used a combination of memory gating unit and encoder, based on the network still extending the structure of the deep neural network and using the residual structure connection in the gating unit to avoid the gradient disappearance problem. At the end of the system, we use a softmax layer to connect the text recognition and voice recognition networks to form a Japanese language teaching aid system. To verify the efficiency of our system, we selected the Japanese text recognition public dataset and voice recognition public dataset for experimental validation. To match the practical application of the system, we created our dataset based on the dataset standard and conducted experimental validation. To compare other Japanese recognition methods, we selected the six most representative Japanese recognition algorithms for experimental comparison. To ensure the balance of the experiments, each algorithm is trained in a separate experimental environment for modeling and tuning parameters. Experimental performance and the experimental results show that our method significantly outperforms the other methods and has better system stability.

1. Introduction

Economic globalization has become an inevitable trend, and a tool to assist it is linguistic communication between different countries. Learning a foreign language can enhance the competitiveness of economic globalization and contribute positively to the cause of multiculturalism. English is now the dominant language in globalization, but for people in non-English-speaking regions, small languages can enhance the efficiency of economic development in non-English-speaking countries. Japan has played an irreplaceable role in today's economic globalization process, and Japanese, as one of the minor languages, is not very difficult to learn and master. Also, Japanese is one of the international languages highly valued by the Malaysian education sector [1].

With the full coverage of the 5G communication network, Japanese language teaching is gradually shifting from traditional face-to-face teaching to online learning and remote instruction mode.

The innovation of small language teaching methods is the inevitable result of technological development. Japanese language teaching has changed from the digital media technology model to the Internet information technology model, different computer technologies have given Japanese language teaching a new teaching model, and students' learning experience and learning efficiency are higher. The Japanese government is now actively contacting Japanese-friendly countries to jointly build a new field of Japanese language teaching based on WEB. In the traditional Japanese language teaching model, Japanese language teachers are

burdened with tedious teaching tasks. Japanese language intelligent teaching system can reduce the teaching tasks of Japanese teachers and also help students to strengthen the foundation of the Japanese language [2]. The Japanese language learning environment is also one of the most influential factors in Japanese language learning, and an excellent Japanese language learning environment can help students quickly improve their Japanese speaking and memorization skills. The Japanese learning environment in an offline classroom is heavily dependent on the teaching style of the Japanese teacher, but the Japanese learning environment in the Japanese smart teaching model is pre-set according to the student's Japanese ability and is more friendly to different students. The Japanese smart teaching system includes more than just Japanese grammar and word teaching tasks; according to the latest Japanese smart teaching research, researchers are creating a virtual environment for Japanese language learning, and virtual reality and augmented reality technologies are increasingly being used in the Japanese smart learning system. This not only enhances the fun of Japanese lessons but also boosts student motivation [3].

Some researchers who focus on building Japanese intelligent teaching systems have found that interactive systems increase Japanese language perception in Japanese language learning, so most Japanese intelligent teaching models use interactive learning methods. Researchers have transplanted visual sensing technology to assist in Japanese language teaching by analyzing student-teacher interactions to recommend appropriate Japanese learning methods for students and more relevant Japanese teaching programs for teachers after class. Some researchers have embedded voice sensors into spoken Japanese-assisted learning to process and analyze data on students' spoken Japanese and provide students with word pronunciation correction and grammar optimization suggestions, and students can receive a real-time Japanese pronunciation suggestion after each Japanese pronunciation. Long-term Japanese speaking practice and feedback can leave data records in the Japanese Speaking Assistance System, which will analyze big data on individual students' pronunciation habits and speaking error point to provide each student with an adapted Japanese speaking training plan [4]. With the change in information technology, the open-source nature of portable electronic device systems has increased. Researchers aim to increase the open-source nature of intelligent Japanese language teaching systems to help students use their free time to learn Japanese efficiently. Researchers have developed Japanese smart teaching systems that integrate WEB and APP, allowing students to select online lessons, learn vocabulary and grammar, practice speaking, learn Japanese culture, view Japanese news, etc., on various portable devices. Some researchers have conducted research on Japanese text recognition to detect handwritten Japanese, improving students' handwritten Japanese skills, and enhancing the handwritten Japanese experience in Japanese classes [5].

In response to the problems of poor open-source Japanese language teaching, cumbersome teaching tasks, and a single teaching model, we propose a hybrid Japanese

teaching aid system with multiple information fusion mapping that can effectively improve the efficiency of Japanese language teaching and reduce the cumbersome human teaching procedures. The system is divided into two branches of Japanese language recognition, the Japanese text recognition branch, and the Japanese voice sequence recognition branch. To verify the efficiency of our system, we selected the Japanese text recognition public dataset and voice recognition public dataset for experimental validation. To match the practical application of the system, we make our dataset according to the dataset standard and perform experimental validation.

The rest of the paper is arranged as follows. Section 2 describes the work related to Japanese voice recognition and text recognition. Section 3 describes in detail the principles and implementation process related to Japanese language recognition methods. Section 4 shows the related experiment setups, experimental dataset, and analysis of experimental results. Finally, Section 5 summarizes our study and reveals some further research work.

2. Related Work

The Japanese language system contains a large number of Chinese characters, so the Japanese text recognition methods have a lot in common with the Chinese language recognition methods. Some researchers studying Japanese document recognition use layout analysis [6] to segment Japanese fragments and then use fixed pixel frames to extract pixel information from Japanese fragments in an iterative manner [7]. The extracted features can be categorized into Japanese character feature databases based on manual labels, and through the neural network layer, different Japanese character features will be linked in independent mappings based on the neural network. For Western languages, most scripts are composed of Arabic letters, while the Japanese system is composed of hiragana, katakana, and kanji. In the character segmentation work, the Japanese character segmentation work is completely different from the English system. In the literature [8–10], the method of segmentation followed by merging was proposed in the study. Due to the high workload of Japanese character segmentation, the experimental cost is high and it is easy to make segmentation errors. Therefore, in the work of Japanese character segmentation, researchers divided it into written Japanese segmentation and handwritten Japanese segmentation. The written style is more standardized, and the character segmentation work is easier, while the handwritten style varies from person to person and the character segmentation is more difficult. The accuracy of character segmentation directly affects the performance of the whole Japanese recognition system. The early research on Japanese character segmentation used machine learning algorithms as the main character feature learning method, and later researchers introduced deep learning methods into character research, which greatly improved the efficiency of hiragana and kanji character segmentation.

The first deep neural network applied to Japanese intelligent teaching system can significantly improve the

recognition accuracy of the Japanese language. The accuracy of support vector machines in character segmentation cannot meet the subsequent Japanese language processing, so many researchers try to use deep neural networks instead. Researchers in the literature [11] have proposed a dual-linked neural network framework by fusing them convolutional neural networks and long short-term memory units. The method aims to improve the recognition accuracy of Japanese computer writing style and concludes by proposing an association with Japanese handwriting style, which provides a great reference for later Japanese handwriting style recognition. Researchers in the literature [12] analyzed the current problems faced by Japanese text recognition work and proposed a handwriting grading algorithm based on the difficulty of recognizing Japanese handwriting style. The grading is based on the complexity of the handwriting style, each level of Japanese corresponds to a separate network layer, and the more complex Japanese recognition corresponds to a network layer consisting of a combination of separate long short-term memory units. Other researchers have also proposed a feature matching mapping model between Japanese computer-written and handwritten corpora inspired by the hidden Markov model [13] to improve the recognition accuracy of Japanese handwriting corpora. The study in the literature [14] addresses the problem of offline Japanese language recognition by proposing a framework for the fusion of two-layer long short-term memory units with temporal classification algorithms. The literature [15] investigated the relationship between Arabic script recognition and Japanese language recognition, and successfully transposed the Arabic language recognition model to Japanese language recognition research, and experiments proved that the method achieved effective results. The studies in the literature [16, 17] are end-to-end training models, and the method embeds the model into the Japanese language intelligent recognition system by pretraining the model, which solves the compatibility problem between the model and the system and reduces the computational cost.

Japanese voice recognition belongs to natural language audio processing, and for Japanese voice recognition, it is first necessary to convert the voice signal into a linguistic feature vector. Then, the Japanese voice features are enhanced by output processing by simulating human ear perception features. Then, the mapping of the voice signal to Japanese text features is completed by matching voice signal features with Japanese features through linear prediction and perceptual prediction. There are also a large number of research results in the field of voice recognition. The research in literature [18] has broken new ground in the field of voice recognition. The authors proposed a voice sequence matching model based on dynamic time regularization, which is simple to understand and has a high recognition correct rate, but is computationally intensive and requires high hardware equipment. So far, the method is still used in voice recognition of access control systems. The literature [19] improves on the former, optimizes the recognition accuracy of small vocabulary and isolated words in voice recognition systems, and also proposes the concept of

frequency scale recognition to improve the generalization of voice recognition systems. The literature [20] proposed a voice recognition model based on vector quantization with a sub-parameter model, which requires less computer memory and has better recognition resulting in large segment voice decomposition. Researchers in the literature [21] proposed a segmented fuzzy clustering algorithm to visualize voice sequences and use vector quantization errors to replace the output probabilities of hidden Markov models, and the network model was experimentally shown to have good performance in voice recognition. Researchers in the literature [22] proposed a fusion model of the hidden Markov model and a self-organizing neural network to obtain precoding parameters by analyzing filter sets in voice signals and then using a self-organizing neural network to predict the mapping relationship between voice and text. The experimental results prove that the model has good robustness and stability.

3. Method

3.1. Hiragana and Katakana Feature Classification. The Japanese language system consists of hiragana and katakana, and the kanji part can also be represented by hiragana and katakana; therefore, the characteristic classification of hiragana and katakana has a great influence on the Japanese recognition system. Researchers in the literature [23] have proposed coarse and fine classification systems in the study of feature classification, and both systems use a combination of line segments and dots. For different hiragana and katakana contours, researchers have purposely designed different stroke contour recognizers. Some researchers have tried to use Markov random field algorithms with unstructured features as the main baseline for contour recognition [24]. For Japanese handwriting, this method cannot accurately obtain the mapping relationship between handwriting patterns and the standard Japanese system, and the structural information is easily lost at the temporal level. The literature [25] modified the recognition sequences of Japanese and Chinese characters based on the former to enhance the acquisition of structural and nonstructural features for the Japanese recognition algorithm. We synthesize the former study and propose a mosaic classification method with coarse classification and fine classification. In our classifier, we set up Markov random field structure classifier (MRF-C), hidden Markov structure classifier (HMM-C), and quadratic discriminant function classifier (QDF-C). The hiragana feature classifier we designed is shown in Figure 1.

For the structure recognizer, we used a top-to-bottom order of hiragana contour trajectory extraction. We reconstruct the hiragana trajectory features by taking the character trajectory start point as a unary feature point, and using the unary feature point as the center, we diverge to adjacent coordinate differences as binary features. The binary features are input to the Markov random field model as nodes, and the coarse classifier will preferentially generate large probability category labels, and after the first matching of large probability category labels is completed, the

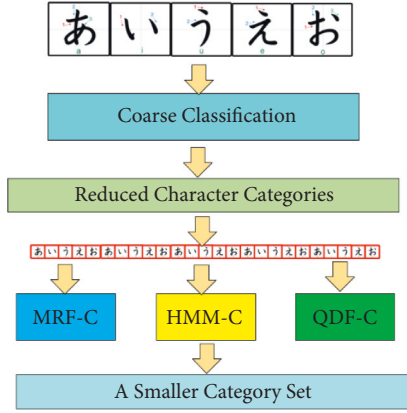


FIGURE 1: The hiragana feature classifier.

character feature vectors with finer dimensions are obtained after inputting the monadic features and binary features to the fine classifier. The hidden Markov model cannot complete the binary feature of point-to-point trajectory recognition and classification. Therefore, single-point hiragana character features are graded by random fields to complete feature traversal.

3.2. Attention Mechanism Feature Extraction. We divided the Japanese computer writing style and handwriting style into two separate branches, and we designed specialized attention mechanisms and long short-term memory networks to decompose the different hiragana contour features. For the Japanese computer-written style, we mainly designed unstructured fine feature recognizers. Based on previous studies, Japanese hiragana characters need to be converted to 2D RGB images for storage, and then stroke features are extracted based on predefined handwriting directions. Some researchers tried to normalize the histogram method for hiragana strings, but the results were not very good. Some researchers proposed a two-dimensional two-moment normalization method [26], which divides the stroke features into eight feature extraction directions. The features in each direction are Gaussian fuzzy processed to ensure a balanced distribution of Japanese character features. The method has the following mathematical equation expression.

$$g_2(x, w) = \sum_{j=1}^k \frac{1}{\lambda_{ij}} \left[\varphi_{ij}^T (x - \mu_i) \right]^2 + \sum_{j=1}^k \log \lambda_{ij} + (n - k) \log \delta, \quad (1)$$

where μ_i denotes the mean vector in the w_i direction, φ_{ij} denotes the eigenvector of the corresponding covariance matrix λ_{ij} , X denotes the number of filters, k denotes the constant eigenvector, n denotes the character eigenconstant parameter, and δ denotes the variable that can be optimized in the training parameters. For Japanese handwriting, we use a decoder mechanism to decompose the hiragana handwriting trajectory. We set the feature decoding handwriting time step as t and the attention weight as ρ_t . Japanese handwriting and trajectories vary from person to person, so to distinguish scribbles from regular handwriting, we set the

implicit computation of the target feature in the encoder feature encoding layer as h_t . The mathematical expression is shown below.

$$h_t, O_t = \text{LSTM}(h_{t-1}, a_t), \quad (2)$$

where O_t denotes the graded output value of the hidden feature layer in time step t and a_t denotes the attentional feature vector in time step t . LSTM denotes the transition network between the two hidden layers. Based on the previously trained model, we adopted the attention mechanism parameters of the pretrained model, encoded the trajectory vectors before and after the Japanese characters, and redesigned the mapping relationship of the hiragana labels of the trajectory features according to the feature pointing in the hidden layer. At the tail end of the encoder, we add a softmax layer and finally generate a predictive distribution for Japanese handwritten fonts through the joint action of the encoder and the softmax activation function, whose mathematical equation expressions are shown below.

$$y_t = \text{softmax}(W_a \times a_t). \quad (3)$$

For feature extraction of Japanese computer-written and handwritten scripts, we used an attention mechanism model. To effectively accomplish the distributed prediction of attention vectors, we try to keep the integrity of the features during the coding process. For the irregularity problem of handwriting style, we store the vectors of different feature directions independently with the network of long short-term memory units. Considering the specificity of trajectory tracking vectors, we use a two-layer memory cell structure to store trajectory information and direction information separately. To prevent repeated prediction of character features, we reconstruct the long short-term memory network by setting a fixed storage length for each memory cell. The softmax activation function generates a predictive distribution of attention vectors for fixed-length memory cells, and the corresponding hiragana features can be matched according to the directional orientation of the attention vectors. The process of hiragana feature extraction by the attention mechanism is shown in Figure 2.

3.3. Japanese Voice Sequence Encoder. In the construction of the Japanese voice recognition system, we summarized previous studies and experimentally demonstrated the methods mentioned in the literature. In the literature [27], a recurrent neural network voice recognition method is proposed, in which the long sequence gradient dependence is first performed for the output voice sequences, and then the voice segments are decomposed by feature gradients in this way, to convert them into mapping links with Japanese hiragana and thus accomplish the task of voice recognition. The literature [28], on the other hand, improves on the former, and the authors propose a voice sequence recognition method with long short-term memory units. The voice sequences are segmented by the gating unit, then the memory unit is used to store the voice sequences, and the

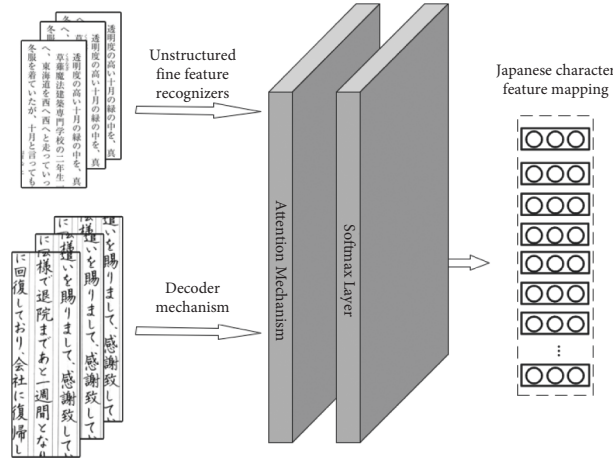


FIGURE 2: The process of hiragana feature extraction by the attention mechanism.

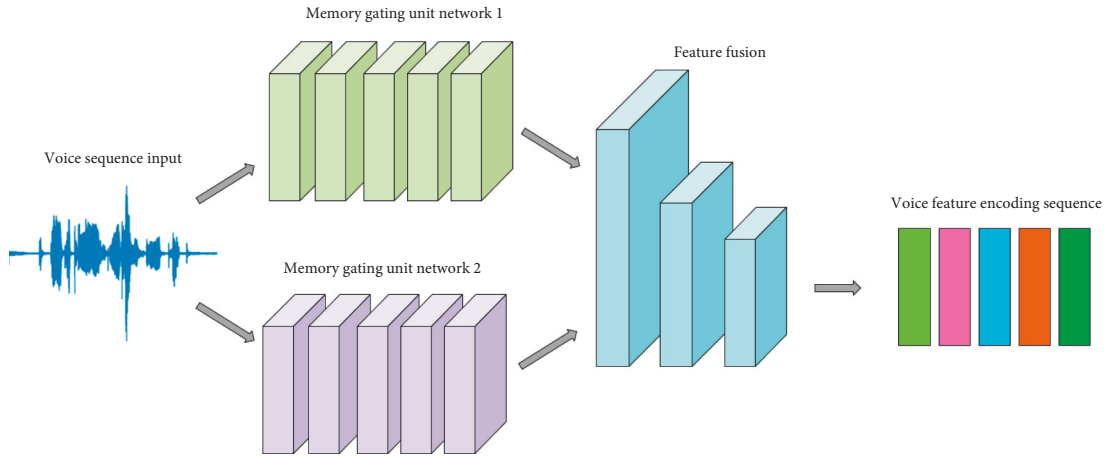


FIGURE 3: Voice sequence processing flow.

voice sequence recognition is accomplished by matching the mapping with hiragana character features. Researchers in the literature [29] improved based on the memory unit network and proposed a voice sequence recognition method with double-layer memory units, which accelerated the processing speed of voice sequences and realized the Internet online dataset variant processing. Combining the experimental results from the above literature, we used a two-way gated memory cell network structure to recognize Japanese voice sequences.

Researchers in the literature [30, 31] have proposed methods to perform encoding on scene voice transformation and feature mapping. We applied the method to a network of gated memory units. The voice sequence is first segmented, and then the segmented voice fragments are assigned to independent gated units, each corresponding to an independent encoder. To capture the temporal information of the voice sequences, we arrange the gating units and hierarchically traverse the voice feature nodes in each row of the network. In the second feature traversal, we set the order of extraction from high-level features to low-level features until the voice sequences are not repeatedly segmented within the

gating units. Our voice sequence processing flow is shown in Figure 3.

3.4. Multi-Source Feature Fusion Mapping System. We design a hybrid intelligent teaching system for the Japanese language with multi-source information fusion mapping, as shown in Figure 4. The system is mainly divided into a text Japanese recognition branch and a Japanese voice recognition branch. In the text recognition branch, we use an attention mechanism to decompose the text information. For Japanese computer-written and handwritten styles, we use different text feature extraction methods and finally feature aggregation is performed by long short-term memory networks. For Japanese voice recognition units, we used memory gating units to segment the voice sequences and then assigned the segmented voice fragments to independent gating units, each corresponding to an independent encoder. The voice sequences will then be automatically extracted by the neural network in the gating unit. We add a double-layer voice sequence memory unit in the network layer to speed up the processing speed of voice sequences.

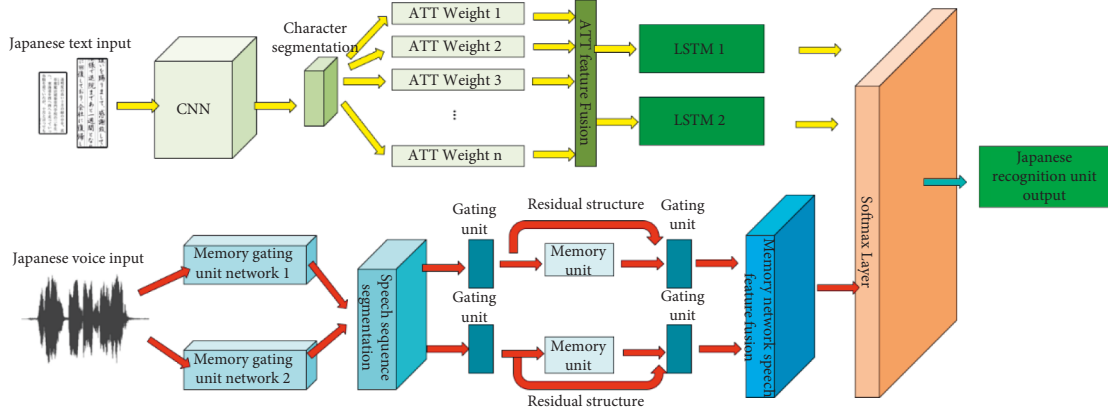


FIGURE 4: Multi-source feature fusion mapping system.

The dual recognition of Japanese text and voice together constitutes a hybrid Japanese intelligent teaching aid system.

4. Experiment

4.1. Datasets. To verify the effectiveness of our designed Japanese hybrid identification system with multi-source information fusion, we chose the public dataset to launch the experiment. The researchers in literature [32] proposed a Japanese character recognition dataset, Kuzushiji, in which most of the Japanese characters were generated by transcription. This dataset was also expanded in later studies, and most of the expanded data were computer-written Japanese characters. Literature [33] proposed a Japanese voice recognition dataset ASR, which contains more than 2000 hours of Japanese voice content, and most of the Japanese scenes are from Japanese dramas and Japanese life scenes on YouTube. The dataset not only prepares the voice content, but also annotates each voice content with hiragana subtitle labels, and this dataset saves data preprocessing costs for voice recognition work. Details of the dataset are shown in Table 1.

In addition to validating our method on a public dataset, we created our Japanese dataset based on the needs of the application. For the Japanese text recognition branch, we produced a small batch text dataset by manually integrating Japanese textbooks. For the Japanese voice recognition branch, we collated some Japanese drama clips and pre-processed them with voice noise reduction, denoising, and audio track separation, respectively. Then, voice segmentation is performed according to duration and subject categories. The segmented voice sequences are processed by us according to the feature alignment of voice sequences in ASR data. The voice sequence data preprocessing process is shown in Figure 5.

4.2. Experimental Results. We select the same type of text recognition algorithm as a comparison. Recurrent neural network (RNN) [34] is one of the most commonly used algorithms in the field of text recognition. Based on RNN, some researchers have improved the neural network structure and proposed the long short-term memory

TABLE 1: Japanese text and voice public dataset details.

	Train	Test	Total
Kuzushiji	35961	3995	39956
ASR	23451	2113	25564

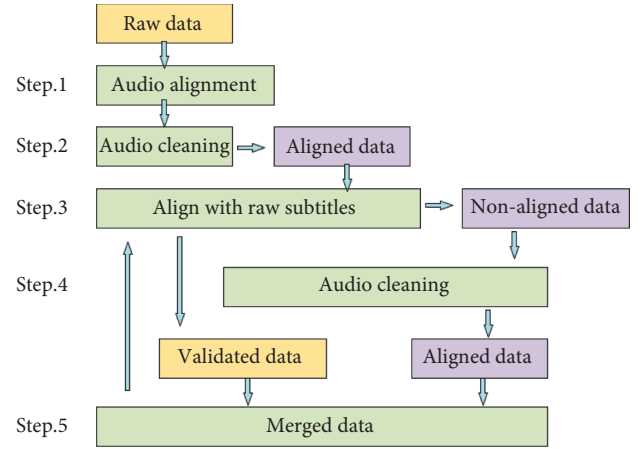


FIGURE 5: The voice sequence data preprocessing process.

TABLE 2: Results of Japanese text detection by different methods.

	Kuzushiji			Self-made datasets		
	Acc (%)	P	E	Acc (%)	P	E
RNN	71	3.4	0.32	69	3.5	0.21
LSTM	79	2.8	0.23	76	2.9	0.16
CTPN	86	2.1	0.15	86	2.1	0.11
Ours	96	0.9	0.08	93	1.1	0.05

(LSTM) unit network [35]. For text segmentation, the CTPN algorithm [36] is more advantageous, which is optimized based on Faster RCNN, and it retains the excellent image recognition ability of the CNN family. The main workflow of this algorithm consists of text box detection, text box recurrent concatenation, and text refinement. To validate the text recognition accuracy of our method on public datasets, we test it on the Kuzushiji dataset and a homemade dataset.

TABLE 3: Japanese text detection experiment results.

Method	<i>S</i>	<i>P</i> (%)	<i>R</i> (%)
RNN	0.5	75	79
LSTM	0.6	88	86
CTPN	0.8	90	90
Ours	0.9	96	97

TABLE 4: Results of Japanese voice sequence recognition by different methods.

	ASR		Self-made datasets	
	Acc	<i>F1</i>	Acc	<i>F1</i>
DNN	76%	0.84	81%	0.82
DNN-HMM	81%	0.86	83%	0.86
TDNN	89%	0.89	91%	0.89
Ours	93%	0.91	95%	0.91

We tested accuracy (Acc), number of parameters (*P*), and error rate (*E*). The experimental results are shown in Table 2.

From the above experimental results, it is clear that all the algorithms perform lower overall on the public dataset than on the homemade dataset for Japanese text recognition. The overall recognition results on the public dataset Kuzushiji are poor due to the wide coverage of the public dataset and the large number of Japanese characters involved, in addition to the inclusion of a large number of ancient transcribed Japanese characters. The sample size of our homemade dataset is too small, and the dataset production cost is large, so the homemade dataset is deficient in terms of data volume. In terms of accuracy, our method achieves 96% on the public dataset, which is better than other methods. At the parametric number level, our method has only 0.9. Since our method additionally adds a lightweight structure, the number of parameters is smaller. At the error rate level, the error rate of our method is only 0.08, while the error rates of other methods are all greater than 1, thus proving the effectiveness of our method. In the Japanese text feature set scatter (*S*) test, we will use the above three algorithms as a comparison. In addition, we also verify the precision (*P*) and recall (*R*) of Japanese text recognition, and the experimental results are shown in Table 3.

From the experimental results in the above table, we can see that RNN and LSTM perform poorly in the Japanese text feature scatter test, CTPN achieves 0.8 in the scatter test, and our method achieves 0.9 in the scatter test. According to the Japanese text test accuracy level, our method achieves 96% Japanese text detection accuracy and 97% recall, which is better than other algorithms, proving the effectiveness of our method.

For the Japanese voice recognition branch, we set up a separate experimental verification session. Deep neural networks (DNNs) [37] are more widely used in voice recognition. Based on DNNs, some researchers fused hidden Markov models and proposed a DNN-HMM method for voice sequence recognition [38]. This method can effectively handle long sequence voice sequences compared to DNN

TABLE 5: Japanese voice sequence recognition experiment results.

Method	<i>S</i>	<i>P</i> (%)	<i>R</i> (%)
DNN	0.7	81	81
DNN-HMM	0.8	85	86
TDNN	0.8	89	90
Ours	0.9	93	95

methods. Other researchers have proposed the TDNN [39] voice sequence recognition model. The method first performs Fourier transform on the voice sequence and then converts the voice sequence into a signal image, and the output unit directly matches the character results. To validate the accuracy of our method for Japanese voice sequence recognition on public datasets, we test it on ASR datasets and homemade datasets. Our testing criteria are accuracy (Acc), *F1* score, and voice sequence segmentation rate. The experimental results are shown in Table 4.

From the experimental results in the above table, it can be seen that our method achieves 93% accuracy on the Japanese voice sequence public dataset, due to all other methods. The *F1* score also reaches 0.91. This shows the high efficiency of our method. In the production of the homemade dataset, we used the same production process as the ASR dataset, so the experimental results of the homemade dataset and the ASR dataset are not very different. For the Japanese voice sequence recognition efficiency test, we also added the set dispersion test (*S*), precision test (*P*), and recall test (*R*). The experimental results are shown in Table 5.

From the experimental results in the above table, we can see that our method achieves 0.9 in the set dispersion, and the precision and recall remain above 90%, which is better than other algorithms. All previous experimental results fully demonstrate that our proposed hybrid Japanese intelligent recognition system can achieve good accuracy criteria.

5. Conclusion

We propose a hybrid Japanese teaching aid system with multiple information fusion mapping that can effectively improve the efficiency of Japanese language teaching and reduce the cumbersome human teaching procedures. The system is divided into two branches of Japanese language recognition, the Japanese text recognition branch, and the Japanese voice sequence recognition branch. In the Japanese text recognition branch, we integrate attention mechanisms and long short-term memory networks as the basic network for Japanese character text recognition. In addition, we set up separate text feature recognition systems for Japanese computer-written and handwritten characters to prevent the problem of feature overlap. For Japanese voice sequence recognition, we use a combination of memory gating unit and encoder, based on the network still extending the structure of the deep neural network, and using residual structure connection in the gating unit to avoid the gradient disappearance problem. To verify the efficiency of our system, we selected the Japanese text recognition public dataset and voice recognition public dataset for

experimental validation. To match the practical application of the system, we make our dataset according to the dataset standard and perform experimental validation. The experimental results show that our method is significantly better than other methods, and the accuracy and precision are maintained above 90%.

Our hybrid Japanese-assisted teaching system has a special application scenario, so we make our own relevant application Japanese scenario dataset to train the model. Based on the previous experimental results, we can see that our dataset is not perfect and the recognition performance is not accurate enough. In future research, we will further expand the number of homemade datasets and further improve the structural optimization work of the network.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Numerical Simulation of Chemical Storage Tank Area Leakage and Explosion Accident Based on FLACS

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The large amount of oil storage tank possesses significant risks of leakage, and once leakage occurs, the combustible gas is prone to fire and explosion accidents. When the combustible gas cloud is exposed to the ignition source, there are possibilities of triggering the domino effect with more serious consequences. As one important kind of protective layers, the combustible gas detectors continuously monitor the leakage of combustible gas, guaranteeing the safety performance of the site. Using the computational fluid dynamics software FLACS as a tool, the impact of the consequences of the raw material leakage with a vapor cloud explosion accident in a large chemical fiber manufacturer's storage tank area is studied, and the risk of domino effect in the tank area during the course of the accident is predicted. The study shows that FLACS can be applied to the simulation study of gas diffusion explosion phenomenon in complex operation and storage areas, with the great capability of the explosion risk quantitative assessment and the reliable prediction to the risk of domino effects.

1. Introduction

As gasoline is flammable, explosive, and toxic, once it leaks, it may cause waste of resources or fire, explosion, poisoning, and other accidents and even escalate to the domino effect with more serious consequences [1, 2]. Combustible gas detectors as an important layer of protection, its automatic alarm function can quickly determine the location of the leak, prompting staff to take a series of measures to prevent accidents or prevent the escalation of accidents. However, the current setup of combustible gas detectors is generally arranged according to the relevant standard regulations or working experience, and the setup method is too subjective, resulting in poor detection effect. The arrangement of combustible gas detectors should conform to the law of gas diffusion, but the external environmental conditions such as wind direction, wind speed, and temperature, as well as the obstruction of equipment in the tank area make the process

of gas leak diffusion more complicated. The development of information technology [3–7], computational fluid dynamics (CFD) [8–12], and their integration has brought new opportunities to numerical simulation of chemical storage tank area leakage and expansion accident. Therefore, the method based on computational fluid dynamics to simulate the consequences of gas leak diffusion to determine the location of detectors is gradually being used. CFD-based methods for determining the location of detectors are becoming widely used.

2. Analytical Principles and Methods

2.1. Analysis Principle. FLACS is a three-dimensional consequence simulation software based on fluid dynamics (CFD) calculation technology developed and launched by the Norwegian company Gexcon, which is widely used in the simulation of ventilation, leakage, diffusion, fire and

explosion consequences in complex process areas. Nowadays, FLACS software [13, 14] has been verified by many experiments and has shown obvious advantages in oil and gas and process industry applications. FLACS is the only CFD software approved for all LING vapor dispersion scenarios required in the siting of LNG facilities, as described in 49CFR193.2059 of the U.S. Federal regulations. In 2010, FLACS software is used for the first time to study the effect of obstacles and complex geometry on air and vapor flow after flashover of a high-pressure jet and to determine the hazard distance of gas cloud diffusion in a flashover accident. Researchers studied the explosion hazard range of gas clouds from leaking LNG tanks by combining theoretical models, numerical simulations, and experiments and found that the results of gas cloud diffusion in three ways were basically the same when the leakage volume was small [15–17]. In 2019, Wang analyzed the effects of wind direction, wind speed, and weir height on the consequences of LNG gas cloud diffusion by using relative deviation rate and found that within 300 s of leakage, weir height has the greatest effect on the diffusion of gas cloud leakage. In 2019, Qin et al. used CFD software to simulate and calculate the dispersion characteristics of gas clouds of storage tanks under different obstacle conditions, taking the actual storage tanks of receiving stations as the prototype [18]. The relevant studies by these scholars basically confirmed the image laws of wind direction and wind speed and other indicators when using FLACS for the analysis of LNG storage terminal leakage. However, there is still a gap in the study of leak location and obstacles that can also affect the diffusion of LNG storage terminal leaks. Therefore, the research in this paper is based on the research methods of related scholars and complements the two indicators of leakage location and obstacle of LNG storage terminal leakage dispersion.

2.2. Analysis Method. First, this paper will be guided by the principles of fluid dynamics calculation, and FLACS software will be used to solve the Navier-Stokes control equations in a three-dimensional Cartesian coordinate system and perform the task of turbulence processing with the standard $k-\varepsilon$ turbulence model to obtain the flow field changes and chemical reaction processes in a specific region [19]. Second, the CASD preprocessing software is opened by running FLACS RunManager and the geometric model is constructed in Geometry→Database, where the creation of Materials (model colors), Objects (geometric parts), and Geometry (geometric components) is addressed. Finally, the model is validated, and the gas diffusion is visualized with the help of FLACS' post-processor Flowvis, which performs 2D and 3D graphical output of various variables and automates the video generation and data analysis. With the help of Flowvis, a postprocessor of FLACS, it is possible to visualize the gas diffusion, perform 2D and 3D graphic output operations on various variables, and complete the automated video generation, which is of positive significance for the presentation and evaluation of the results [20].

3. Numerical Simulation of Chemical Storage Tank Area Leakage Explosion Accident Based on FLACS

3.1. Theoretical Model. The FLACS explosion model has been validated by full-scale tests and is widely used in the field of natural gas leak explosion [21–23]. FLACS couples turbulence and chemical reactions and establishes the mass, momentum, energy, and component conservation equations describing the fluid characteristics. The finite volume method with boundary conditions is used to solve for the values of variables such as overpressure, combustion products, flame velocity, and fuel consumption in the computational region as follows:

$$\frac{\partial}{\partial t}(\rho\varphi) + \frac{\partial}{\partial x_j}(\mu_j\rho\varphi) + \frac{\partial}{\partial x_j}\left(\Gamma_\varphi\frac{\partial\varphi}{\partial x_j}\right) = S_\varphi, \quad (1)$$

where φ is the generic solution variable (including mass, momentum, energy, and other variables), ρ is the gas density, t is time, and x_j represents the j coordinate position in the direction, μ_j represents the velocity vector in the j direction, Γ_φ is the diffusion coefficient, and S_φ is the source term. The method takes into account the interaction and influence between the flame and obstacles such as equipment and pipes and can be directly calculated for the explosion shock wave. FLACS turbulence model is the standard $k-\varepsilon$ model, which belongs to the two-equation model in the vortex viscosity model, and the transport equation for the turbulent kinetic energy k is as follows:

$$\begin{aligned} \frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho k\mu_j)}{\partial x_j} &= \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] \\ &+ G_k + G_b - \rho\varepsilon - Y_m + S_k. \end{aligned} \quad (2)$$

The transport equation for the dissipation rate ε is as follows:

$$\begin{aligned} \frac{\partial(\rho\varepsilon)}{\partial t} + \frac{\partial(\rho\varepsilon\mu_j)}{\partial x_j} &= \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial\varepsilon}{\partial x_j}\right] \\ &+ C_{1\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon. \end{aligned} \quad (3)$$

In the formula, μ is the laminar viscosity coefficient, and μ_t is the turbulent viscosity coefficient [13].

$$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon}, \quad (4)$$

where G_k is the generation term of turbulent energy k caused by the mean velocity gradient; G_b is the generation term of turbulent energy k caused by buoyancy; Y_m represents the contribution of pulsation expansion in compressible turbulence; σ_k is the Prandtl number corresponding to the turbulent energy k , taken as 1.0; σ_ε is the Prandtl number corresponding to the dissipation rate ε , taken as 1.3; S_k and S_ε are the

user-defined source terms; $C1\varepsilon$, $C2\varepsilon$, $C3\varepsilon$, and $C\mu$ are empirical constants, taken as 1.44, 1.92, 0.80, and 0.09, respectively.

3.2. Simulation Scenario Setting and Geometric Model.

The raw material tank unit of a large chemical fiber production enterprise consists of four vertical vault tanks of the same size, the storage medium is naphtha, the tanks are made of low alloy rigid material, normal temperature and pressure storage, the top of the tank is an internal floating roof with nitrogen seal, and the internal floating disk adopts a secondary seal [24–26]. Single tank volume $V = 20,000 \text{ m}^3$, diameter $D = 38 \text{ m}$, tank height $H = 17 \text{ m}$. The east side of the tank area is equipped with substation room, foam station, sewage tank, and pumping unit. The distance between the tanks is 23 m, the distance between the tanks and the fire embankment (dike) is 9 m, the height of the fire embankment of the whole tank group is 1.8 m. In order to reduce the scope of influence caused by the leakage accident of the tanks in the fire protection, the dike is used to separate the tank group into two partitions, each partition contains two tanks, the height of the fire protection dike is 0.8 m, the design liquid level in the tank area is 1.5 m, and the effective volume of the fire protection of the tank group is $29\,107.31 \text{ m}^3$. The specific arrangement of the tank area is shown in Figure 1.

Using the Flash leak module of FLACS software, assume that the bottom of storage tank T-01A inlet and outlet pipeline leakage, leakage aperture of 100 mm, leakage rate of 243 kg/s, leakage time of 10 s, after the leakage of naphtha in the fire dike to form a liquid pool, set up an ignition source near the side of the corridor, naphtha liquids are volatile liquids, encountering the ignition source is easy to occur after the vapor cloud explosion [27, 28]. Naphtha belongs to the mixture, its main component is alkane C5–C7 components; in the volatile gas, light components dominate.

3.3. Simulation Parameters Setting and Mesh Selection.

The boundary conditions are set to “WIND” and “NOZZLE” in X and Y directions, and “EULER” in Z direction. Monitoring points were set along the leak point+Z direction, and two groups of 14 monitoring points were set on the surface of the tank wall in the storage tank (T-01A)–(T-01D) near the leak area; one monitoring point was set every 25 m on the two sides of the intermediate corridor, and eight monitoring points were set in total; one monitoring point was set on each side of the substation, foam station, sump, and pump room near the storage tank. The monitoring parameters are pressure and temperature [29].

Assume that the atmospheric temperature is 20°C , do not consider the influence of wind direction, the entire simulation space for $200 \text{ m} \times 150 \text{ m} \times 50 \text{ m}$ rectangular, divided into $150 \text{ m} \times 150 \text{ m} \times 45 \text{ m}$ total 1012500 grid for calculation, as shown in Figure 2. FLACS software calculates the gas combustion and explosion motion processes in each cell which are then integrated over all cells. Finally, we get the explosion results for the entire simulation space [30].

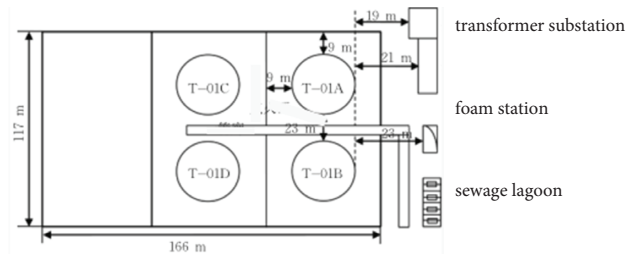


FIGURE 1: Tank area layout diagram.

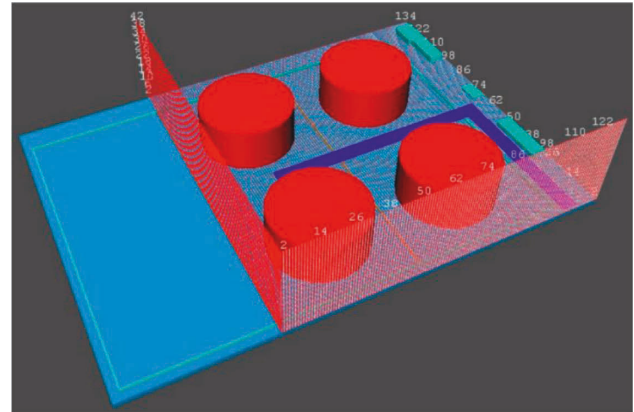


FIGURE 2: FLACS mesh model diagram.

4. Analysis of Simulation Results

4.1. Flame Spread. The XZ cross-sectional diagram is intercepted along the Y-axis to observe the flame propagation law of the leak source after the explosion of the vapor cloud at the ignition source [31, 32]. Figure 3 intercepts the XZ cross-sectional view of the center of the ignition source, the center of the pipe corridor, and the center of each storage tank, respectively. For the development of the flame throughout the leakage process, it can be found that the flame is first generated at the ignition source, and due to the rising effect of heat flow, a certain thickness of flame layer is formed at the upper part of the exploding gas cloud, shaped like a mushroom cloud, with a thin strip in the middle of the flame. The width of the flame can cover the intermediate corridor and leaking tanks, the ignition source as the center of the formation of the fireball diameter of about 20 m, the height of the flame is close to 40 m. The temperature of the outer edge of the flame is lower than the internal temperature, the temperature of the middle layer of the flame is lower than the temperature of the bottom and top, the maximum temperature of the flame can reach more than 2000°C . From the simulation results, the flames did not form direct contact with the three tanks outside the leaking tank.

4.2. Temperature Field Distribution. Figure 4 shows the temperature field distribution on the two sides of the middle corridor. It can be seen that the pipe wall temperature near the ignition source is high, away from the ignition source of the pipe wall temperature is close to the ambient temperature. The temperature of the pipe wall at the center of the

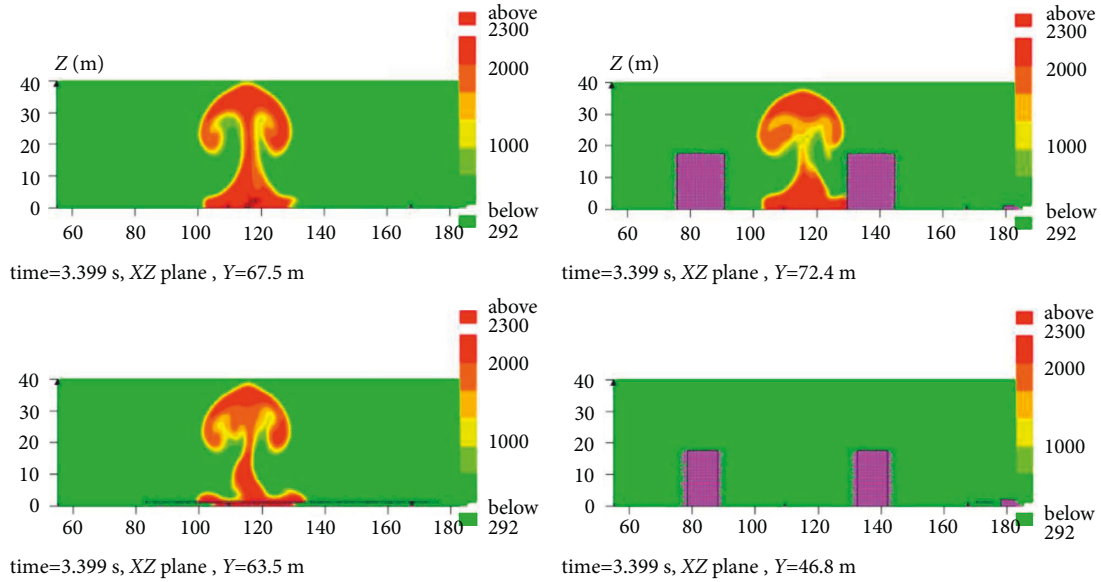


FIGURE 3: Flame development at different positions.

explosion flame is as high as $2,000^{\circ}\text{C}$, and the temperature of the pipe wall at the edge of the explosion flame is about 227°C , and the temperature decreases with the full reaction of the fuel [32–34]. Figure 5 shows the temperature distribution of the surface of the tank wall near the ignition source side of the leaking tank; it can be seen that the temperature of the tank wall did not immediately rise in the instant of the explosion but gradually increased with the development of the explosion flame, the highest temperature reached 4 s after the explosion, the highest temperature reached $2,000^{\circ}\text{C}$, and then with the end of the explosion process, the temperature of the tank wall dropped to about 200°C . From the simulation results, it can be seen that both the leaking storage tank and the intermediate corridor will be affected by the explosion and cause fire, two explosions, and other disaster accidents.

From the distribution of the temperature field on the tank wall surface throughout the leakage process (T-01B)–1000 (T-01D), the temperature of the tank wall is basically maintained at ambient temperature, and at the moment of the explosion due to fluctuations in airflow, the temperature only increased by less than 0.2°C , and then with the full reaction of the fuel, the temperature dropped to ambient temperature again. This is due to the short duration of the explosion, generally in the range of seconds, so the total amount of heat radiation received outside the explosion area is small; the temperature will basically remain near room temperature. However, the high temperature generated by the explosion will cause pool fires, flowing fires, and smoke, and in a long term, flame baking, smoke poisoning, and the impact of two explosions will produce damage and injury to the equipment and facilities outside the explosion area [35].

4.3. Pressure Field Distribution. From the simulation results, it can be found that the explosion generated the maximum overpressure of 2.9 kPa than the overpressure damage

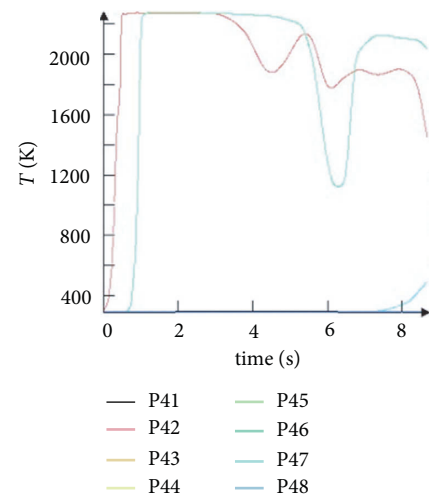


FIGURE 4: Temperature field distribution diagram on both sides of the middle pipe gallery.

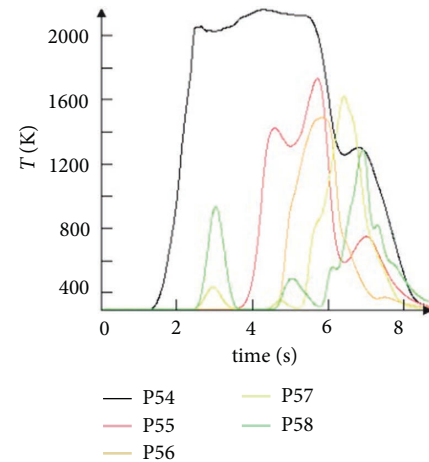


FIGURE 5: Temperature field distribution diagram on the tank wall on one side of the leakage storage tank near the fire source.

guidelines for minor damage overpressure value of 3.5 kPa is lower, so there will be no damage to neighboring buildings and structures.

5. Chemical Enterprise Storage Tank Area Leakage Explosion Emergency Management Problems and Optimization Measures

5.1. Analysis of the Problems of Emergency Management of Leaking and Exploding Storage Tank Areas in Chemical Enterprises (as Appropriate). Combining literature research, case law, and field visits to petrochemical enterprises, it is found that the following problems generally exist in the construction of emergency management in enterprises.

5.1.1. Low Importance of Emergency Management Deployment in the Top-Level Design of Enterprises. The development of enterprises depends on the top-level design to a great extent, especially for the construction of emergency management. Whether the person in charge of the enterprise can clearly understand the emergency culture, its connotation, and whether this emergency idea can be penetrated into the construction of the enterprise and implemented to the extent that all work is carried out around “safety first” and “preparedness,” focusing on “It has a fatal impact on whether the enterprise can eliminate possible hazards in time and whether it can take active measures to implement rescue after the accident” [36].

5.1.2. Backward Early Warning Technology, Early Warning Processing Is Not in Place. Early warning as the most scientific and timely technical means of releasing danger signals is the “most important information” before the incident. If we can pay attention to and take active and effective preventive and control measures, we can completely avoid the occurrence of the incident. The advanced early warning technology, the normal operation of the early warning platform, the professionalism of the early warning information processing and integration staff, and many other factors will affect the attitude and treatment of the “signs.” The data of typical major production safety accidents show that a large proportion of enterprises ignore the construction and use of safety monitoring systems and lack the awareness of intelligent early warning platforms to guide practical work.

5.1.3. Emergency Plans Are “Poorly Grounded.” The emergency plan is a guiding document for enterprises to start emergency response and carry out emergency rescue operations in the face of emergencies, and its importance is self-evident. However, at present, most enterprises’ emergency plans are entrusted to third-party safety intermediary service agencies for preparation. Looking at the plan, there are many problems in the preparation process, for example, whether the preparation process is based on a comprehensive assessment of the enterprise’s hazardous and

harmful factors, for the enterprise’s special emergency plan, whether it is combined with the actual objective situation of the enterprise, is the more dangerous accident to unfold; for different response levels, whether the enterprise’s rescue forces and rescue materials are true, and for different linkage collaboration departments, whether there is relevant communication.

5.1.4. Lack of Emergency Supplies Reserve. In other words, the proportion of emergency material reserve can also show the attention and importance of enterprises to the construction of emergency business to a certain extent. In addition, the emergency funds are not always executed as planned from time to time due to the lack of understanding to the safety and emergency management. This has led to the emergency supplies have been in the satisfaction of helmets, safety ropes, fire extinguishers, fire blankets, protective clothing and other simple items, while new, high technology emergency items are always “on the road.” The construction of emergency teams is also limited to the internal strength of the enterprise [37].

5.1.5. Most of the Emergency Drills Are “Floating in the Form,” With Poor Effect. According to the “Production Safety Accident Emergency Management Measures,” enterprises are required to conduct emergency drills for the corresponding emergency rescue plans. This makes enterprises carry out emergency drills according to the actual situation. However, the following problems exist in the process of drills: first, weak emergency awareness and improper attitude of drills; second, multidepartmental and multiparticipant collaborative drills. A large part of the forces are not familiar with the content of the emergency plan, the purpose of the drill is not clear, for what each should do, how to cooperate and other issues are not clear. The drill becomes a walk-through: the main party of the emergency drill is on the problems and technical shortcomings. The main parties of emergency drills are still stuck on “paper” for problems, technical shortcomings, and poor linkage mechanism and fail to solve and revise the plan in a targeted way after the drills are over, which leave hidden dangers for “real combat.”

5.1.6. Little Audience for Emergency Publicity. Emergency work concerns everyone, and many enterprises confine emergency propaganda and emergency work to emergency organizations, which is not a comprehensive understanding. In the face of a major disaster rescue, in addition to the emergency leadership group, command group, professional emergency teams, and so on, play a major role, each individual in the affected area has the necessary knowledge of certain emergency to carry out self-help and call for help; this contribution is immeasurable; in front of the accident, all people will be involved in the “community of fate.” A small step by anyone can save the whole situation.

5.2. Emergency Management Measures for Chemical Enterprises to Prevent Leakage and Explosion in Storage Tank Areas. Combining the current problems in the construction of emergency management in enterprises, this paper puts forward the following suggestions.

5.2.1. Strengthen Emergency Management Training for Leaders at All Levels and Relevant Personnel. Each enterprise should carry out emergency management training in batches and at different levels. Combined with the emergency training audience, the training purpose should be clear and the training content targeted. For enterprise senior managers, the training would focus on topics related to the emergency management leadership and awareness to ensure the establishment of mature emergency management system. On the other hand, emergency rescue forces would improve their fire fighting skills, hazardous environment detection, decision-making, and response abilities by various training.

5.2.2. Pay Attention to the Preparation of Emergency Plans and the Effectiveness of the Implementation of Emergency Drills. The preparation and implementation of the emergency plan plays a key role in guiding the whole emergency rescue and disposal [38]. The preparation of the plan must comply with the objective facts on the basis of the full identification of enterprise risks and targeted emergency response. As a part of emergency plan preparation, the communication of the plan by brainstorming with expertise including the purpose, content, applicable scenarios, and cautions during rescue activities is also important to identify potential improvement for the plan. The plan can be improved and revised to ensure its operability.

5.2.3. Focus on Intelligent Construction to Provide Scientific Decision-Making. Strengthen the investment in intelligent construction of enterprises, introduce and integrate advanced technology as far as possible on the basis of budget, strengthen digital management, and provide a broader world for early warning and intelligent decision-making.

6. Conclusion

Compared with other numerical simulation software, FLACS software for complex explosion scenes and explosion propagation flame description more detailed, making the simulation results more realistic and accurate, and can be risk assessment results in the form of graphs and charts to express intuitively; in addition, the use of FLACS simulation technology for quantitative analysis of the domino effect in the process of accident expansion can effectively improve the accident near-field area. In addition, the quantitative analysis of the domino effect in the accident expansion process by using FLACS simulation technology can effectively improve the efficiency and accuracy of risk assessment of key equipment units in the near-field area.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Using Spectral Clustering Association Algorithm upon Teaching Big Data for Precise Education

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With the continuous deepening of the application of educational OA, massive educational data has been produced. Hence, the application of teaching big data (TBD) has a certain theoretical basis, practical methods, and research methods in the field of education. How to fully play the leading role of education on TBD in professional education, guide and recommend students to carry out personalized learning, change the teaching mode, enrich the teaching evaluation, then further improve the quality of talent training is a current issue, which has yet to be solved. Based on the analysis and mining of big data, this paper uses the spectral clustering algorithm to construct the curriculum association classification model and realizes the clustering of core courses. Then, through the analysis of the academic achievements of previous professional core courses, we can master the current situation of students' learning, construct the model as the portrait of students' individual, curriculum, and professional characteristics through deep learning, so as to realize the precise referral of personalized learning courses, provide students with targeted academic guidance, and further dynamically adjust the teaching syllabus, including the teaching methods and teaching means. Vice versa, we can improve the core courses clustering to further feedback on the curriculum association classification model by analyzing the job position technical requirements. Experiments show that the proposed model using a spectrum clustering algorithm could be better provided strong technical support for the decision-making of precision education in colleges and universities.

1. Introduction

Nowadays, with the wide spread and application of the big data concept, its connotation is constantly evolving and extending. People are gradually realizing that big data is not only a kind of technology but also a kind of ability, such as the to find meaningful associations from massive and complex data, mine the changing rules of things, and accurately predicting the development trend of things. In addition, big data is also a way of thinking; it can let data speak, and let data become the basic starting point of human thinking and decision-making behavior. However, TBD refers to the data set generated in the whole process of educational activities and collected according to the needs of education, which can be used for the development of education and create great potential value [1]. TBD has a clear

goal orientation, that is, to the development of education. It can play an effective role in improving the quality of education, promoting educational equity, realizing personalized learning, optimizing the allocation of educational resources, and assisting scientific decision-making of education [2, 3]. The ultimate value of big data should be reflected in the deep integration with the mainstream business of education and the continuous promotion of the intelligent reform of the education system [4, 5]. At present, there are some innovative application cases of education big data at home and abroad, covering teaching, management, evaluation, service, and other fields [6–8]. With the support of TBD, upon the mining and analysis of students' teaching data, we can more accurately predict learners' action trajectory, and then, effectively support students' personalized adaptive learning, which is the key to realize precision education [9]. As early as

the 1990s, some scholars studied the referral service. With the continuous development and improvement of the referral algorithm, Resnick, and others proposed the concept of personalized referral, and personalized referral service is respected [10]. It was first used in the commercial field, mainly represented by American business giants such as Amazon and Walmart. It collects relevant data from users, calculates the similarity of various goods, and connects users with goods through the referral algorithm, which greatly improves the personalized and commercial level of the referral service. With the continuous application of computer technology, there are many information referral systems in different fields, such as web watcher, Lira, Letizia, and other personalized referral systems [11]. The application of personalized referral services in the field of education has gradually developed. For example, the e-learning system supported by online course resources [12], or the learning resources provided according to the dynamic progress of students [13], and the e-book Package based on the information of learners' personal, preference, academic, performance, and so on [14]. TBD covers the knowledge of educational data mining and learning analytics [15, 16]. However, in precision teaching, in addition to promotion services, the learning effects are also a part that we must pay attention to, so the early warning of academic performance based on teaching big data is also the focus of this research. When it comes to academic achievement early warning, is naturally related to data mining and analysis. TBD [17], whether it involves students or teaching managers, should focus on finding hidden valuable information [18], so as to provide effective guidance for future teaching activities, which is of great significance. Academic early warning is an important means for colleges and universities to strengthen students' learning management and improve the level of education and teaching management. Similarly, in the 1990s, many foreign universities used students' academic achievement as the data source for academic early warning [19]. In China, it started relatively late to predict and explain the learning performance with academic risk through the first semester scores and college entrance examination scores, so as to help implement academic early warning [20]. However, the mechanism and method of early warning are relatively simple, and once problems are found, we are unable to solve them timely with an effective response [21]. Therefore, based on the score data of software majors in a certain school, this paper focuses on the three aspects of teaching quality and establishes the school's running orientation and quality objectives in line with the actual situation of the school in order to meet the needs of economic and social development and students' personal development [22].

Specifically, implementing precise teaching referral, for students, mainly includes precise referral of students' chosen courses and precise warning of great academic fluctuations. The core of precise teaching referral is a precise prediction of student-course achievement to get professional referral courses. Through the multidimensional teaching quality evaluation model, we can adjust the professional courses. Considering that the student courses' score is a

comprehensive problem involving all aspects, in which the more complex curriculum factors include: syllabus, teaching focus, and assessment difficulties, etc., and some other accidental factors, such as whether the examination is good or not. Therefore, it is a challenging issue to precisely predict student-course achievement and professional course referral. In the process of solving this problem, this paper focuses on solving the following key technical problems, as shown in Figure 1: refining the professional portrait, core curriculum portrait, and students' personal portrait; constructing a curriculum association classification model to complete the correlation measurement between various professional courses and job positions; modeling the similarity of student achievement distribution; and multidimensional constructing and improving precise courses referral. On the whole, the work of this paper includes:

- (1) To construct a frequent pattern spectral clustering classification model of professional core courses.
- (2) To study the potential relationship between professional courses, the characteristic model of students' individual, curriculum, and a professional portrait, and to use the deep learning method to train the same professional achievements in the past, so as to realize the prediction of the related curriculum achievements between the lower grade and the higher grade. We should give early warning of the courses that may be difficult and guide teachers to provide targeted guidance to students.
- (3) To build a multidimensional precise referral of teaching course, dynamic adjustment to guide teachers in the adjustment of the syllabus, teaching methods, and teaching means.

2. Theoretical Methods

2.1. Spectral Clustering Algorithm. Spectral clustering is a dimensionality reduction clustering method based on graph theory, which has a smaller calculation amount, is easy to implement, and is good at processing high-dimensional data [23]. Generally speaking, the difficulty of extracting professional portraits from the syllabus and training plan with complex structure lies in the description of the complex structure of the professional training plan, especially from the professional plan to the curriculum. We can use frequent pattern spectral clustering to classify courses and determine the weight proportion of professional courses. According to the feedback effect of the teaching quality evaluation, the professional courses should be adjusted appropriately. Therefore, we must further obtain the job skills required by the Internet through crawlers and determine the curriculum system to support such skills. The spectral clustering algorithm is used to construct the relationship between job position skills and professional core courses.

Spectral clustering (SC) is a clustering method based on graph theory, which divides the weighted undirected graphs into two or more optimal subgraphs to make the subgraphs as similar as possible and the distance between subgraphs as far as possible, so as to achieve the purpose of common

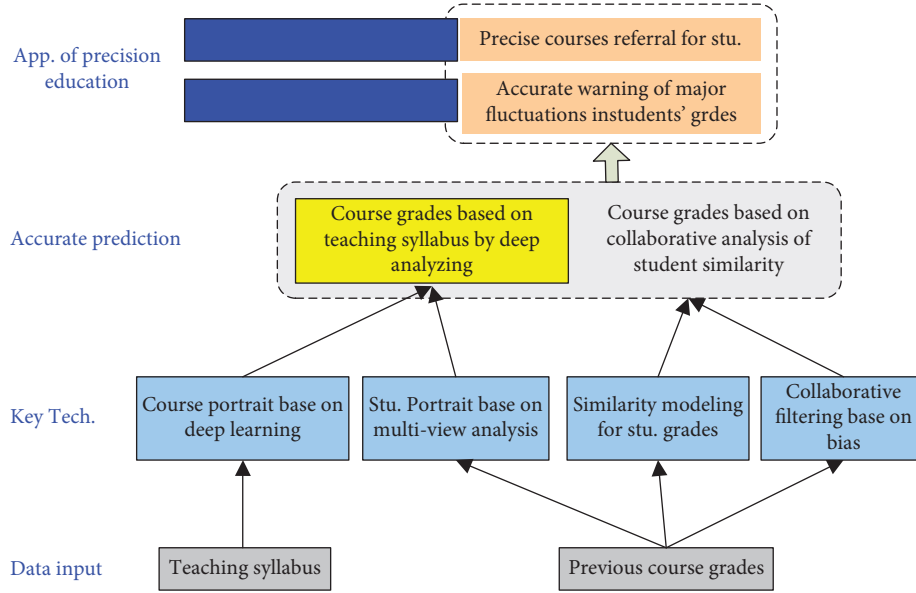


FIGURE 1: Flow of accurate prediction for precision education.

clustering. Among them, the best means that the optimal objectives function is different. It can be the smallest cut and the best cut of the cut edge, such as the normalized cut in Figure 2.

In this way, spectral clustering can identify any shape of sample space and converge to the global optimal solution. The basic idea is to use the feature vectors obtained from the feature decomposition of the sample data similarity matrix (Laplace matrix) to cluster. For the space vector and item-user matrix, see Table 1.

Now, according to Figure 3(a), we can calculate the similarity between items, and then we can get a similarity matrix with only items. Furthermore, we regard items as vertex (V) in the graph (G), and the similarity between items as an edge (E) in g . In this way, we can get our common concept of the graph. Then we get the adjacency matrix e as shown in Figure 3(b), where e_{ij} represents the weights of VI and the edges of VI , e is a symmetric matrix, and the elements on the diagonal are 0. Thus, the Laplacian matrix as shown in Figure 3(c) is obtained: $l = D - e$, where d_i (the sum of row or column elements).

First, consider an optimal image segmentation method. Take bisection as an example, divide the graph into S and T parts, which is equivalent to the following loss function cut (s, t), as shown in formula (1), that is, the minimum (weighted sum of cut edges).

$$\text{cut}(S, T) = \sum_{i \in S, j \in T} e_{ij}, \quad (1)$$

$$q = [q_1, q_2, \dots, q_n]^T, \quad (2)$$

$$q = \begin{cases} C_1, & i \in S, \\ C_2, & i \in T. \end{cases} \quad (3)$$

Suppose that the two categories are divided, S and T , and Q as shown in formula (2) is used to represent the

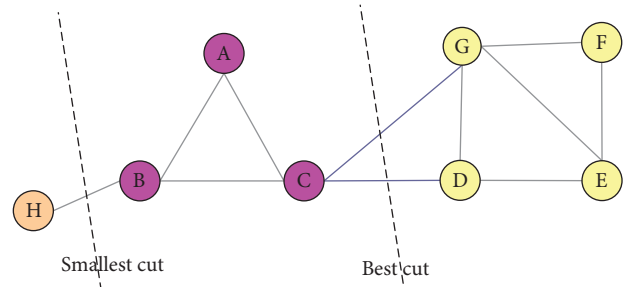


FIGURE 2: Spectral clustering for undirected graph division.

TABLE 1: Item-user matrix for space vector.

	User 1	User 2	...	User m
Item 1	W_{11}	W_{12}	...	W_{1m}
Item 2	W_{21}	W_{22}	...	W_{2m}
...
Item n	W_{n1}	W_{n2}	...	W_{nm}

classification, and Q satisfies the relationship of formula (3) used for class identification.

$$\text{cut}(S, T) = \sum_{i \in S, j \in T} e_{ij} = \frac{\sum_{i=1}^n \sum_{j=1}^n e_{ij} (q_i - q_j)^2}{2(c_1 - c_2)^2}, \quad (4)$$

where,

$$\begin{aligned} \sum_{i=1}^n \sum_{j=1}^n e_{ij} (q_i - q_j)^2 &= \sum_{i=1}^n \sum_{j=1}^n e_{ij} (q_i^2 - 2q_i q_j + q_j^2) \\ &= \sum_{i=1}^n \sum_{j=1}^n -2q_i q_j e_{ij} + \sum_{i=1}^n q_i^2 \left(\sum_{j=1}^n e_{ij} \right) \\ &= 2q^T (D - E)q = 2q^T Lq, \end{aligned} \quad (5)$$

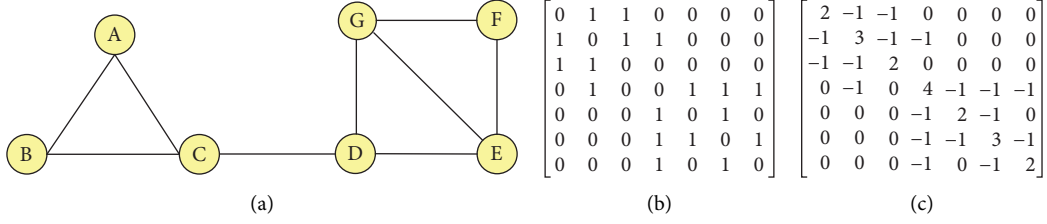


FIGURE 3: Representation of graphs. (a) Undirected graph. (b) Adjacency matrix. (c) L -matrix.

Where D is the sum of row or column elements in the diagonal matrix, and L is the Laplacian matrix. From formula (5):

$$q^T L q = \frac{1}{2} \left(\sum_{i=1}^n \sum_{j=1}^n e_{ij} (q_i - q_j)^2 \right), \quad (6)$$

$$q^T q = n.$$

We have,

- (a) L is a symmetric positive semidefinite matrix, which guarantees that all eigenvalues are greater than or equal to 0;
- (b) L -matrix has a unique 0 eigenvalue and its corresponding eigenvector is 1.

2.2. Similarity Calculation of Professional Core Courses. According to PCC (Pearson's correlation coefficient), within the given threshold range, the calculation of PCC between previous students' academic achievement and current students' academic achievement is to realize the curriculum referral and early warning of academic achievement, as well as the job referral. PCC is widely used to measure the degree of correlation between two variables, and its value ranges from -1 to 1. It evolved from a similar but slightly different idea, put forward by Francis Galton in the 1880s by Carl Pearson. This correlation coefficient is also called the Pearson product-moment correlation coefficient.

PCC between two variables is defined as the quotient of covariance and standard deviation between two variables. We have,

$$\rho_{X,Y} = \frac{\text{cov}(X, Y)}{\sigma_X \sigma_Y} = \frac{E[(X - \mu_X)(Y - \mu_Y)]}{\sigma_X \sigma_Y}. \quad (7)$$

The above formula defines the overall correlation coefficient, which is usually represented by the Greek small letter ρ . PCC can be obtained by estimating the covariance and standard deviation of the sample, which is usually expressed by the letter r .

$$r = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^n (X_i - \bar{X})^2} \sqrt{\sum_{i=1}^n (Y_i - \bar{Y})^2}} \quad (8)$$

Similarly, it can be estimated from the mean value of the standard fraction of (x, y) sample points to obtain the equivalent expression of the above formula.

$$r = \frac{1}{n-1} \sum_{i=1}^n \left(\frac{X_i - \bar{X}}{\sigma_X} \right) \left(\frac{Y_i - \bar{Y}}{\sigma_Y} \right), \quad (9)$$

Where $(X_i - \bar{X}/\sigma_X)$, \bar{X} and σ_X are the standard fraction of sample points X_i , the mean value and standard deviation, respectively.

3. Proposed Models

Considering that the spectral clustering algorithm is the method of dimensional reduction, it is more suitable for high-dimensional data processing and does not need to consider the shape of the sample space. The algorithm only needs to calculate the similarity matrix between the data sets to achieve clustering. Compared with the traditional clustering method, it is more efficient in dealing with the high-dimensional and sparse matrix of university curriculum scores.

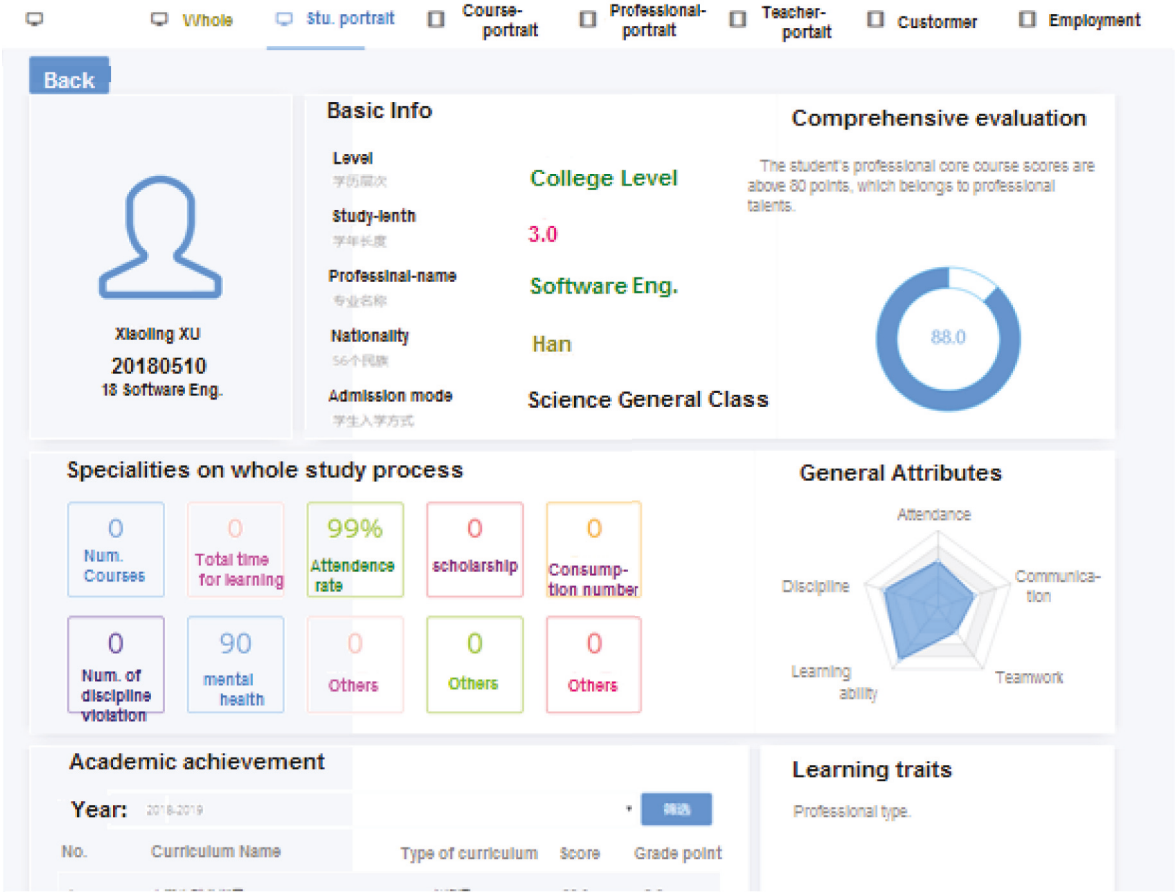
In order to realize the spectral clustering algorithm of course grades, first, the undirected weight graph based on similarity metrics is constructed. Then the graph is divided into different subgraphs according to the trimming rules, and finally to realize clustering. The clustering algorithm is described as follows:

4. Testing and Experiments

In Python, we developed a big data visual platform for the overall overview of the college of computer science, and our experiments are conducted on a server with an Intel Core5i@1600HZ and 16 GB of memory. The platform is as shown in Figures 4(a)–4(c), which includes student portraits, teacher portraits, professional portraits, and so on. Also we took the academic achievement from TBD as an example to analyze the personalized learning, to implement precise teaching referral and precise warning of great academic fluctuations. Therefore, we studied the relationship between student attributes and job positions, and mined the association rules of student groups, namely feature vectors [24]. Herein, let the feature vectors be the basis of student clustering. According to the attribute value of historic achievement, assume that the E.Score or Re.score divided into 5 levels, more than 90 is 'A', range from 80 to 90 is 'B', 70 to 80 is 'C', 60 to 70 is 'D', and less than 60 is 'E'. We generalize the values of each attribute for historic achievement, as shown in Table 2, technical capability on job position got from web mining in Table 3, and a sample of employment historic data in Table 4.

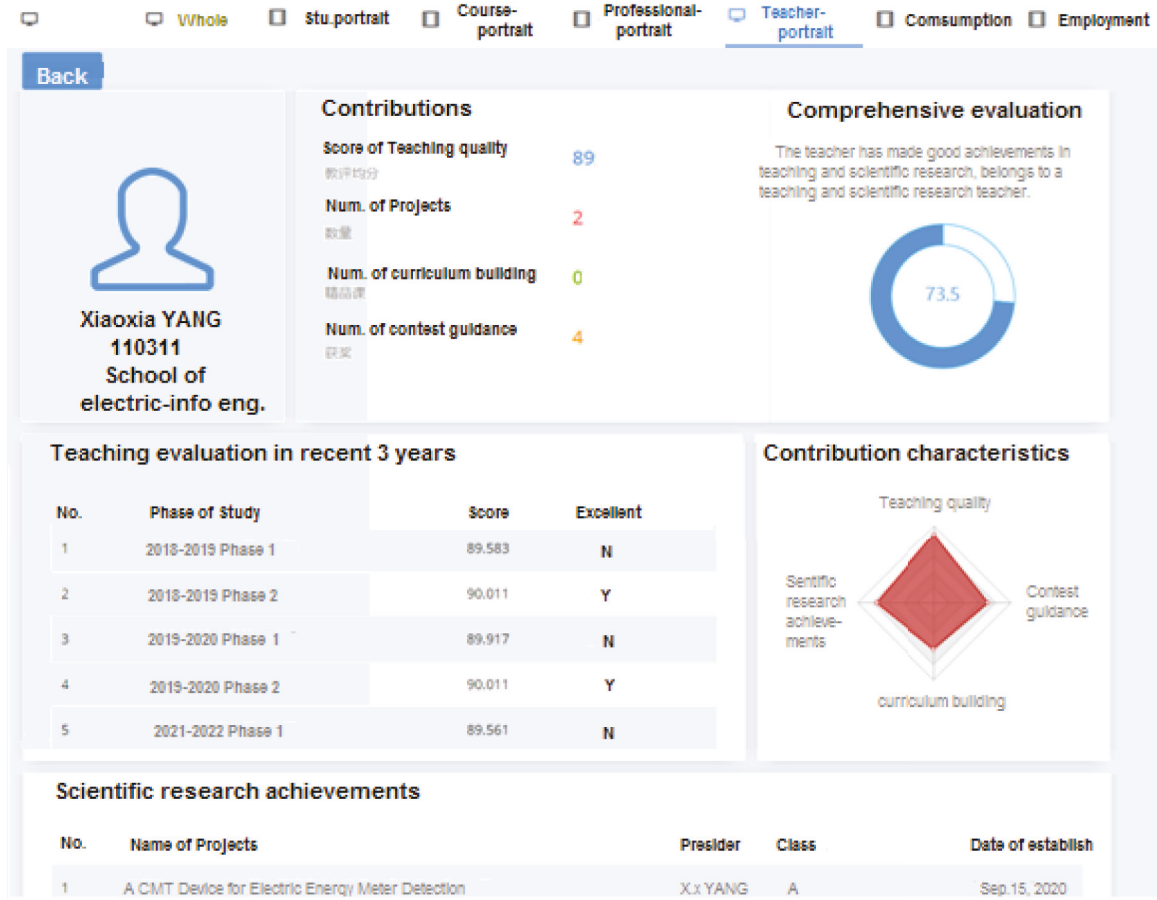


(a)



(b)

FIGURE 4: Continued.



(c)

FIGURE 4: Big data analysis and visualization platform for college of CS. (a) Outline of big data visualization platform. (b) Portraits of personal data analysis for student. (c) Portraits of personal data analysis for teacher.

There are two kinds of courses: compulsory and optional. More specifically, compulsory courses include some professional basic courses and professional core courses. Therefore, as far as computer-related professional majors are concerned, job skills needs should pay more attention to the professional core courses. Now, assuming that the core courses of job requirements have been mined from the external recruitment website, we can calculate the correlation degree between the job and these courses by PCC according to the professional core courses. In this way, we can regard each course as a vertex and the correlation between courses as weighted edges. Spectral clustering uses the graph segmentation method to divide the weighted undirected graph of all courses into several optimal subgraphs so that the weight of edges connecting different courses is as low as possible, and the weight of edges connecting the same courses is as high as possible. Table 5 is an example of a core curriculum set for technical capability in a job positions. Therefore, let the min-support threshold and credibility be 0.1, respectively, and the undirected graph of spectral clustering is built as Figure 5.

From Figure 4, we can see the clustering results of professional core courses are constructed by the spectral

clustering algorithm. Now, taking the above Table 2 as an example, there are four types of job positions, which need to possess the related professional courses. To calculate the distribution between job positions and the professional courses by formula (1), we adjusted the core courses of the major specified in the training program, such as increasing or reducing the existing courses.

$$H(P) = - \sum_{i=0}^m p_i \log p_i. \quad (10)$$

Among them, p_i represents the distribution of professional courses. Figure 6 describes the distribution of job positions' intervals, and courses are divided into first intervals, indicating that such courses mainly belong to the first type of job positions, and so on.

For the purpose of validation of the professional core courses, we can calculate the correlation by PCCs for different job positions, choose the maximum value for the core courses according to the final result, and subsequently adjust the professional courses for the training program. Figure 7 shows the referral process for professional core courses for learners.

TABLE 2: Sample of historic achievement.

StuNo	Name	Sem.-year	Sem	M.ID	Major	C.No	E.Score	Re.Score	C.Char	S.Num/P
019120801	Q.H W	2014–2015	1	1109	ST.	C1	D		Comp	0.5/1.5
2019100802	Z.Z	2017–2018	1	1107	CS.	C2	C		Opt.C	2.0/3.0
2019130801	Y.F Zh	2018–2019	2	1108	NT.	C3		D	Comp	0.5/1.5
2019100802	Q.H W	2018–2019	1	1107	CS.	C2		A	Comp	0.5/1.5
2019120801	Z.W	2017–2018	2	1109	NS.	C2		B	Opt.C	2.0/3.0

TABLE 3: Sample of technical capability on job position.

J-position	Course1	Course2	Course3	Course4	Course5	Course6	Course7	Memo
Web.Dev	C1	C2	C3	C6	C7	C5	C10	
Arm.Dev	C1	C2	C3	C5	C8	C11	C15	
Net.Eng	C1	C2	C4	C6	C9	C10	C13	
Net.Secu	C1	C2	C4	C7	C9	C10	C16	

TABLE 4: Sample of employment historic data.

StuNo	Name	Grad.Y	Emp/Stu.	Major	Corp./Sch	City	Salary	Memo
2014120812	Q.H W	2016	Emp	NT.	N.Grid.C	HY	4000.0	
2014120802	Z.Z	2018	Stu	CS.	PKU.	PK	0.0	
2014120826	Y.F Zh	2020	Emp	ST.	IBM	SZ	12000.0	

TABLE 5: Sample of core curriculum for differ major.

StuNo	Major	Curriculums
2019120801	ST.	{C1, C2, C3, C6, C7, C10, C15}
2019120802	ST.	{C1, C2, C3, C6, C8, C10, C12}
2019130801	NT.	{C1, C2, C3, C5, C8, C11, C14}
2019120803	ST.	{C1, C2, C3, C5, C7, C10, C15}
2019130801	NS.	{C1, C2, C3, C5, C8, C11, C15}
2019100801	CS.	{C1, C2, C3, C7, C11, C13, C16}
2019100802	CS.	{C1, C2, C3, C7, C9, C13, C16}

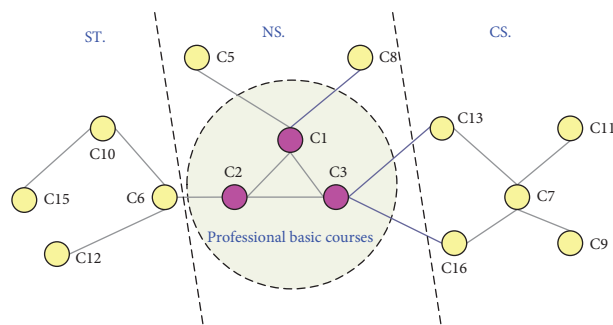


FIGURE 5: Minicut of professional core courses.

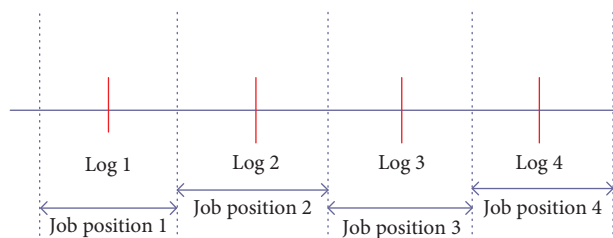


FIGURE 6: The distribution of job positions' intervals.

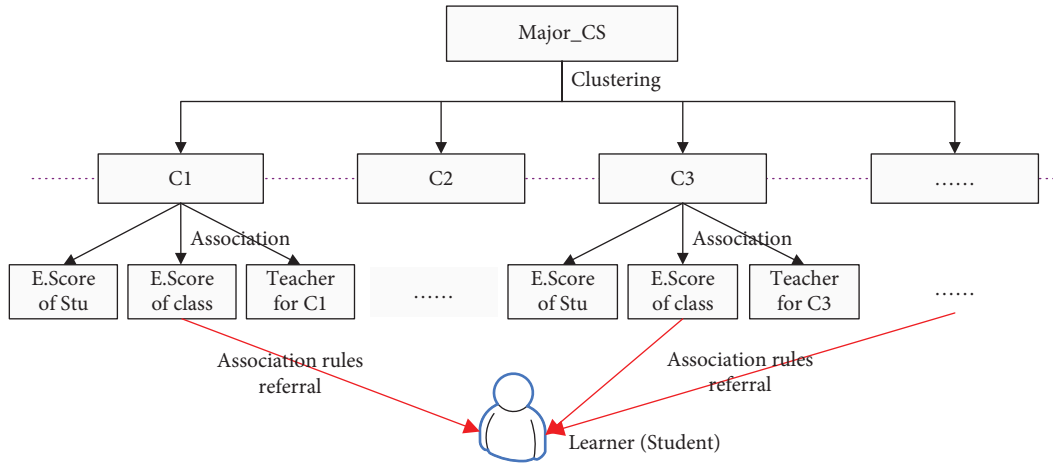


FIGURE 7: The referral process upon professional core courses for learner.

TABLE 6: PPC of the historic score in each course between previous and fresher students.

	C1.S	C2.S	C3.S	C4.S	C5.S	C6.S
Avg.	72	65	78	66	74	76
S.E.	3.5	2.0	6.0	2.5	5.0	3.5
Med.N	70	67	79	68	76	78
Mode	72.5	68	80	70	78	80
Std.D	3.087	5.026	3.615	5.263	5.033	5.031
Vari.	9.5	8.4	7.2	8.5	8.47	8.42
Max.V	92	86	95	89	92	90
Min.V	44	37	47	32	23	34

Generally speaking, we can predict the course performance of the new students and recommend the course to realize personalized learning or calculate the pass rate of the course according to the grade performance of the previous students, so as to realize the adjustment of teachers or syllabus.

In order to qualitatively analyze the similarity between students, due to the uncertainty of the two group data dimensions, PCC can be calculated according to the historical scores of a student in the last term and the current students' scores to measure the similarity of their learning characteristics.

In general, to use the Pearson correlation coefficient, it is necessary to determine whether two variables are linearly correlated. In other words, the Pearson correlation coefficient can explain the degree of linear correlation between variables. If it is not clear whether it is a linear relationship, PCC is meaningless. If PCC equals 0, it is unable to show that the two variables are not related, and it may meet a more complex relationship. Therefore, before using the Pearson correlation coefficient, it is suggested to draw a scatter diagram to roughly judge whether the overall linear relationship between the two variables is reflected.

Assume that the scores of six major core courses are extracted, the two groups of data are calculated first, and their linear correlation is then obtained. Then, the PCC is calculated. The value range is $[-1,1]$, the greater the absolute value of the correlation coefficient, the more significant the correlation is, and the positive and negative correlation are respectively expressed by positive and negative values.

From Table 6, we can see that most data do not satisfy a linear relationship, but we still should calculate the correlation coefficient. All individuals are used to calculate the overall Pearson correlation coefficient directly. We can use Matlab to analyze and summarize the statistics into a matrix. Figure 8 shows the distribution trend of scores and employment between a previous and newer student. The Std.D with Avg scores could satisfy the function relationship of a normal distribution with courses therefore it is in the line with the expectations of the teaching law, see Figure 8(a). Careful observation shows that there is a certain linear relationship between the average score and the correlation rate of professional employment, see Figure 8(b).

The following matrix reflects the PCC for students' scores between ranks.

$$\begin{matrix}
 1.0000 & 0.0556 & -0.3217 & 0.0546 & -0.2192 & 0.0945 \\
 0.0556 & 1.00000 & 0.0864 & 0.0316 & 0.0675 & -0.0719 \\
 -0.3217 & 0.0864 & 1.0000 & 0.0348 & 0.0316 & -0.0216 \\
 0.0546 & 0.0316 & 0.0349 & 1.0000 & -0.0462 & -0.0037 \\
 -0.2192 & 0.0675 & 0.0316 & -0.0462 & 1.0000 & -0.0214 \\
 0.0945 & -0.0719 & -0.0216 & -0.0037 & -0.0214 & 1.0000
 \end{matrix} \quad (11)$$

Through PPC calculation, we can predict professional scores with previous students' scores as individual students, course referrals, and job positions for every portrait model.

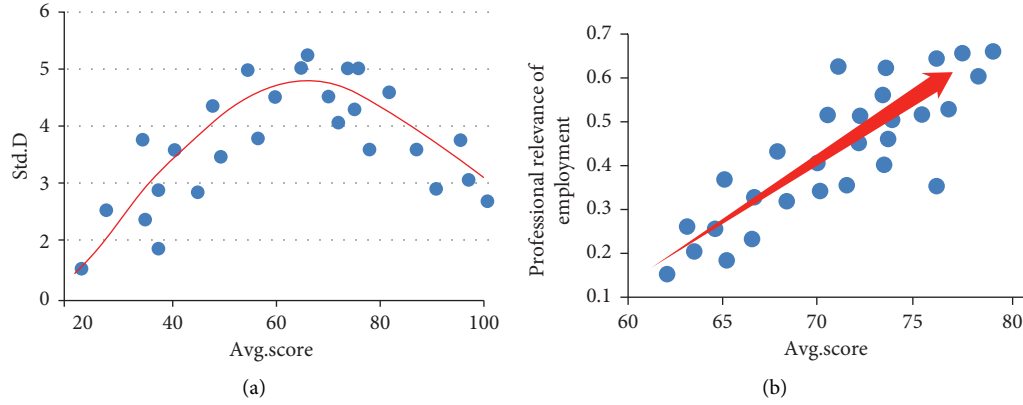


FIGURE 8: The distribution trend between previous and fresher students. (a) Std.D with Avg scores (b) Professional relevance with Avg scores.

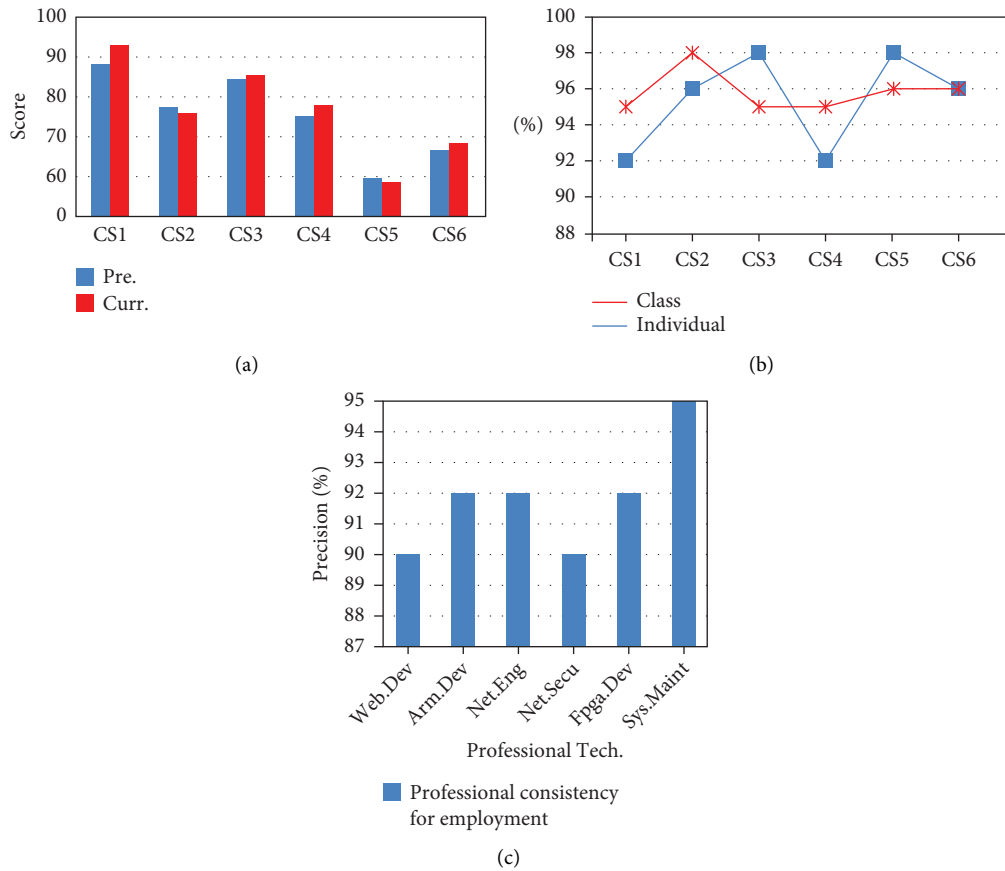


FIGURE 9: Precision, score and professional consistency for position of prediction. (a) Prediction of scores for individual (b) Precision of prediction on individual-class. (c) Precision of prediction on professional consistency for position.

Figure 8 shows the precision and score of prediction on individual-class. According to the previous student's scores, the current score of every course is the same as prediction, see Figure 9(a). Also, we can see the precision of the individual and average score in a class for one course keep the high level, see Figure 9(b). According to the scores, the prediction of professional consistency for the position was seen in Figure 9(c). The main reason is that professional technology is decided by many courses, especially since the

technical content is relatively high, such as the course on network security.

5. Conclusions

To establish the internal quality management platform in colleges or universities, implementing teaching quality evaluation and rectification systems helps meet the practical needs of the separation of management, operation and

evaluation, and the transformation of functions of educational administrative departments. It also helps meet the need for vocational education to actively adapt to the new economic development, independently guarantee quality, and enhance core competitiveness. Therefore, the analysis of the data of graduating and employed graduates can directly reflect whether the teaching, decision-making, and management can meet the skill requirements of the new era.

In general, the evaluation and improvement of the teaching quality assurance system must adhere to the concept of total quality management, focus on playing the main role of quality, implement all staff, all process, and all factor evaluation and improvement, integrate the preplanning, in-process monitoring, and postimprovement, and establish a normalized information feedback analysis and improvement mechanism. Finally, the quality assurance system and working mechanism of three-year complete education programed are established.

In future work, we will devote time to improve the predict accuracy and efficiency, optimize the curriculum association classification model. Moreover, there are still several unsolved problems. The key point of the predicted accuracy mentioned here is that it is related to the accuracy of the portraits of students' individuals, curriculum and professional portraits, and the similarity of technical requirements of positions mined from the Internet. Of course, besides that, the accuracy of the proposed model is also related to the continuous correction of the feedback model. Hence, the universal consistency between the individual and the whole for precision teaching service is a direction of our efforts in the future.

Data Availability

The data used to support the findings of this study have not been made available because of student and teachers' private datasets including their ID and achievements.

Disclosure

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Retraction

Retracted: Analysis of the Factors Influencing the Adaptability of College English Learning Based on Artificial Intelligence Teaching Assistance

Mathematical Problems in Engineering

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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] L. Cao and S. Zhu, "Analysis of the Factors Influencing the Adaptability of College English Learning Based on Artificial Intelligence Teaching Assistance," *Mathematical Problems in Engineering*, vol. 2022, Article ID 8543492, 9 pages, 2022.

Research Article

Analysis of the Factors Influencing the Adaptability of College English Learning Based on Artificial Intelligence Teaching Assistance

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Good learning adaptability is the key to ensure students' learning quality. Learning maladjustment not only affects students' learning effect but also affects the effectiveness of AI-enabled English learning. Although some studies have found that there is a certain degree of poor learning adaptability in the practice of artificial intelligence (AI) supporting English teaching, most studies only describe the phenomenon and do not further explore the causes of poor learning adaptability. Therefore, the research intends to understand the current situation of college students' English learning adaptability under the support of AI through the investigation and analysis of college students' English learning adaptability under the support of AI and clarifies the impact of various influencing factors on learning adaptability as well as the relationship between learning adaptability and various factors, and put forward strategies to improve students' learning adaptability. This research is a new exploration of learning adaptability in the field of AI English learning. At the same time, it is also an extension of the research environment of learning adaptability in information-based learning and a supplement to the research results. This paper combs the composition structure of college students' English learning adaptability under the support of AI and constructs the influencing factor model of college students' English learning adaptability under the support of AI. The research has certain theoretical significance and practical value.

1. Introduction

The iterative updating of science and technology has accelerated the transition from the information age to the intelligent age, and the society has entered a new era of intelligence and informatization [1–4]. The development of technology in the new era has changed the traditional educational concept [5], innovated the educational model and optimized the teaching methods. The purpose of educational reform is to promote the improvement of education. From the early stage, we practiced pronunciation with the help of phonograph, conducted listening and speaking training with the tape recorder, started audio-visual learning through video recorder, realized a wide range of TV teaching with TV, and brought network learning and mobile learning with

modern multimedia and network. Technology always acts as a “booster” in English learning. At present, modern information technology led by artificial intelligence (AI) technology is playing a role in English learning [6–11]. Based on AI technology, it conducts personalized and accurate tests on students' English level, helps students correct their pronunciation in time, tracks and accurately records students' learning behavior data, and then promotes learning efficiency through scientific digital portrait analysis [12–16]. AI supporting learning has become the research frontier of the current English education informatization. It tries to change the traditional teaching mode through AI technology, improve teachers' teaching quality, enable students to get a better learning experience, and promote the improvement of English learning quality.

Learning adaptability, as one of the important indicators to measure students' learning effect, is the key to determine the quality of learning. Many studies have shown that good learning adaptability is an important guarantee for students to achieve better academic performance, and learning adaptability has a significant positive predictive effect on academic performance. On the contrary, poor learning adaptability may lead to decline in interest, lack of motivation, emotional instability, and lack of confidence, thus affecting the normal academic development and physical and mental health growth of students. Educational psychology research shows that learning adaptability is a common problem. Learning through any form of teaching organization has the problem of learning adaptability. Even if the class teaching has been used for hundreds of years, not all learners can adapt. The integration of AI and English education has brought about changes in English teaching environment and teaching content, as well as in teachers' teaching mode and students' learning style. For college students, participating in English learning supported by AI is still a new experience. They need to adapt to the new learning environment and new learning methods and master new learning methods so as to ensure the good development of their English performance in the intelligent learning environment.

At present, the support of AI for English learning is in continuous development, and relevant research is in full swing. It has preliminarily realized the diversification of the functions of AI to support English learning with full coverage of application scenarios. It has been widely recognized by many students and teachers in practical applications. Relevant studies have found that in English teaching and learning, AI has been very effective in personal assisted writing, man-machine dialogue writing, and machine automatic writing and group collaboration. At the same time, some studies have found that with the development of AI to support English learning practice, there is also a certain degree of learning inadaptability, such as the lack of participation of some students in intelligent speech learning, the inadaptability of autonomous learning strategies, and the poor adaptability to English resources and platforms. These problems directly affect the effect and quality of students' English learning and the effectiveness of AI enabled English learning and are not conducive to the development of students' psychological quality in the intelligent education environment. Therefore, it is necessary to further explore the problem of students' English learning adaptability under the support of AI so as to improve students' learning adaptation level and learning quality under the support of AI.

Learning adaptability is one of the important indicators to measure students' learning effect, and it is the key to determine students' learning quality in the information environment. Learning maladjustment not only affects students' learning effect but also directly affects the effectiveness of AI enabled English learning. Therefore, based on the current situation, what is the learning adaptability of college students to English learning supported by AI? And what factors affect the learning adaptability of college students? This is an urgent problem to be solved in improving

the quality of college students' English learning supported by AI. Therefore, the author believes that the premise is to help AI support the improvement of English learning quality, to understand the specific situation of English learning adaptability supported by AI, and mainly to identify the main factors that affect students' adaptability to AI support English learning.

2. Related Work

English bears the labels such as "worldwide," "global," "globalization," and "most important," and plays an important role in the global language. Moreover, with the development of world economic globalization, the use of English has expanded, and its importance has become prominent. People have a stronger demand for English acquisition. For a long time, English learning has always been closely linked with technology. At the beginning of the advent of computers, the United States began the experiment of "computer-assisted instruction" (CAL), in which "computer-assisted language instruction" (call) is an important field in many research fields of call. Call stands for a new language teaching method. Learners learn the language learning resources provided by the computer through the computer screen. At the same time, the computer is also an intelligent assistant for language teachers' teaching or research. It can be said that call has a significant change in the traditional language teaching method. In the development of technology, call makes full use of computer science, information technology, psychology [17–20], and the further combination with automatic analysis technology, the Internet (WWW), natural language processing, and other technologies so that the call system has high intelligence (such as oral response and voice scoring) and further develops call into "AI computer-assisted language teaching" (Icall). Icall is the combination of language teaching and AI technology, which promotes the modernization of language teaching. At present, the research results of the combination of AI and English teaching have been very fruitful. From the combining of relevant literature, the process of technology development has never been interrupted in the research of AI and English teaching, and more and more attention has been paid to the practical application in education and teaching in recent years. Next, it will be described from the two research perspectives of "technology inquiry" and "teaching practice." From the perspective of "technological inquiry," in the field of technology development, the early American scholar Marina Dodigovic developed an intelligent tutor of academic English for non-native English learners. With the help of AI technology, it helps non-native English learners correct errors in language learning. Marina Dodigovic's teaching practice has verified the effectiveness of the system. In 1990, the United States educational examination center began to develop an automatic scoring system. By the end of the 1990s, three automatic composition scoring systems, such as intelligent essay assessor (IEA), electronic essay rater (e-rater), and intellimetric, had come out. And the ETS' criterion English practice system can score and analyze students' English compositions within 20

seconds. In the early development stage of Tennessee University, the United States introduced AI technology into English teaching and developed an AI teaching system. Through the AI teaching system, students can learn English, which improves the efficiency of English teaching, breaks the wall of English classroom teaching, realizes independent learning, customizes the “personalized” learning mode, changes the traditional knowledge presentation mode, and innovates the traditional teaching mode. It has promoted the improvement of school English education.

With the maturity of technology and the deepening of research, the research on AI supporting English education has changed from “technology inquiry” to “teaching practice.” The research of “teaching practice” is mainly to explore the design of English teaching mode and learning path supported by AI and further explores the rules of English teaching and learning in the intelligent environment based on technical support so as to optimize the learning effect and improve the teaching quality. AI has a great potential in English education. Machine translation, natural language understanding, and speech recognition technology have been applied to English learning. As for how AI supports English learning, from the existing research, it is mainly reflected in the following aspects: AI supports listening training, AI supports oral learning, and AI supports writing training, as shown in Figure 1.

- (1) AI supports listening training: Listening is an important module in college students’ English test. The AI supports English listening training mainly by providing students with a huge English listening learning resource base based on the AI corpus. Intelligently assess students’ listening level, automatically retrieve appropriate listening learning materials for students according to their personalized choices and record their learning habits, and provide personalized and accurate learning services for students.
- (2) AI supports oral practice: Oral English is an important part of language learning, which combines listening and speaking. Oral expression can test students’ language learning and reflect their ability to apply language knowledge. Based on AI technology, the machine can understand human language and give timely feedback. Manually support oral learning, create a virtual oral dialogue and exchange scene, and timely correct the wrong expression in the students’ dialogue scene. Oral expression pays attention to accurate pronunciation and smooth expression. For pronunciation practice, AI can demonstrate pronunciation, recognize and analyze students’ pronunciation through speech recognition, natural language processing, and other technologies, conduct accurate and real-time evaluation, correct pronunciation, and students can practice pronunciation repeatedly through extensive reading and follow-up for unlimited times. The training of students’ oral fluency is mainly virtual scene dialogue practice. AI technology creates various virtual “mother tongue” communication scenes. Students

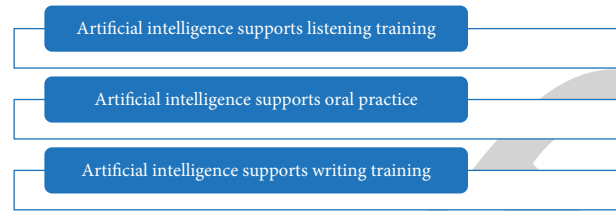


FIGURE 1: AI supports English learning.

conduct man-machine dialogue based on virtual scenes. AI technology will comment on the accuracy, pronunciation, intonation, and speed of students’ language expression, so that students can understand their oral learning in real time.

- (3) AI supports writing training: The writing level reflects the students’ comprehensive language application ability and logical thinking ability. The training of English writing supported by AI is mainly to guide students’ writing and to correct and comment on English compositions. The AI writing system is mainly based on corpus, cloud computing, natural language processing technology, etc. On the one hand, virtual teachers guide students’ writing according to the writing theme, help students build a writing framework, provide reference vocabulary according to the writing process, exercise students’ writing language organization ability, and assist students to complete writing. On the one hand, it can automatically identify the misspellings of students’ compositions, analyze sentence patterns, words, grammar, collocation, expression content, etc., make specific corrections, make revision guidance, and score the overall score. Students can revise it repeatedly to improve their writing ability.

3. An Analysis of the Influencing Factors of College English Learning Adaptability Assisted by AI Teaching

This study is about the adaptability of college students’ English learning under the support of AI. The subjects of the study are mainly college students. The samples are randomly selected from colleges and universities in Beijing. Exclude the options set in the basic information section of the questionnaire that have not participated in AI English learning as well as the questionnaires that have the same choice of all the scale topics and are suspected of being perfunctory and filling in indiscriminately. Finally, 552 valid questionnaires were obtained.

3.1. Reliability and Validity Test of Questionnaire

3.1.1. Reliability and Validity Test of Learning Adaptability Questionnaire

- (i) Reliability test: Cronbach’s alpha was used to measure the reliability α . The value range is (0, 1). The larger the coefficient, the higher the reliability, and the higher the reliability of the measurement results.

SPSS 25.0 was used to conduct “reliability analysis” on the questionnaire. The analysis results are shown in Table 1. The total reliability of the learning adaptability questionnaire was 0.913, and the reliability of a single dimension was tested. In addition to the “physical and mental health” dimension $\alpha = 0.749$ for other dimensions, i.e., α above 0.800. According to the Cronbach’s coefficient α criteria, if the coefficient is more than 0.8, the reliability is good; it is acceptable between 0.7 and 0.8; if it is less than 0.7, then the reliability is poor. Then the reliability of the learning adaptability questionnaire in this study is acceptable, and the internal consistency of the data is good.

- (ii) Validity test: The structural validity was tested by the KMO test and Bartlett’s spherical test. SPSS 25.0 was used to conduct “factor analysis” on the sample data. $KMO = 0.903$ and $P = 0.01$ of the learning adaptability questionnaire; the criterion for academic basis is the KMO value range (0, 1). The closer the KMO value is to 1, the stronger the correlation between variables. When the KMO test coefficient is greater than 0.5 and the Bartlett sphere test P value is less than 0.05, then factor analysis can be performed only when the two indicators meet the standard. It shows that the validity of the learning adaptability questionnaire in this study is acceptable, and factor analysis can be carried out. Factor analysis verifies whether the dimension division of the learning adaptability questionnaire is reasonable. The principal component analysis method is used for factor analysis to extract the common factor with five-factor eigenvalues greater than 1, which is basically consistent with the research idea. The cumulative variance contribution rate reached 70.980%, which is more than 60% of the total, indicating that the selected factors are well representative and the factor extraction results are ideal. Using the maximum difference method for factor rotation, the indicators and corresponding dimensions are basically consistent with the scales preliminarily combed in the study, so the dimensions divided in the study are more scientific and reasonable. In conclusion, the reliability and validity of the learning adaptability questionnaire in this study have passed the test and can be used for subsequent research and analysis.

3.1.2. Reliability and Validity of the Questionnaire on Influencing Factors of Learning Adaptability

- (i) Reliability test: Cronbach’s reliability coefficient test of learning adaptability influencing factors questionnaire results, as shown in Table 2, show the total table reliability coefficient of the questionnaire on influencing factors [21] of learning adaptability $\alpha = 0.809$ and single dimension reliability α . All factors above 0.785 and if the reliability of test results are acceptable, then the reliability of the questionnaire is good.

- (ii) Validity test: The KMO test and Bartlett’s spherical test of learning adaptability questionnaire gives $KMO = 0.904$ and $P = 0.01$ for the questionnaire of influencing factors of learning adaptability. When the KMO test coefficient is greater than 0.5 and the Bartlett sphere test P value is less than 0.05, factor analysis can be performed when the two indicators meet the standard. To sum up, the reliability and validity (structural validity, convergent validity, and discriminant validity) of the questionnaire on the influencing factors of learning adaptability in this study have passed the test and can be used for subsequent research and analysis.

3.2. Analysis of College Students’ English Learning Adaptability Supported by AI

3.2.1. Analysis of the Learning Adaptation Level. Descriptive analysis describes the overall situation of the data through the mean or median and generally uses the mean to measure the overall level of the variables. The questionnaire adopts “five points” scoring. According to the score, four levels can be specified: low adaptability ($1 \leq$ average adaptability < 2), general adaptability ($2 \leq$ average adaptability < 3), medium adaptability ($3 \leq$ average adaptability < 4), and high adaptability ($4 \leq$ average adaptability < 5). First of all, from the average value m , it can be seen that the average adaptation value of each dimension is above 3, and the average value of the total score is $m = 3.382$, indicating that the overall learning adaptability level of college students in AI supported English learning is medium ($3 < m < 4$), the standard deviation is less than 1 which is relatively small, and the dispersion of sample data is relatively low, indicating that the overall learning adaptability level of college students is relatively stable in AI supported English learning.

The average values of each dimension from high to low are learning interaction ($M = 3.499$), learning attitude ($m = 3.448$), learning environment ($m = 3.425$), physical and mental health ($m = 3.33$), and autonomous learning ability ($m = 3.208$). It can be seen that the average value of a single variable in the learning adaptability level of college students in the process of AI supporting English learning is also above 3 points, which is at the medium level. Among them, the average value of “learning interaction” is the highest, with a score of 3.499, but it does not reach more than 4 points, which needs to be improved. Looking at the ranking of scores, the scores of “physical and mental health” ($m = 3.33$) and “autonomous learning ability” ($m = 3.208$) are lower than the overall learning adaptability level ($m = 3.382$). It can be seen that if you want to improve the learning adaptability of college students in AI English, you can focus on how to improve the education and training of learners in these two aspects. Further analysis is done on the two dimensions of “physical and mental health” and “autonomous learning ability.”

3.2.2. Analysis on the Difference Characteristics of Learning Adaptability. In order to deeply understand the specific situation of college students’ English learning adaptability

TABLE 1: Learning adaptability questionnaire Cronbach's α reliability analysis.

Dimensions	Number of items	Sample size	Cronbach's α coefficient
Learning attitude	3	552	0.858
Autonomous learning ability	3	552	0.826
Learning interaction	3	552	0.893
Learning environment	3	552	0.867
Physical and mental health	3	552	0.749
Total reliability value	15	552	0.913

TABLE 2: Cronbach's questionnaire on influencing factors of learning adaptability α reliability analysis.

Dimensions	Number of items	Sample size	Cronbach's α coefficient
Learning motivation	3	552	0.809
Self-ability accomplishment	3	552	0.812
Learning self-efficacy	3	552	0.785
Teacher support	3	552	0.789
Resource platform	3	552	0.818
Total reliability value	15	552	0.896

supported by AI, independent sample t -test, one-way ANOVA, and other methods are used to analyze the differences. Its various dimensions in individual variables include gender, grade, discipline background, and English major or not.

- (i) Differences in adaptability of AI to English learning among college students of different genders: The independent sample t -test is used to study the differences of English learning adaptability of college students of different genders under the support of AI. The results show that the learning adaptability of male and female students is consistent in the level of AI support for English learning, there is no significant difference, and they are all at the medium level. However, in the dimension of "learning interaction," female students are significantly higher than male students.
- (ii) Differences in the adaptability of AI to English learning among college students of different grades: One-way analysis of variance (ANOVA) was used to analyze the adaptability of AI to English learning of college students in different grades. The results show that there is no significant difference in the level of learning adaptability among college students of different grades in AI supported English learning, but there are significant differences in "learning interaction" and "learning environment." The learning adaptability of third grade students is significantly lower than that of other grades.
- (iii) Differences in the adaptability of AI to English learning among college students with different subject backgrounds: The independent sample t -test is used to study the differences of students' learning adaptability in different subject backgrounds. The results show that there is no significant difference in the adaptability of college students' AI to support English learning in different subject backgrounds. From the perspective of specific dimensions, there

was no significant difference in each dimension between different subject backgrounds ($P > 0.05$).

- (iv) Differences in learning adaptability between English majors and non-English majors: The independent sample t -test is used to study the differences of English learning adaptability. The results show that English/non-English majors show significant differences in the level of learning adaptability in English learning supported by AI. The learning adaptability of English majors is significantly higher than that of non-English majors. There are also significant differences in learning attitude, learning interaction, and learning environment. English majors' adaptability to learning attitude, learning interaction, and learning environment is significantly higher than that of non-English majors.

4. Result Discussion and Analysis

4.1. Discussion and Analysis of Investigation Results of the Learning Adaptation Level

- (1) Under the support of AI, college students' English learning adaptability is at the medium level, and relatively speaking, the adaptability of students' autonomous learning ability is poor, and the adaptability of learning interaction is good. Through descriptive statistical analysis, it is found that college students' English learning adaptability supported by AI is at the medium level ($m = 3.382$). This is consistent with previous studies. From the perspective of specific dimensions, there is no significant difference between the dimensions. The score of "learning interaction" dimension is higher than that of other dimensions ($m = 3.499$), and the score of autonomous learning ability is the lowest ($m = 3.208$), which is contrary to the previous survey results. On the one hand, the possible reasons for these differences lie in different types of students, different sampling, different research environments, etc., so the research

results will also be inconsistent. Second, language itself is a tool for communication. Compared with other disciplines, there may be more opportunities for communication and interaction in the learning process. In addition, the learning supported by AI can timely feedback and instructions to students and evaluate students' learning results in real time so as to improve students' learning interaction experience and better adaptability of learning interaction.

- (2) There are differences in individual variables of college students' English learning adaptability supported by AI: Through the analysis, it is found that the overall level of college students' English learning adaptability supported by AI has no significant difference in gender, grade, and subject background, but there are significant differences between English majors and non-English majors. Among them, in terms of gender, the adaptability of AI support for English learning of female students is higher than that of male students, but there is no significant difference, which is consistent with the research conclusions in other information-based learning environments. For boys and girls in "learning interaction," "there is a significant difference in language learning. Girls' learning interaction adaptability is significantly better than boys' learning adaptability. Many foreign studies on the differences between gender and language learning show that girls usually have more advantages in language learning than boys. Girls' thinking tends to imitate, think in images, and are better at language learning, while boys are more into independent thinking, abstract thinking, and good at logical reasoning. Therefore, this may be a branch of girls' AI." The reason that English learning interaction is better among girls than boys and learning adaptability is slightly higher among girls than boys hold true. In terms of subject differences, there is no significant difference in English learning adaptability supported by AI in different subjects. The research results are basically consistent with the findings of Liushujun et al. It shows that no matter other information-based learning environments are still in the learning environment supported by AI, disciplines have little impact on college students' learning adaptability.

4.2. Discussion on the Investigation Results of the Factors Influencing Learning Adaptability

- (1) In English learning supported by AI, college students' learning motivation, intelligence literacy, learning self-efficacy and resource platform all have a significant direct and positive impact on learning adaptability. When one aspect is improved, it will directly improve students' learning adaptability to a certain extent. Among them, the improvement of learning self-efficacy (0.237) has the greatest direct

impact on their learning adaptability. For every unit of learning self-efficacy, learning adaptability will increase by 0.237 units.

- (2) In English learning supported by AI, intelligent literacy, teacher support and intelligent platform have an indirect impact on college students' learning adaptability. Through indirect influence, the total effect value of learning adaptability is increased. Among them, improving students' intelligence literacy, strengthening the support of learning teachers, and optimizing the intelligent platform will improve students' learning motivation and indirectly improve learning adaptation.
- (3) The effects of each influencing factor on learning adaptation from large to small are intelligent literacy (0.401), resource platform (0.280), learning self-efficacy (0.237), learning motivation (0.228), and teacher support (0.163). Whether it is the direct effect or the total effect, the effect value of intelligent literacy on learning adaptability has a high effect value. When improving students' learning adaptability, improving students' intelligence literacy can achieve good results in improving learning adaptability.

5. Strategies for Improving College Students' English Learning Adaptability Supported by AI

Through the analysis of the level of college students' English learning adaptability supported by AI and the effect relationship of its influencing factors, it is understood that at present, college students' learning adaptability in English learning supported by AI is at a medium level, and the level of students' learning adaptability in all aspects needs to be improved, and there is a complex structural relationship between the influencing factors of learning adaptability. According to the research results, aiming at improving college students' English learning adaptability under the support of AI, combined with constructivist learning theory and social learning theory, this study puts forward corresponding strategies from the individual level of students, the level of teachers, and the level of resources. as shown in Figure 2.

5.1. Individual Level: Autonomous Learning Ability and Intelligent Literacy Improvement

5.1.1. Improvement of Autonomous Learning Ability. It is found that college students' autonomous learning ability is relatively poor in the English learning supported by AI. Therefore, we should focus on improving students' autonomous learning ability in order to better adapt to the English learning supported by AI. In the learning environment supported by AI, with the teaching concept "learner centered" and relying on AI technology, students can change from the original "knowledge receiver" to "knowledge builder," truly realize the transformation from "educatee" to

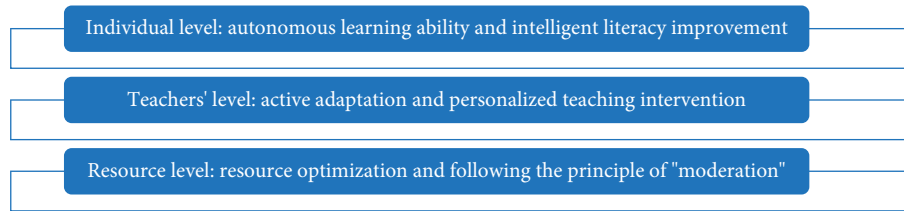


FIGURE 2: Corresponding strategies at different levels.

“learner,” and let students have more free and independent power. While students get more freedom, autonomy, and personalization, it also requires students’ autonomous learning ability to adapt to intelligent learning so as to achieve effective development. Therefore, the better autonomous learning ability of college students is the key to promote the development of students’ intelligent learning and realize the transformation of college students’ adaptation from “educatee” to “learner.” The adaptation of students’ autonomous learning ability is an important part of students’ learning adaptability.

5.1.2. Intelligent Literacy Improvement. The education of intelligent society poses a challenge to students’ intelligent literacy. Sitting on high-quality learning resources does not mean that students can carry out effective learning. Students need to have the ability to independently select resources and reasonably use resources in order to obtain effective learning. Therefore, the improvement of students’ intelligence literacy can not only enhance the objective evaluation of AI English learning tools to a certain extent but also improve students’ ability to control the AI English learning resource platform. The cultivation of college students’ AI literacy is inseparable from the direct education of the school. Universities offer courses in the public basic disciplines of AI to guide students to understand the relevant knowledge and applications of AI, stimulate students’ curiosity and interest in AI, and enable students to form intelligence awareness. Moreover, teachers, as the practitioners of intelligent education, are also the guide for students’ intelligent literacy. Teachers integrate “AI” into English classroom teaching, drive students to learn to use AI learning tools to complete learning tasks, promote students’ intelligence application level through practice, help students establish correct intelligence ethics, and thus improve students’ intelligence literacy.

5.2. Teachers’ Level: Active Adaptation and Personalized Teaching Intervention. With the integration of AI and education, AI has gradually realized the simulation, extension, and even replacement of teachers’ work to some extent. However, it must also be clear that “AI will not replace teachers, but teachers who use AI will replace teachers who do not use AI.” Human-computer cooperation is the trend of future education development. AI can improve teachers’ teaching efficiency and help teachers carry out personalized teaching. Only when teachers take the initiative to adapt and

make full preparations, can they meet the challenges of AI and adapt to the future educational form of human-computer cooperative operation. Teachers should take the initiative to adapt to the change of their roles as a guide in the era of AI. Teachers should take the initiative to adapt to the teaching in the era of AI. First, they should establish the educational concept “learner centered,” carry out teaching design guided by the educational concept “learner centered,” and innovate teaching models. Second, they should actively accept and make objective evaluation. In learning, students are teachers oriented and imitative. Students’ learning behavior and learning style are influenced by teachers. Therefore, teachers are required to “set an example for others and set an example.” Teachers should first adapt to the teaching form of AI. The acceptance and the skillful use and good evaluation of AI teaching tools will affect students’ subjective evaluation of AI learning, arouse students’ attention to AI learning tools, stimulate learning motivation, and improve learning adaptability. Third, teachers should take the initiative to improve their own intelligent education literacy. Teachers’ intelligent education literacy refers to mastering basic AI knowledge and principles, making reasonable judgments on the educational value of AI, using AI to improve subject ability and teaching ability, and cooperating with AI to carry out teaching. Teachers actively and consciously participate in teacher education and training, make full use of the Internet platform to observe excellent teaching cases, actively participate in AI teaching competitions, enrich their own AI knowledge, create a teaching mode of “AI +” discipline, and education literacy in practice.

5.3. Resource Level: Resource Optimization and Following the Principle of “Moderation”. Learning takes place in a certain environment. In a learning environment, learning resources have an important direct impact on students’ learning adaptability. High-quality learning resources can bring better learning experience to students, can enhance students’ perceived usefulness and perceived ease of use of resources, that is, improve students’ acceptance, so as to achieve better learning results. In addition, high-quality learning resources can attract students’ attention, stimulate their learning motivation, and promote appropriate learning. At present, there are already a large number of English learning resources based on AI technology. Their functions and positioning are different, showing the phenomenon of excessive resources and uneven quality. To a certain extent, it is more difficult for students and scholars to choose

resources that adapt to their own learning needs. For students, the simpler and the more convenient the operation is, the more applicable the learning content is, and the easier it is to be accepted. Therefore, in the design and development of learning resource platform, students' perception should be taken as an important reference item. The content of learning resources should adapt to students' cognitive development. Too simple or difficult learning content is not suitable for students' development. In a word, the development of resource platform should follow the principle of "moderation."

6. Conclusion and Future Prospects

It is an important period for the integration and development of AI. The importance of AI to educational reform is self-evident. English learning is the frontier of the research on the development of English educational technology. At present, great achievements have been made in the practice of AI to support college students' English learning. A certain degree of learning adaptability is also found to be poor. The learning adaptability of college students is not only related to the quality of learning but also affects the performance of AI to support learning to a certain extent. AI supporting learning is the inevitable trend of future education development. Students' learning adaptability is the key to students' academic development and the effectiveness of AI. This research on college students' English learning adaptability under the support of AI is a preliminary study on the problem of students' learning adaptability in the education and teaching supported by AI. The study only conducted data collection in Guizhou universities. Whether the research conclusions can be applied to all college students remains to be further studied and verified. Learning adaptability is affected by many factors. This study discusses the impact on learning adaptability from five aspects. There are other dimensions that are not involved. We will continue to explore in-depth in the follow-up research.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Chinese Decorative Color Based on Improved AlexNet in Interior Decoration Design

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Since the twenty-first century, with the improvement of China's comprehensive national strength and cultural confidence, our country has paid more and more attention to the protection and development of Chinese traditional culture, and more and more attention to the protection and development of China's traditional culture, traditional culture has no longer become a simple symbol in history books but has gradually entered people's daily life with the characteristics of vitality and gradually evolved into various characteristics and forms and integrated into all walks of life. Under the background of the evolution of this culture, this paper discusses the application of Chinese decorative color for interior decoration design and puts forward an application model of Chinese decorative color for interior design based on the AlexNet network improved by Adam, BN, dropout, and data enhancement optimization algorithm. Through analysis, it is found that the AlexNet network improved based on the above optimization algorithm has a good application prospect for interior decoration design. For the traditional AlexNet network, the improved AlexNet network is obviously better than the traditional AlexNet network in color extraction and can greatly reduce the loss value in the process of color recognition, up to 70.77%. Finally, the application forms and decorative functions of Chinese decorative color elements based on the improved AlexNet network in interior decoration design are analyzed. Relevant research can not only promote the integration of new and new technologies into traditional art but also effectively carry forward Chinese traditional culture and promote the internationalization of Chinese color.

1. Introduction

With the accelerated development of the industrialization process, the trend of urban construction has swept the country rapidly. Each metropolis is chasing each other, building large-scale buildings, building bridges, and roads. The quiet and elegant natural beauty of the past has been seriously damaged, and the Earth's ecological environment is getting worse and worse. Under the three "P" crises of "population explosion," "environmental pollution," and "resource depletion," interior design, as an important link in the relationship between man, society, and environment, should shoulder a new historical mission and take these three issues as factors that must be considered in the design. The future society must be a society of sustainable development. The design of sustainable development should be a

design that has the ability to develop new and renewable resources, control the use of nonrenewable resources to a minimum, respect the design of nature and artificial environment, emphasize the harmony between man and nature, and emphasize the infiltration and integration of artificial environment and natural environment, which is the perfect embodiment of ecology [1, 2]. The ancient Chinese decorative color is the exquisite combination of man-made and nature. The central idea of all planning is to create a healthier and vibrant environment, a safer, effective, peaceful, and fruitful lifestyle; that is, the ancient Chinese philosophy of "the unity of heaven and man" [3, 4]. Natural spatial elements have created a harmonious ecological beauty, which has become a new development field of aesthetics. The interior decoration has existed since ancient times. From Banpo site of primitive society in China to Afang palace in

Qin Dynasty and Weiyang palace in Western Han Dynasty, the interior decoration at that time was quite fine and gorgeous. In foreign countries, ancient Greece and Rome have developed to a very high level in architectural art and interior decoration [5–8]. In 1890, candelswheeler published his first article entitled “interior decoration as a female profession,” which contributed to the emergence of the industry called interior designer today. The publication of her book “high-grade room” has laid a foundation for the formation of the interior design industry since then. Since then, with the development and innovation of new concepts and concepts in the construction industry, the foreign interior design industry has formed a unique interior design style system [9–13]. China has also formed its own decorative design techniques and styles, forming a decorative style with Chinese local and national characteristics [14].

The environment similar to nature created by ancient Chinese interior decoration design gives people the beauty of returning to nature. It is more vibrant and full of vitality than ordinary handicrafts and enhances the sense of life of the internal environment with its unique natural beauty [14–17]. Its spiritual function is related to the psychological activities of “communication” and affects people’s emotions. The relationship between man and nature is rest, which has become the subconscious need of people. It has become or is becoming a need to make up for the gap between modern urban housing and nature, increase people’s opportunities to contact nature in high-rise housing and introduce ancient Chinese interior decoration colors. The indoor natural landscape is both derived from nature and higher than nature. It coordinates a series of contradictions between large and small, true and false, far and near within an appropriate range to achieve harmony between man and nature [18]. They often use the technique of “shrinking the Dragon into an inch, close to thousands of miles” to extract the mountains, peaks, valleys, cliffs, rivers and lakes, exotic flowers, and plants in nature. After artistic treatment and years of careful maintenance, they form a miniature reflecting various beautiful natural landscapes. They are big in small, true in false, far in near, and far in deep. Their artistic conception is detached, giving people the feeling of being in the real mountains and water. It is really called “within a short distance, thousands of miles away, within a square inch, and distinguishing the precipitousness of thousands of miles,” so that people can fully enjoy the artistic beauty of harmony and unity with nature [8, 19, 20]. Human dependence on sunlight, air, water, and plants full of vitality has become the standard for designing indoor space environment.

Indoor natural landscape is included in the field of landscape ecology because of its unique ecological function. As a part of ecological architecture design, with the development of ecological architecture theory and technology, the trend of combining design with nature and ancient decorative colors is more obvious, which also provides theoretical guidance for interior design. However, the technology is still in the experimental stage, and the combination of design is relatively stiff and not harmonious. More and more

designers are actively exploring an ecological design road that can meet the harmonious coexistence between man and nature [21–23].

This paper attempts to explore the relationship between the interior ecological landscape and interior decoration design by analyzing the relevant theories and design techniques and with the help of the improved AlexNet convolution neural network [24, 25]. The relationship between ancient Chinese decorative color and interior decoration design is not only a subordinate relationship, which should be paid more attention to because although the interior design is a plastic art activity, this kind of plastic art work should not only be through visual. We should also sense and experience through hearing and smell. Without the construction of an indoor ecological landscape, we can not perceive the natural flavor. Similarly, without the construction of an indoor ecological landscape, we will lack the flavor of life. Make the interior ecological landscape design and interior decoration design integrate each other in design ideas and design methods, so as to design and create both scientific and artistic; a modern indoor environment that can not only meet the functional requirements but also have a cultural connotation, people-oriented, emotional and rational [26–29]. Therefore, its research results will provide a reference value for getting rid of the shackles of inherent concepts such as the abuse of energy, the malpractice of excessive decoration, and the disregard of human care, building the future ecological building space, and creating a sustainable modern interior design style.

2. Interior Decoration Design and AlexNet Convolution Neural Network

2.1. Interior Decoration Design. Interior decoration design is divided into the following concepts: interior space, decoration, and interior design.

2.1.1. The Concept of Interior Space. Usually, we regard the interior of the building as the interior space, and the exterior of the building as the outdoor space. The interior space is composed of ground, wall, and roof. Japanese architect Yixin Luyuan made a conceptual definition for the internal and external space. He took the presence or absence of “top interface” as the main symbol to distinguish the internal and external space: all building spaces with roofs are regarded as indoor spaces, and all open-air building spaces are regarded as outdoor spaces. However, in the face of diversified contemporary architecture, this definition of interior space is not complete. If a complete indoor space loses some four sided interfaces, it will lose its “shell” to varying degrees, thereby weakening the indoor characteristics and increasing outdoor factors. Such space is the interior space with different degrees of “externalization.” Similarly, if the outdoor external space is surrounded by different degrees of enclosure interfaces, the outdoor characteristics will be weakened and the indoor factors will be incorporated. Such a space is an outdoor space with different degrees of “Internalization.”

Therefore, the interior space should not be a single limited concept of the top interface, and its boundary with the outdoor space is a fuzzy transition. The space with obvious internalization characteristics and a close relationship with the interior of the building can also be understood as interior space. Such an indoor space is determined by the following two aspects: the size of the space, the scale ratio of the enclosure interface, and the degree of integration of the enclosure space.

2.1.2. The Concept of Decoration. Decoration, as a special term commonly used in the field of art and covering a large amount, has a broad sense and a narrow sense. In English, the words related to the meaning of decoration, except for the word decorative art, the so-called decoration of other words can generally be divided into two categories. One category, such as decoration, mainly refers to the decoration phenomenon in a broad sense, and represents the decoration and decoration in the overall sense, such as all the designs and furnishings inside and outside the building; it refers to the narrow sense of decorative phenomena such as specific categories or individual ornaments, patterns and decorative patterns, which are generally expressed by ornament [18]. The modern Chinese Dictionary interprets decoration as something attached to the surface of the body or object to make it beautiful. If it is derived from architecture, it can be understood as “adding some ancillary things to the surface of the building to increase the beauty of the building.” This is the most common and direct understanding of architectural decoration. According to this definition, architectural decoration is attached to the building surface, rather than the basic needs of the building. The purpose of additional architectural decoration is “beauty.” If architecture is compared to music, architectural decoration is only the decorative sound of decoration, in order to make people’s eyes feel happy, relax, and rest [8]. However, architectural decoration is not just something attached to the building surface. We understand it not only as an art but also as a cultural symbol. In essence, it expresses the nature, purpose, and use of the space environment and also shows the identity, status, and aesthetic taste of the users. Its content and themes focus on all aspects of human culture, including religion, folk custom, and superstition. It covers everything from people’s daily production and life to their deep ideology. They are expressed in architectural decoration in different forms.

2.1.3. Interior Decoration Design. As an integral part of the architecture, “decoration and architecture are like the relationship between the flowers and leaves of trees and plants and their structures. It is a component of things rather than an additional part” [21]. It is also linked with building structure, materials, and functions to complete the design of the space environment. The interior decoration design is to grasp the space from the interior of the building, and according to the use of nature and environment of the space, use material technology and artistic means and other decorative techniques to create an internal space environment

design of an ideal place with reasonable functions, comfort, and beauty, which meets people’s physiological and psychological requirements, makes users happy and is convenient for life, work and study. In other words, interior decoration design is a form of space design, which is the improvement and recreation of the existing building interior space.

2.2. AlexNet Network Structure. AlexNet was first proposed by Alex Krizhevsky in 2012 and won the imagenet2012 image recognition challenge that year with great advantages. Since then, a convolutional neural network has developed rapidly in the field of image recognition. The network structure of AlexNet is shown in Figure 1. The network consists of 8 different layers, including 5 convolution layers, 2 fully connected hidden layers, and 1 fully connected output layer. The difference between this method and ordinary convolutional neural network is that the network activation function is changed from sigmoid to ReLu, which helps the neural network better solve complex nonlinear problems. At the same time, the local response normalization algorithm (LRN) is added after the pooling layer, and the dropout layer is added before the full connection layer is hidden, so as to improve the generalization ability of the whole network. This paper mainly optimizes and improves the normalization method, optimization function, and dropout layer in the AlexNet network structure [30–32].

2.3. Optimization and Improvement of AlexNet Network Model Algorithm

2.3.1. Adam Optimization Algorithm. The optimization algorithm plays a very important role in the training process of neural network. It aims to update and calculate the network parameters that affect the model training and model output, make them approximate or reach the optimal value and thus minimize the loss function. A good optimization algorithm can accelerate the convergence of the network model and avoid the influence of local minimum, saddle point, and so on. The most commonly used first-order optimization algorithm is the random gradient descent algorithm (SGD), which is also adopted by AlexNet, which speeds up the network update and reduces the operation cost of each iteration. However, this method is easy to deviate from the global best, fall into a saddle point, and the network training is not stable enough.

SGD is the most classical optimization algorithm. It calculates the error gradient of the parameters to be optimized in random samples and uses the error gradient to iteratively update the parameters to be optimized. The specific steps are summarized as the following three steps.

Step 1. Calculate the gradient of the objective function with respect to the current parameter.

$$g_i = \nabla f(w_i). \quad (1)$$

Step 2. Calculate the descent gradient.

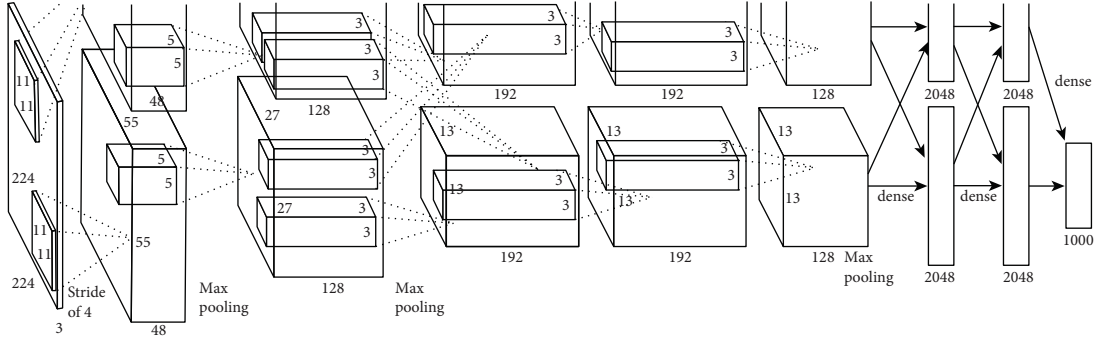


FIGURE 1: AlexNet network structure diagram.

$$\eta_i = \alpha \cdot g_i. \quad (2)$$

$$w_{i+1} = w_i - \eta_i. \quad (7)$$

Step 3. Update the parameters according to the error gradient.

$$w_{i+1} = w_i - \eta_i, \quad (3)$$

where g_i is the gradient of the current parameter of the objective function; w_i is the parameter to be optimized; α is the learning rate.

Because the SGD algorithm only uses gradient for parameter optimization, it is easy to produce gradient oscillation, which is greatly affected by the training samples, and the convergence is unstable. For the data whose statistical characteristics are not obvious and the error surface is complex, the optimization effect is poor, and it is very easy to be affected by the saddle point or local optimum, resulting in the problem of slow convergence or no convergence.

Adam algorithm combines the ideas of SGDM and rmsprop. SGDM algorithm proposes to use the first-order moment to obtain the inertia holding, and rmsprop algorithm proposes to use the second-order moment to obtain the ability of environment perception. The steps of the Adam parameter update are summarized as the following four steps.

Step 4. Calculate the gradient of the objective function with respect to the current parameter.

$$g_i = \nabla f(w_i). \quad (4)$$

Step 5. Calculate the first-order moment and the second-order moment according to the historical gradient.

$$\begin{aligned} m_i &= \beta_1 \cdot m_{i-1} + (1 - \beta_1) \cdot g_i, \\ V_i &= \beta_2 \cdot V_{i-1} + (1 - \beta_2) \cdot g_i^2. \end{aligned} \quad (5)$$

Step 6. Calculate the descent gradient.

$$\eta_i = \frac{\alpha \cdot m_i}{\sqrt{V_i}}. \quad (6)$$

Step 7. Update parameters by using descent gradient.

Since the first-order moment is introduced to add inertia, the cumulative empirical effect can be played to make the convergence direction deviate to the current downward direction while inheriting the previous cumulative direction, so as to reduce the oscillation of the gradient. The introduction of the second-order moment enables different parameters to adjust their learning rate according to the updated speed, further accelerate the convergence process and ensure the stability of convergence.

Therefore, this paper considers to replace the optimization function in the AlexNet network and adopts [7] Adam optimization algorithm to replace the SGD algorithm. The algorithm can calculate the adaptive learning rate of each parameter and has a better convergence speed. Due to parameter updating, it will not have a great impact on the loss function. It can effectively avoid the problem that the network cannot converge and reduce the impact of interference factors such as image color deviation.

2.3.2. Batch Normalization (BN) Algorithm. Local response normalization (LRN) creates a competition mechanism for local neurons so that the neurons with larger response values are larger and the neurons with smaller response values are suppressed, increasing the contrast between them and reducing the interference of noise information, so as to highlight local features and enable them to be expressed in the next layer. After introducing LRN into AlexNet, its accuracy is improved by 1%~2% [17, 21]. The calculation formula is as follows:

$$b_{xy}^i = \frac{a_{xy}^i}{\left(k + \alpha \sum_{j=\max(0, im/2)}^{\min(N-1, i+(n/2))} (a_{x,y}^j)^2\right)^\beta}, \quad (8)$$

where n is the number of channels, i is the position of the channel, x, y is the coordinate position of the point, $B = \{x^{(1)}, x^{(2)}, \dots, x^{(n)}\}$ are superparameters, where n is the length of the neighborhood, α, β is a self-determined constant, k to prevent the denominator from being zero.

However, with the development of time, people have found that the improvement of the LRN algorithm is very limited, and there has been a batch normalization (BN)

algorithm with better performance. Ioffe et al. Proposed that the BN algorithm can more effectively solve the instability in the process of parameter update iteration. This algorithm adjusts the output of the network by comparing the mean and variance of batch data, reduces data offset, and avoids the problems of gradient disappearance and gradient explosion. Improving the stability of the middle layer output value is conducive to training an effective depth network model. Therefore, this paper chooses to add a BN algorithm between the first layer and the second layer convolution layer and the activation function. Through practice, the BN algorithm can effectively accelerate the convergence of the model and improve the recognition accuracy of the model.

In Table 1, x represents a d -dimensional input data; B refers to batch data with quantity n ; $y^{(i)}$ is the output after batch normalization; μ_B is the mean value of batch data; σ_B is the variance of batch data; $\hat{x}^{(i)}$ is the result of $x^{(i)}$ standardization; where ϵ is a small constant that ensures that the denominator is not 0; γ and β . There are two parameters that you can learn: stretch and offset.

The BN algorithm normalizes the data of a certain dimension in the batch, arranges the data into a unified interval, reduces the divergence of the data, speeds up the training convergence of the model, and makes the training process more stable. The normalized data can better avoid gradient explosion and disappearance. At the same time, batch normalization can play a certain role in regularization, and can replace dropout to a certain extent.

2.3.3. Dropout Regularization. After batch normalization (BN), the initialization weight falls inside the data, and the overfitting position is often outside the data boundary. Therefore, the BN algorithm can play a certain role in regularization, so the introduction of the BN algorithm can help to avoid overfitting to a certain extent. Therefore, the dropout layer in the network structure can be removed or a low drop rate can be used. After experimental verification, this paper removes the last dropout layer in the AlexNet network and interacts with the BN algorithm to improve the training speed of the model and ensure that the network model can be better fitted.

In this paper, the BN algorithm is added between the first two maximum pooling layers and the activation function to stabilize the data of the first two convolution layers. The whole network uses the Adam optimization algorithm and discards the last dropout layer. The improved AlexNet network structure is shown in Figure 2.

3. Classification and Application of Chinese Decorative Color Based on Improved AlexNet Network

3.1. Data Collection and Pretreatment. This study crawls Baidu pictures through Python crawler algorithm (<https://image.baidu.com/>) There are five categories of Chinese decorative color pictures with the keywords of “Chinese decorative color,” “Chinese ancient decoration,” “Chinese color” (Mint), “ancient decorative color” (Patchouli), and

TABLE 1: BN algorithm.

Input: Small batch $B = \{x^{(1)}, x^{(2)}, \dots, x^{(n)}\}$ composed of n samples	
Output: Vector y with the same dimension as input $y^i = BN(x^i)$	
Mean value of small batch data	$\mu_B = (1/n) \sum_{i=1}^n x^{(i)}$
Variance of small batch data	$\sigma_B^2 = (1/n) \sum_{i=1}^n (x^{(i)} - \mu_B)^2$
Standardization	$\hat{x}^{(i)} = (x^{(i)} - \mu_B) / \sqrt{\sigma_B^2 + \epsilon}$
After introducing learnable parameters	$y^{(i)} = \gamma \odot \hat{x}^{(i)} + \beta$

“ancient color” (Hedyotis diffusa). Each category selects 600 of them, a total of 3000 pictures to form the data set, of which 2400 are used as the training set, 300 as the verification set, and 300 as the test set, each accounting for 80% and 10% of the total number of images 10%, and the data set is named zgzscc. In order to solve the problem that the small number of samples in the data set zgzscc may affect the accuracy of training, the following three methods are proposed to increase and expand the data set zgzscc.

3.1.1. Horizontal Mirror Image. As shown in Figure 3, if the horizontal mirror point of the original point is calculated, according to the coordinate relationship shown in Figure 3:

$$\begin{cases} x_1 = -x_0 + w, \\ y_1 = y_0. \end{cases} \quad (9)$$

Therefore, it is expressed in matrix form as follows:

$$\begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix} = \begin{bmatrix} -1 & 0 & w \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_0 \\ y_0 \\ 1 \end{bmatrix}. \quad (10)$$

3.1.2. Rotate. According to the principle of Figure 4, if point $A_0(x_0, y_0)$ rotates θ To point $A(x, y)$, the radius is r , and the coordinates of point $A_0(x_0, y_0)$ of the original image are

$$\begin{cases} x_0 = r \cos \alpha, \\ y_0 = r \sin \alpha. \end{cases} \quad (11)$$

The coordinates of the rotation to the new position $A(x, y)$ are

$$\begin{cases} x = x_0 \cos \theta + y_0 \sin \theta, \\ y = -x_0 \sin \theta + y_0 \cos \theta. \end{cases} \quad (12)$$

Expressed in the following matrix:

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_0 \\ y_0 \\ 1 \end{bmatrix}. \quad (13)$$

This example is to rotate θ clockwise. If you rotate counterclockwise, just set $\theta = -\theta$.

3.1.3. Add Noise. There are many algorithms for image noise enhancement. In this study, the additive zero mean Gaussian

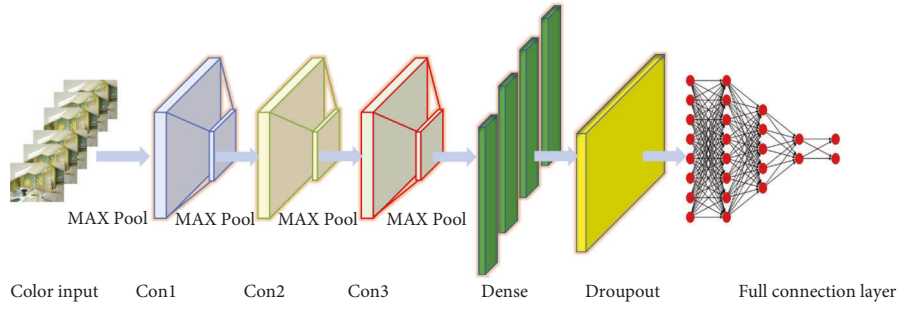


FIGURE 2: Structure diagram of improved AlexNet network (AlexNet En).

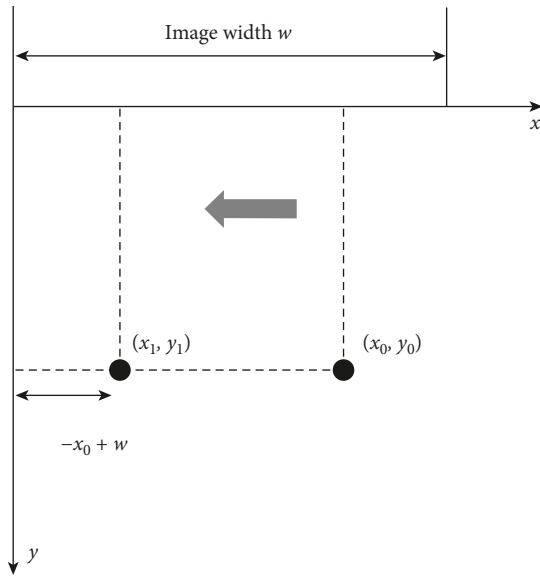


FIGURE 3: Horizontal mirror schematic.

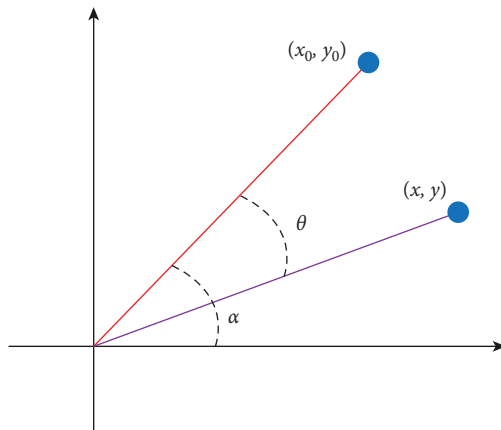


FIGURE 4: Rotation schematic.

noise method is used to add the corresponding noise to the image. The way to increase the noise is to add a noise value to the gray value of each point on the image. The way to generate the noise value is to use the box Muller algorithm to generate Gaussian noise. The box Muller algorithm generates two groups of independent standard normal distribution random variables X and y by using two groups of

independent random numbers u and V uniformly distributed in the interval $(0, 1]$. Figure 5 shows the home decoration image of an ancient style mixed with Chinese color after noise enhancement using the box Muller algorithm.

The sample size of the data set amplified by the above three methods reached 12000, of which 9600 were used as training sets, 1200 as verification sets, and 1200 as test sets, accounting for 80%, 10%, and 10% of the total number of images respectively. The data set was named “Chinese decorative color expansion map” and recorded as “zgzsck.”

3.2. Experimental Test. This experiment is based on the tensorflow2.0 platform. Tensorflow2.0 platform is a deep learning framework developed by Google formula, which supports command line, keras, and python interfaces. The framework uses matrix operation libraries such as matmul, matrixinverse, and matrixdeterminant to accelerate calculation and GPU acceleration. It has the characteristics of rich routine scripts and fast entry. The experimental software and hardware environment is Windows operating system, Intel Core i5 1.6 g GPU and 8 G memory. Four groups of experiments listed in Table 2 were carried out without considering the training time.

It should be noted that the default AlexNet model uses 1000 types of Imagenet data sets, while only 5 kinds of Chinese herbal medicine images are collected in this study. Therefore, it is necessary to modify the parameter num of each experimental model_ output = 5. In addition, during the training process, many tests found that the accuracy and loss value of each group basically stabilized after about 150 iterations. Therefore, Experiment 3 and Experiment 4 only analyzed the first 200 iterations, and Experiment 1 and Experiment 2 analyzed the complete 500 iterations. Figures 6–9 show the change curve of loss value during the four groups of experiments.

3.3. Analysis of Experimental Results. The experiment process can be divided into four groups: experiment 1, experiment 3, experiment 2, and Experiment 4 verify the influence of data expansion on the training results; experiment 1, experiment 2, experiment 3, and experiment 4 verify the impact of the improved AlexNet model on the training results. The statistical results of loss values of each group are shown in Table 3.



FIGURE 5: Home decoration drawing of an ancient style with Chinese color and the picture after noise enhancement.

TABLE 2: Experimental groups and setting information of each group.

Group	Data set	Network model	Iterations
Experiment 1	ZGZSSC	AlexNet	500
Experiment 2	ZGZSSC	AlexNet-en	500
Experiment 3	ZGZSSCK	AlexNet	200
Experiment 4	ZGZSSCK	AlexNet-en	200

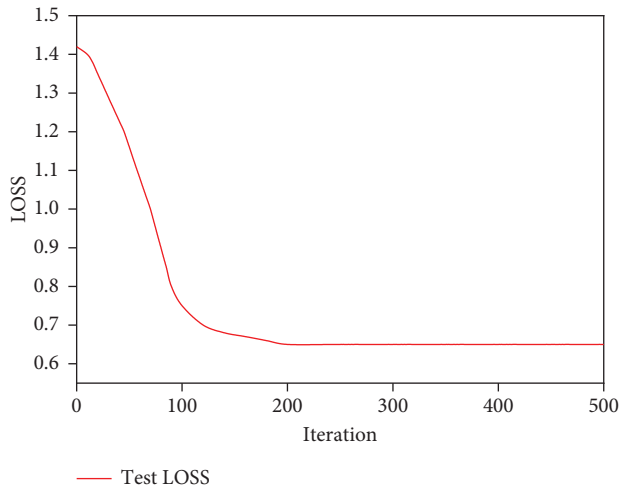


FIGURE 6: Experiment 1 test loss curve.

It can be found from Table 2 that data expansion can indeed reduce the loss rate in the training process. It can be verified from 0.65 in Experiment 1 to 0.45 in Experiment 3, and from 0.19 in Experiment 2 to 0.15 in Experiment 4. Secondly, in the improved AlexNet model, the training loss caused by data expansion is less than that caused by the original AlexNet model. The loss value from 0.65 in Experiment 1 to 0.19 in Experiment 3 decreased by 70.77%, while the loss value from 0.45 in Experiment 2 to 0.15 in Experiment 4 decreased by 66.67%, which was 0.16 less than the former and 4.1 less than the former. In addition, the loss values in the training process of Experiment 2 and Experiment 4 are lower than those in the training process of Experiment 1 and Experiment 3, respectively. Therefore, it can also be concluded that the improved AlexNet model can significantly improve the application ability of AlexNet

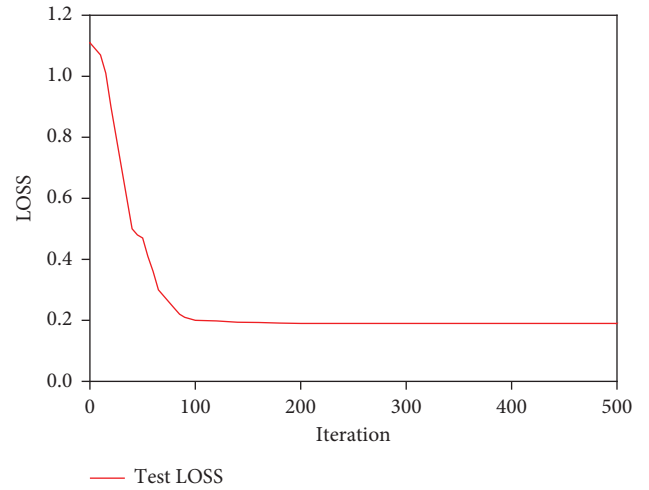


FIGURE 7: Experiment 2 test loss curve.

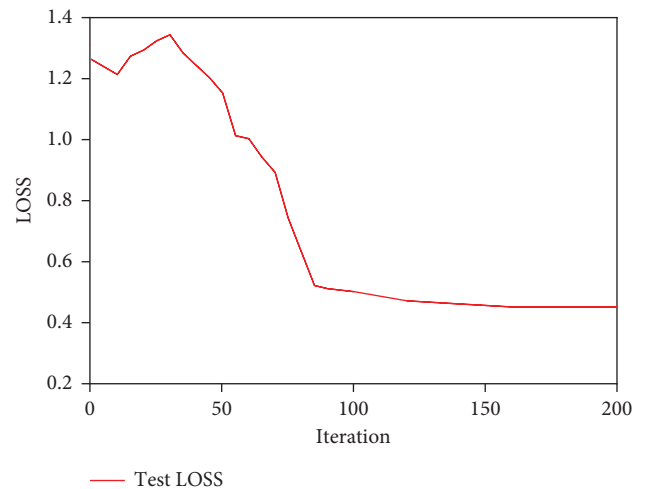


FIGURE 8: Experiment 3 test loss curve.

model in interior decoration design, and improve the separation rate and matching degree of interior decoration colors. It can be found that the combination of data expansion and an improved AlexNet model can maximize the accuracy of image classification.

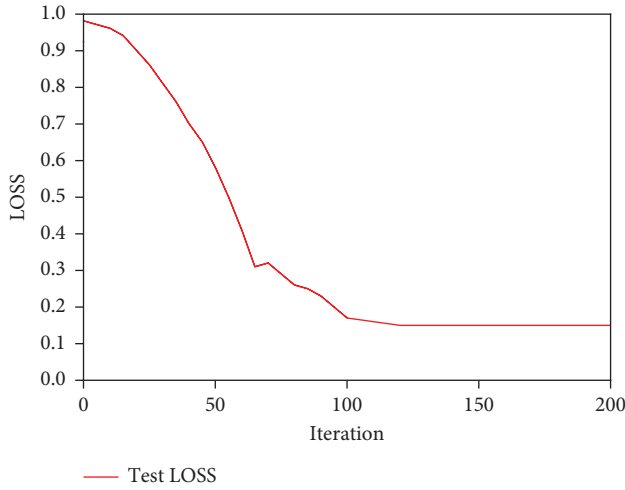


FIGURE 9: Experiment 4 test loss curve.

TABLE 3: Statistical results of different experimental loss values.

Item	Experiment 1	Experiment 2	Experiment 3	Experiment 4
LOSS	0.65	0.19	0.45	0.15

4. Application and Function Analysis of Chinese Decorative Color in Interior Design Based on Improved AlexNet Network

4.1. Application of Chinese Traditional Colors. The use of color in China has a long history, and the forms are more abundant and diverse. It can be seen from all kinds of art in ancient times that most of the works adopted the color expression form with Chinese characteristics developed from the basic color. For example, colored glaze yellow, rich purple, Chinese red, blue, and white these colors not only have the basic functions of color but also carry the traditional Chinese culture to a certain extent. When designing interior decorations (such as tapestries and Chinese curtain bedding), some or all of the traditional color elements of ancient China can be integrated into them, such as Chinese red and bright yellow. Through the collocation between these traditional colors and patterns, it can enhance the overall style and lasting appeal of the room. In the interior design of Chinese decoration, some tapestries and pillows with Chinese red as the main color are usually matched. The overall style is coordinated with Chinese decoration, giving people a luxurious and elegant feeling.

4.2. Effect of Chinese Color Integration

4.2.1. Improve Process Quality. Traditional techniques are also widely used, such as tie dyeing, embroidery, batik, and weaving. These crafts generally have strong national characteristics and cultural connotations, representing a period of history and a crystallization of wisdom. When using the improved AlexNet network to add Chinese

traditional decorative color elements in modern interior decoration, it can be innovatively combined with color, pattern, and other forms and applied to some decorations with cultural characteristics and classical charm, such as bed curtains, tapestries, and bedding. Combine these traditional color process elements with modern bedroom environment design to enhance the overall design grade and soften the bedroom layout style. In addition, the design works can be enriched and vivid through the selection of multiple colors [29].

4.2.2. Integrate Indoor Space and Improve the Overall Style. Chinese decorative colors have the characteristics of soft texture and comfort. The innovative integration of Chinese decorative colors into modern interior decoration design based on the improved AlexNet network can play a role in softening the space and improving the overall style to a certain extent. At present, people try their best to reflect the sense of space and artistic style in the decoration of the bedroom. Adding textile decorative elements to the bedroom layout can alleviate the chill brought by reinforced concrete buildings and soften the overall space. In addition, the addition of Chinese decorative colors can not only enhance the artistic taste of space but also reflect its unique warmth retention, covering, and hue in some special elements (such as textiles). In particular, at present, many textiles incorporate a variety of Chinese cultural elements, mostly using natural materials such as cotton, hemp, and silk, which makes it easier to create a sense of nature and intimacy and enhance the overall softness and “cultural flavor” of the space.

4.2.3. Reasonably Divide the Space and Improve the Sense of Spatial Hierarchy. In addition to playing the role of soft space, Chinese decorative colors can also play a unique role in reasonably dividing space and improving the sense of spatial hierarchy. In the tough home decoration environment, Chinese decorative colors can divide different spaces into different functional areas. For example, you can choose carpets, draperies and other textiles with Chinese cultural characteristics to divide the space of different functional areas, which can not only make the room full of cultural atmosphere and improve the cultural pattern of the space but also avoid the cold and hard feeling of the room space as a whole and play a role of combining hardness and softness and clear hierarchy.

4.2.4. Render the Cultural Atmosphere of the Space and Add Aesthetic Interest. The last decorative function of Chinese decorative color in interior decoration is to render the cultural atmosphere of the space and add aesthetic interest. The interior decoration color integrated with Chinese cultural elements, whether from the perspective of color elements, pattern elements, cultural symbolism, and technological techniques, can give people the enjoyment of beauty. At the same time, the decorative color with Chinese cultural elements can also make the space full of cultural

flavor, and strengthen people's perception and resonance of aesthetics, so that the layout of the space is no longer simply based on various simple decorative styles, but increase the deep-seated connotation and increase the cultural sense and aesthetic interest through the embellishment of decorative textiles.

5. Conclusion

The Chinese culture has a long history, with rich artistic characteristics and spreading value. Alexnet has outstanding color blending ability, strong image color processing ability, and high application value. Nowadays, with the enhancement of China's cultural soft power and people's love for Chinese classical culture, more and more people are willing to participate in their daily life, including the use of ancient colors. The innovative integration of Chinese decorative colors with the improved AlexNet network into interior decoration design can not only improve the artistic taste of the room space, soften the feeling of space, and enhance the aesthetic taste but also provide an opportunity to carry forward China's excellent traditional culture. Therefore, this paper proposes an application model of Chinese decorative color for interior design based on AlexNet network improved by Adam, BN, dropout, and data enhancement optimization algorithm. After analysis, it is found that the improved AlexNet network based on the above optimization algorithm has a good application prospect for interior design. For the traditional AlexNet network, the improved AlexNet network is significantly better than the traditional AlexNet network for color extraction. And, it can significantly reduce the loss value in the process of color recognition, up to 70.77%. Through this study, we can learn that in the future interior design, we should follow the corresponding principles, pay attention to the use of artistic conception, and improve the inheritance of traditional decorative elements. At the same time, we should also give full play to the color integration ability of modern technology and the spatial decorative role of Chinese decorative colors, so that they can become the carrier of Chinese cultural symbols so that interior design can show Chinese style and be in line with international standards, Show the infinite charm of Chinese traditional culture.

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 there are no conflicts of interest.

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Research Article

Why Does Distributed Leadership Foster or Hamper Bootlegging Behavior of Employees: The Role of Exploratory-Exploitative Learning Tension and Paradox Mindset

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Bootlegging innovation, the act of developing an idea by an employee even when it was banned by the leader, is a novel and interesting construct that can bring both positive and negative outcomes to organizations. It is of interest to the organizations, leaders within those organizations, and the employers. Drawing upon paradox theory and organizational learning perspectives, we theorize and test a moderated mediation model to explore the relationship between distributed leadership and bootlegging behavior. We use a three-stage questionnaire method to collect data from 517 employees of information technology enterprises in China. Our results corroborate the following: (a) distributed leadership is positively related to the bootlegging behavior of employees; (b) exploratory-exploitative learning tension mediates the linkage between the distributed leadership and the bootlegging behavior of employees; (c) employee's paradox mindset moderates the positive relationship between exploratory-exploitative learning tensions and the bootlegging behavior and also moderates the positive direct relationship between the distributed leadership and employee's bootlegging behavior, so that the relationship is amplified when paradox mindset is strong. We discuss the implications for theory development and practice concerning how distributed leadership can influence personal bootlegging behavior.

1. Introduction

In a dynamic and uncertain surroundings, innovation is recognized as a pivotal factor for competitive advantage and successful organizational performance [1], and a mass of companies have targeted initiatives focusing on the individuals' knowledge, information, experience, and creativity [2, 3]; however, due to the limitations of resources, potential risks, and other reasons [4], organization leaders cannot support all employees' innovation activities and often only support the new ideas that they think are the most practical and most likely to be realized [5, 6], and at the same time, they also establish a set of rules to restrict employees' innovative behavior [7]. If the individual believes that those ideas that are not adopted by the superior may create great value for the enterprise [8], he or she may continue to carry

out innovative behavior secretly [9, 10]. This kind of behavior is called bootlegging innovation, which is not uncommon in the workplace [8, 11]. Under the background of innovation orientation, it is supposed that employees' bootlegging behaviors will be more and more emerging and prominent [8, 9].

According to the existing literature, a limited number of studies focusing on bootlegging behaviors suggest that bootlegging behaviors is beneficial for individuals and organizations because some bootlegging behaviors with altruistic motivation and functional role can stimulate employees' creativity and organizational innovation performance [12–14]. It is notionally and practically significant to explore the antecedent variables of bootlegging behavior [15], which is a localization for understanding the conceptual logic of bootlegging innovation nowadays. Previous

explorations has shown that an organizational innovation atmosphere can induce employees' bootlegging innovation behavior [10, 16, 17], as well as organization policy factors in influencing bootlegging innovation. It is suggested that temporal leadership positively affects the bootlegging behavior of employees [15], and paradoxical leadership can accelerate the emergency of bootlegging behavior in Chinese organizational situation [18]. However, a theoretical framework for understanding how leaders can facilitate individuals' bootlegging behavior has not been thoroughly developed [18].

Distributed leadership has become one of the most influential leadership theories in recent years [19, 20]. While the notion of shared, collaborative, or participative leadership has become increasingly prevalent in recent years, distributed leadership theory has provided a vicissitudinary angle of view on the familiar theme [21]. Distributed leadership theory and recent findings in the organizational researches acknowledge the possibility that distributed leadership can be considered as a paradox, a process in which leadership is retained and dispersed [22]. The distributed leadership pattern advocates and encourages the positive emergence of heterogeneous employees in the organization [23], which provides an organizational climate for employees' bootlegging innovation. Although the relationship between distributed leadership and employee bootlegging innovation can be found through logical derivation, few studies have explored the influencing mechanism between them. Our framework and study address their call for examination of how distributed leadership facilitates employees' bootlegging innovation.

Our research jump-starts the conversation on bootlegging innovation behavior at work by examining why distributed leadership can have a significant impact on bootlegging innovation behavior. In addition, some scholars pointed out that bootlegging innovation was gradually understood as a process involving multiple tension problems [24], and they ignored that employees might face a variety of competitive psychological activities in the process of bootlegging innovation [8], which have not attracted enough attention and still lack in-depth investigation, in particular, the learning tension and its mechanism of distributed leadership situation which stimulates employees' bootlegging innovation. The contradictory and related goals and processes make the research of employees' bootlegging innovation more challenging. For this reason, we also examine the impact of exploratory-exploitative learning tension between distributed leadership and bootlegging innovation. Drawing from paradox theory, the theory of other orientation, and research on paradox mindset, we further explore the moderating influence of paradox mindset, which refers to "the extent to which one is accepting and energized by tension" [25, 26].

Our research makes important theoretical and practical contributions in three ways. Firstly, existing studies have not paid a comprehensive and systematic attention to the leading factors in the employee bootlegging innovation mechanism. Leadership pattern (e.g., distributed leadership) is significant in the bootlegging behavior literature but has

been paid limited attention. In recent years, relevant researchers have constantly called for further investigation into it and suggested exploring the role mechanism of leaders in employees' bootlegging innovation from the perspective of organizational norms [10]. The results of this study are a direct response to such calls and suggestions. We fertilize the literature on the antecedents of bootlegging behavior by confirming the character of distributed leadership, consequently encouraging a novel theoretical direction for future research (i.e., leadership pattern).

Secondly, from the view of organizational learning theory, this study analyzes the effect of distributed leadership on individuals' bootlegging behavior by using a new psychological mechanism of conflict. It explains the internal mechanism of the influence of distributed leadership on employees' bootlegging innovation through the competitive exploratory-exploitative learning tension generated in the context of high innovation demand, which is quite different from previous studies, and can provide an idea for the organizations to expand the theoretical framework of the relationship between leadership pattern and employees' bootlegging innovation, which helps to understand the formation process of bootlegging innovation systematically.

Finally, based on the paradox theory, we are more concerned about the moderating roles of the paradox mindset in strengthening the positive impacts of the relationship between leadership pattern and bootlegging innovation, identifying the boundary conditions that promote bootlegging innovation from the renewal level, and providing a more integrated understanding of the correlation between distributed leadership and employees' bootlegging innovation behavior.

2. Conceptual Framework and Research Hypotheses

2.1. Distributed Leadership and Employees' Bootlegging Behavior. Bootlegging behavior is defined as a course by which individuals work on creativity that have no official support but produce innovations [9, 17]. Leadership is an important environmental factor for employee innovation [27], yet, it is remarkable that the foundation of the creative aspect of dynamic capabilities lies in leadership distributing [28]. Distributed leadership is viewed as the exercise of mutual effect of leaders, followers, and their dynamic situations [29]. According to Cannatelli et al. distributed leadership is prevalently depicted as "postheroic" [30], which forecasts that the leadership function is not just attributes of leaders but rather those of other members who have relevant heterogeneous knowledge [31]. The distributed leadership approach refutes the conventional heroic of leadership that magnifies leadership as a phenomenon [20, 32, 33]. For knowledge-based employees, distributed leadership is considered as a challenge and refutes to conventional heroic approaches of leadership, and this is conducive to enhancing their bootlegging behavior.

First, the bootlegging for employees is somehow derived from the distributed leadership pattern. Against the

backdrop of distributed leadership, heterogeneous employees in an organization emerge endlessly, driven by the encouragement of leaders in such a manner that the subordinates are endowed with more autonomy and flexibility in work [23], so that they can try new solutions. The organizational context gives a higher degree of tolerance for innovation risk, thus setting the stage for a relaxed atmosphere of innovation. Once employees perceive the leaders' support for innovation, they will have the freedom to give full play to bootlegging. Previous studies reported that bootlegging is more likely to be translated into innovative performance if leaders not only forgive but also reward bootlegging [34]. If an organization is inundated with strong distributed leadership, employees' desire for studying heterogeneity-related knowledge will be unprecedentedly high, and their enthusiasm for innovation will be stimulated. At this time, the restriction of limited organizational resources will become more prominent. The support of considerable resources is indispensable for innovation, yet the organizational resources are not always sufficient [13], which may lead to the fact that employees may look for more informal channels, i.e., bootlegging behavior, to effectuate their innovative ideas.

Second, distributed leadership stimulates the bootlegging motivation of employees. The study of Burns (2007) revealed that each individual had the motivation to go after uniqueness, because this is a learned desire that drove individuals to participate in innovative activities, and any member could wield influence based on their specific strengths [35]. The employees who have accumulated a mass of heterogeneous knowledge by themselves always keep an eye on the self-learning of new knowledge and skills to improve their business level [36]; if a wet blanket is thrown on an employee's creativity or it is not understood by his/her leaders, he/she will take delight in continuing to working on it in an informal manner. To top it all, the likelihood is that employees innovate by running counter to the warning line of the organizational rules and workflows [37]. Moreover, the heterogeneous knowledge of employees underpins bootlegging, and those with heterogeneous knowledge have a certain intraorganizational "discourse power" in the context of distributed leadership where the bootlegging behavior will be triggered to some extent.

Third, distributed leadership makes a dent in the concerns of employees about bootlegging. The risk of employees' bootlegging mainly stems from the punishment of their organizations that bootlegging may bring, which is none other than one of the concerns of employees when distinguishing the bootlegging. Accordingly, the distributed leadership dispels employees' misgivings about bootlegging to a certain extent, where this model itself is new and is open and inclusive to organizational employees. Distributed leadership has become a popular representation of "post-heroic" leadership [38]. Every individual in the organization with heterogeneous knowledge is considered and given informal leadership responsibilities and thereby is motivated to get hold of and improve heterogeneous knowledge. In view of this, we propose the first hypothesis as follows.

Hypothesis 1. Distributed leadership is positively associated with bootlegging behavior of employees.

2.2. The Mediating Role of EELT. The only thing employees can do against the backdrop of distributed leadership is to demonstrate an "informal leadership" when they have a lot of knowledge and learn to support and continuously enrich their heterogeneous knowledge. Under this circumstance, their enthusiasm for learning heterogeneous knowledge will be unprecedented. On the one hand, employees need to have a better understanding of their existing knowledge and keep expanding. And on the other hand, they need to delve into and search for new knowledge. Therefore, exploitative learning and exploratory learning, a pair of competing innovative learning tasks, are formed.

Exploratory-exploitative learning tension is defined as follows: when developing new ideas vs. expanding existing ideas, there are tensions tabulating across time between building upon and undermining the past to invent the future [26]. Such concepts as optimization, selection, production, efficiency, and execution are used in exploratory and exploitative learning, while exploration encompasses search, change, risk-taking, discovery, and flexibility [39]. Generally, a person's attentional resources are relatively given. If the attentional resources reach either exploitative learning or exploratory learning, the resource scarcity against the other object will be exacerbated. In this case, the aggravated conflict will result in the exploratory-exploitative learning tension, which is the perception of tension due to the relationship between opposing and unifying paradoxical elements that are interrelated and contradictory in terms of learning tension [26, 40, 41].

Specifically, those who perceive the distributed leadership may prospect to acquire more heterogeneous knowledge through considerable exploratory learning. They may also converge to exploitative learning in order to maintain their own heterogeneous knowledge, which will result in exploratory-exploitative learning tension due to psychological conflict. If employees perceive stronger distributed leadership, it is more likely that they need to invest in exploratory learning and intend to rest on exploitative learning and increase the tension. For this reason, this paper predicts that the learning-situated context formed by the distributed leadership pattern is closely related to the exploratory-exploitative learning tension. Therefore, this study proposes the second hypothesis as follows.

Hypothesis 2. Distributed leadership is positively related to exploratory-exploitative learning tension.

Bootlegging is an intricate process involving multiple tension issues [24]. Previous studies have demonstrated that the learning tension emerges when exploring new knowledge (exploratory learning), and taking advantage of existing knowledge (exploitative learning) is the most distinct tension for bootlegging [42]. Innovation inevitably sets foot on unknown areas, in view of which innovative ideas that need to be realized through bootlegging are even more advanced

and difficult [43]. It is evident that employees' bootlegging should be underpinned by a lot of heterogeneous knowledge. In this context, employees who are inclined to bootlegging activities need to understand and expand their existing heterogeneous knowledge and delve into and develop new heterogeneous knowledge.

This situation becomes more apparent in the organizationally distributed leadership. If the exploratory-exploitative learning tension brings about much anxiety and discomfort to individuals, there is no doubt that they will spare no efforts in freeing themselves from the sense of incongruity. The greater the tension, the stronger the individual's motivation to get rid of the sense of incongruity. In this case, it is more likely that individuals will think about how to deal with the exploratory-exploitative learning tension. A rational analytical processing system [44] is thus initiated. In response to the distributed leadership pattern for exploratory-exploitative learning, the exploratory-exploitative learning tension is more likely to escalate cognitively and rationalize their own choices by analyzing the role of the processing system. Meanwhile, efforts should be made to learn to live in harmony with the exploratory-exploitative learning tension, thereby generating the bootlegging. Therefore, this study proposes the third hypothesis as follows.

Hypothesis 3. Exploratory-exploitative learning tension is positively associated with bootlegging behavior of employees.

Social cognitive theory goes to show human psychosocial functioning in the light of the interaction between behavior, cognition, and situation. The three factors interact as triadic reciprocal causation [45, 46], which decide whether to perform the bootlegging behavior on this basis or not. According to the sense-making theory of innovation, the extent to which an individual chooses bootlegging behavior depends on his/her demand for innovation, perception of opportunities, and the understanding of circumstances. Individuals often come through complex cognitive and meaning-making processes before making decisions [47]. Distributed leadership, as a situational factor of organizational leadership, may be transmitted to employees in the organization through social cognition. Employees are generally encouraged to enrich their knowledge once they perceive the empowerment from their leaders, where maintaining the uniqueness cannot be done without new heterogeneous knowledge. In this way, exploratory learning and exploitative learning are seen as conflict with each other, thus triggering the exploratory-exploitative learning tension. In analyzing the role of processing systems in cognitive escalation, exploratory-exploitative learning tension evidences itself as bootlegging. According to Hypothesis 2 and Hypothesis 3, we propose the following.

Hypothesis 4. Exploratory-exploitative learning tension will mediate the relationship between distributed leadership and bootlegging behavior.

2.3. The Moderating Role of PM. In recent years, paradox mindset has provided a new perspective for understanding how employees integrate contradictory requirements in the process of innovation, which helps employees find the connection between the two sides of the contradiction and establish a new thinking structure and ideas. Paradox mindset shapes the way people understand contradictions [48], based on which they can understand those opposing and complex interactions through defining a paradox in a more complete environment. In this sense, it can be depicted as a process by which an individual establishes a new relationship with the situation in which he or she finds himself/herself. Building on the definition given by Miron-Spektor, Ingram, Keller, Smith, and Lewis [26], paradox mindset refers to the extent to which individuals undertake, and are motivated by, those opposing and complex interactions in the organizational life full of contradictory situations. When individuals have formed paradox mindset, they not only recognize the conflicting relationship between opposing task elements, but also are adept in integrating opposing task elements to eliminate the reverse influence of each element, so as to find a solution that synergizes both elements [49]. Those paradoxical demands are embraced by them as a challenging opportunity, which will further help to inspire new understandings. Conversely, those individuals who do not have the paradox mindset will view paradoxical demands as dilemmas that need to be traded off in pursuit of consistency and will be prone to feeling anxious due to the conflict and discomfort that paradox mindset brings [40].

This article argues that employees' paradox mindset affects the relationship between distributed leadership and bootlegging. Judging from paradox theory, individuals employing the framework of paradox will, compared with other cognitive frameworks, be more likely to identify and accept contradictions and perceive the tension between task elements. This perception further enhances their perception of conflict and enhances the ability to integrate paradoxical elements, thereby expediting individual creativity [50]. Paradox mindset enables individuals to generate new ideas, breaks through the constraints of existing rules, and even runs counter to the warning line of organizational rules and workflows [37]. Employees with a high level of paradox mindset may be more likely than not to comprehend and take the initiative in the organizational context in which formal and informal leadership complement each other under the distributed leadership pattern and even realize the synergies brought about by the pattern. In turn, employees may observe and adapt to the organizational strategy of both this and that. Employees are therefore motivated to exhibit more bootlegging behaviors. Individuals with a high level of paradox mindset may show lower adaptability in distributed leadership situations, which can be considered as a kind of maladjustment. Even in the relaxed atmosphere of distributed leadership, employees whose paradox mindset is not high often generate negative self-evaluation due to their concerns about making mistake. In turn, they will not have a high degree of acceptance of innovation risk and tend to choose the stability brought by abiding the rules and regulations, as well as workflow, rather than bootlegging.

Second, Smith and Tushman [51] proposed, based on the analysis of individual cognitive differences, that individuals with paradox mindset were adept in discovering differences in situations and finding solutions to reconcile contradictions according to the nonlinear relationship between tasks. This situational perception may prompt individuals to look beyond existing norms to find new combinations of existing knowledge and bring forth meaningful solutions. Broadly speaking, employees often face the exploratory-exploitative conflict in the context of distributed leadership. Innovating while completing the tasks prescribed by the organization will hold the limited time and resources of employees. Those with high level of paradox mindset can pursue both exploratory activities and exploitative activities at the same time and synergize the two through integration [52]. As a result, what they will do is to engage in more bootlegging behaviors [53]. Therefore, we propose the following.

Hypothesis 5. Paradox mindset will moderate the relationship between distributed leadership and bootlegging behavior of individuals, such that the relationship is stronger for employees with high (vs. low) paradox mindset.

In accordance with the paradox theory, doers' paradox mindset triggers transformation from potential tension to the active one [41]. Paradox mindset is defined as the degree to which individuals accept contradictions and are invigorated by the tension between paradoxical elements [26]. The exploratory-exploitative learning tension, derived from the opposition and conflict between the two types of learning, will increase with the stimulation of distributed leadership. The more pronounced the tension, the higher the reliance on cognitive resources; in this case, paradox mindset is more likely to be a key influencing fact. Individuals with paradox mindset will generally use the strategy of "both this and that" to actively deal with tension problems when they experience it [40]. The higher the level of paradox mindset of employees, the more likely they are to constructively manage learning tension. They will learn to live with, actively face, and embrace the learning tension and even gain energy from it [26, 41]. Meanwhile, they will be brave to break through the organizational routines and conventions and be good at flexibly switching between the dual tasks of exploratory learning and exploitative learning to adapt to new situations. This makes for resolving the contradiction between exploratory learning and exploitative learning and better stimulating bootlegging. Employees with low level of paradox mindset tend to be rigid in their thinking, rather than keeping a watchful eye on, and balancing, both exploratory learning and exploitative learning that are mutually conflicted [26]. Lacking the ability to recognize and process the tension of exploratory learning makes them unable to establish distinctions between exploratory learning and exploitative learning and discover new connections within them [51]. In consequence, in their view, the prominent exploratory-exploitative learning tension is seen as the dilemma that can make a dent in one's zealotry for engaging in bootlegging.

Therefore, this study proposes the sixth hypothesis as follows.

Hypothesis 6. Paradox mindset will moderate the relationship between exploratory-exploitative learning tension and bootlegging behavior of knowledge-based employees, such that this relationship is stronger for employees with high (vs. low) paradox mindset.

3. Materials and Methods

3.1. Procedures and Participants. Data were collected as a part of a large-scale research project from the information technology companies in China. According to the preliminary depth interview, we realized that the leadership distributing phenomenon was widespread in two companies. Considering that this research involves bootlegging innovation, its object is also limited to knowledge-based enterprises such as high-tech industry. Thus, we acquire data from two high-tech companies.

With the help of the office clerk of human resource, we first casually chose from the employees who were reliable for developing new products, as well as testing and maintaining software programs. Then, we preached the process of our research in frequent meetings. In addition, we used an inductive approach to reduce the ambiguity of scale items. To bring down the impact of common method variance (CMV) [54], we designed an anonymous questionnaire and used a three-wave field survey.

Finally, we received 517 valid questionnaires. In the final sample, 293 (56.7%) participants were male; 167 (32.3%) participants were between 20- and 30-year-old, and 207 (40.0%) participants were between 31- and 40-year-old, with an average age of 30.49 years; 93.4% had completed college study, and 83.4% had at least 1-year occupational history.

3.2. Measures. In this study, the scales we adopted were initially developed in English, and they were validated by previous scholars in the Chinese context. 5-point Likert was adopted for the four variable scales (1 = forcefully disagree, 5 = forcefully agree). Brief measurement items are detailed in Table 1.

3.2.1. Distributed Leadership. We measured distributed leadership using the 8-item scale revised by Canterino and colleagues (2020) [55]. A representative item is "I discussed with and helped my peers in solving problems." Cronbach's alpha is 0.906.

3.2.2. Paradox Mindset. A 9-item scale was adapted to measure paradox mindset developed by Miron-Spektor and colleagues (2018) [26]. A representative item is "I feel stimulative when I try to address contradictory problems." Cronbach's alpha is 0.917.

3.2.3. Exploratory-Exploitative Learning Tension. Exploratory-exploitative learning tension was evaluated through a 3-item scale compiled by Miron-Spektor and colleagues (2018) [26]. A sample item is "I need to acquire

TABLE 1: Measurement items of the variables and the reliability and validity test results.

Variable	Item	Factor loading	Cronbach's alpha	CR	AVE
DL	My leader discussed with and helped my peers in solving problems.	0.800	0.906	0.908	0.531
	Both my leader and my peers could clearly describe the vision.	0.759			
	The organization provided me and my peers with a set of shared values that guided the change.	0.795			
	All units were expected to achieve high levels.	0.732			
	My leader and my peers met regularly to discuss performance.	0.675			
	My leader and my peers regularly met to discuss standards and objectives.	0.681			
	My leader provided structure that encouraged all my peers to participate in improving the process.	0.794			
	Informal leaders played an important role in improving the change implementation effectiveness.	0.701			
PM	When I consider conflicting perspectives, I gain a better understanding of an issue.	0.707	0.917	0.919	0.557
	I am comfortable dealing with conflicting demands at the same time.	0.829			
	Accepting contradictions is essential for my success.	0.710			
	Tension between ideas energize me.	0.760			
	I enjoy it when I manage to pursue contradictory goals.	0.708			
	I often experience myself as simultaneously embracing conflicting demands.	0.728			
	I am comfortable working on tasks that contradict each other.	0.724			
	I feel uplifted when I realize that two opposites can be true.	0.824			
EELT	I feel energized when I manage to address contradictory issues.	0.717	0.825	0.828	0.618
	I need to gain new skills while relying on my existing skills.	0.860			
	I need to develop new capabilities but also demonstrate my existing capabilities to others.	0.718			
BB	I need to learn and explore new opportunities while exploiting existing solutions.	0.773	0.855	0.855	0.542
	I have the flexibility to work my way around my official work plan, digging into new potentially valuable business opportunities.	0.773			
	My work plan does not allow me the time to work on anything other than the projects I have been assigned to.	0.699			
	I enjoy tinkering around with ideas that are outside the main projects I work on.	0.728			
	I am running several pet projects that allow me to learn about new areas.	0.728			
	I proactively take time to work on unofficial projects to seed future official projects.	0.751			

new skills while depending on my existing skills.” Cronbach’s alpha is 0.825.

3.2.4. Bootlegging Behavior. We assessed bootlegging behavior of knowledge-based employees through a 5-item scale compiled by Criscuolo et al. [17]. A sample item is “I enjoy piecing up with ideas that are outside the core projects I engage in.” Cronbach’s alpha for the scale is 0.855.

3.2.5. Control Variables. We controlled for the demographic variables which may influence the bootlegging behavior of an employee, such as gender, age, education, and work tenure [18]. Following up with previous research, in addition, we commanded the relationship tenure, which has an influence on the consciousness of the leadership with employees [56]. Considering the relationship between superior and subordinate, gender, age, and education of the immediate supervisor were also commanded in our research [57, 58].

3.3. Analysis Strategy. Considering that the four variables were recount by oneself, we conducted a confirmatory factor analysis (CFA) firstly to examine the common method bias

(CMB) [54]. Next, a hierarchical regression model was used to test the hypotheses in SPSS25.0. In addition, we take advantage of the macro PROCESS 3.3 [59] to inspect the mediating role of exploratory-exploitative learning tension, as well as the moderating effects of paradox mindset. Finally, we used the macro PROCESS 3.3 [59] to perform the hypothesis test of our theoretical model in this part and employed an alternative measure of bootlegging innovation to check on the adaptability of theoretical model.

4. Results

4.1. Data Analysis. The hypothesized relationships can be summarized as the proposed model shown in Figure 1. Considering that data come from two incorporations, we firstly employed an independent sample *t*-test to check on whether the two samples could be merged with each other. The results showed that there is no significant differentiation between the two samples in the aspect of age, gender, and education, which makes clear that it is suitable to merge.

4.2. Validity of the Constructs. In this study, we had a test at the convergent validity of all variables. The composite reliability and average variance extracted metrics of four

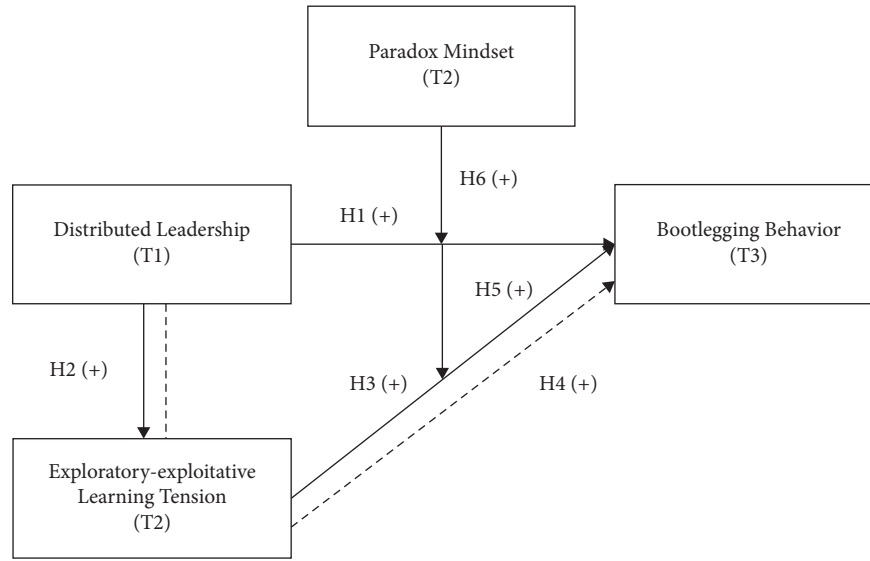


FIGURE 1: Theoretical model. Note(s): the solid line means direct influence; the dotted line means indirect impact; T1 = time 1; T2 = time 2; and T3 = time 3.

variables all exceeded the corresponding threshold values [60], indicating the good internal consistency and validity of the scale.

We also used confirmatory factor analysis (CFA) strategy to test the discriminant validity between DL, PM, EELT, and BB. As shown in Table 2, the four-factor model had a better matching effect, and the indexes were fitting in a desired scope, $\chi^2/df = 1.375$, CFI = 0.985, TLI = 0.984, and RMSEA = 0.027, while the other index models failed to fit the standard range. Therefore, DL, PM, EELT, and BB have good discriminant validity for the constructs.

4.3. Common Method Variance Test. We adopted the Harman single-factor method to test common method and single-respondent biases [54, 61]. The numerical value of the Harman single-factor indicated that the KMO of the exploratory factor analysis was 0.951 with a significant Bartlett spherical test ($p \leq 0.001$). In addition, the results of factor analysis displayed that four factors were extracted, and the cumulative variance interpretation percentage of the first factor was 39.648%, which did not surpass 40%. Furthermore, referring to the proposition of Podsakoff and colleagues (2003) [54], we controlled for an unmeasured latent “method” factor to confirm Harman’s single-factor test; results showed that the model fit did not change significantly ($\Delta CFI = 0.004$, $\Delta TLI = 0.001$). Thus, we can conclude that common method bias is unlikely to have shaped our findings.

4.4. Descriptive Statistics and Correlations. Table 3 displays the means of variable, standard deviations of variable, and correlations between variables. As can be seen from Table 3, DL and EELT showed a significantly positive correlation ($r = 0.343$, $p < 0.01$), EELT and BB showed a significantly positive correlation ($r = 0.440$, $p < 0.01$), and DL and BB showed a significant positive correlation ($r = 0.440$, $p < 0.01$),

which displayed preliminary support for the hypothesis. According to [60], all the square roots of AVE for the constructs should be bigger than the off-diagonal elements or coefficients in the relative columns; hence, the results in Table 3 proved the satisfactory discriminant validity.

4.5. Hypotheses Testing. Table 4 presents the numerical results of hierarchical regression model. When testing hypotheses, we controlled for individuals’ gender, age, education, work tenure, leader’s gender, leader’s age, leader’s education, and relationship tenure. We determine that DL has a positive direct relation with BB of employees (Model 4: $\beta = 0.460$, $p < 0.01$). In support of Hypothesis 2, EELT is positively associated with BB of employees (Model 5: $\beta = 0.377$, $p < 0.01$). Consistent with Hypothesis 3, DL has a positive impact on EELT (Model 2: $\beta = 0.363$, $p < 0.01$).

Hypothesis 4 suggests that EELT will mediate the influence of DL on BB. As shown in Table 5, the positive effect of DL on BB has been weakened, but it is still significant after adding EELT (Model 6: $\beta = 0.355$, $p < 0.01$). We used PROCESS macro to examine the mediating role of EELT [59]. As shown in Table 5, bootstrapping technique is advised to test the indirect effect [59]. Results from PROCESS showed that the indirect effect of DL on BB through EELT was 0.085 (95% CI [0.053, 0.123], 5000 bootstrap resamples). Thus, Hypothesis 4 was supported.

There are theoretical reasons to expect that PM may exacerbate the DL on BB as stated in Hypothesis 5. As shown in Table 5, the interaction of DL and PM ($DL \times PM$) was positively and significantly associated with EELT ($\beta = 0.207$, $p < 0.01$). On this basis, we next ran a simpler model with PM as moderator only, using Hayes’ (2013) PROCESS v3.3 Model 5. The bootstrap sampling interval estimation method was used for testing, and the repeated sampling times were set at 5000. If the 95% confidence interval did not contain 0, it would indicate that the regulating effect was significant.

TABLE 2: Fitting indexes of different factor models.

Models	χ^2/df	GFI	RMSEA	RMR	CFI	TLI	IFI
Five factors (DL; PM; EELT; BB; “method” factor)	1.380	0.952	0.027	0.020	0.986	0.983	0.987
Four factors (DL; PM; EELT; BB)	1.375	0.948	0.027	0.023	0.985	0.984	0.985
Three factors (DL + EELT; PM; BB)	5.397	0.686	0.092	0.053	0.826	0.808	0.827
Two factors (DL + EELT; PM + BB)	6.869	0.643	0.107	0.064	0.766	0.744	0.767
One factor (DL + PM + EELT + BB)	8.947	0.596	0.124	0.071	0.682	0.653	0.683

$N=517$. “+” represents two factors merged into one. DL, distributed leadership; PM, paradox mindset; EELT, exploratory-exploitative learning tension; and BB, bootlegging behavior.

TABLE 3: Descriptive analysis and correlations among variables.

Variables	1	2	3	4	5	6	7	8	9	10	11	12
(1) Gender												
(2) Age	0.024											
(3) Education	−0.033	−0.031										
(4) Work tenure	0.002	0.603**	0.075									
(5) Leader’s gender	0.142	−0.034	−0.005	0.010								
(6) Leader’s age	−0.044	0.200	0.037	0.180**	−0.053							
(7) Leader’s education	0.026	0.042	0.265**	0.130**	0.028	−0.101*						
(8) Relationship tenure	−0.029	0.180**	−0.035	0.297**	−0.009	0.056	0.040					
(9) DL	0.048	−0.001	−0.067	0.009	0.181**	−0.171**	0.050	0.031	0.744			
(10) PM	0.027	−0.008	−0.105*	0.032	0.153**	−0.084	−0.029	0.052	0.552**	0.746		
(11) EELT	0.107*	0.132**	−0.158**	0.163**	0.150**	−0.146**	−0.003	0.099*	0.343**	0.525**	0.786	
(12) BB	0.046	0.031	−0.078	0.063	0.086	−0.008	0.016	−0.016	0.440**	0.467**	0.440**	0.736
Mean	1.430	2.070	3.200	3.550	1.290	2.410	3.280	2.930	3.707	3.535	3.821	3.854
SD	0.496	0.975	0.540	1.788	0.453	0.921	0.638	1.342	0.627	0.643	0.777	0.646

$N=517$. DL, distributed leadership; PM, paradox mindset; EELT, exploratory-exploitative learning tension; and BB, bootlegging behavior; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; the diagonally bolded number is the square root value of AVE.

TABLE 4: Regression analysis results.

	EELT					BB			
	Mo 1	Mo 2	Mo3	Mo 4	Mo 5	Mo 6	Mo 7	Mo 8	Mo 9
Constant	4.038**	2.701**	3.894**	2.200**	2.372**	1.420**	1.299**	1.299**	1.325**
Gender	0.119	0.112	0.039	0.031	−0.005	−0.001	0.006	0.002	0.002
Age	0.051	0.047	−0.010	−0.015	−0.030	−0.029	−0.018	−0.022	−0.019
Education	−0.221**	−0.191**	−0.110*	−0.072	−0.027	−0.017	−0.025	−0.030	−0.035
Work tenure	0.066**	0.064**	0.032	0.030	0.007	0.011	0.009	0.013	0.011
Leader’s gender	0.224**	0.139*	0.111	0.003	0.027	−0.037	−0.048	−0.045	−0.049
Leader’s age	−0.147**	−0.107**	−0.005	0.046	0.051	0.077**	0.070*	0.066*	0.067*
Leader’s education	−0.012	−0.028	0.028	0.008	0.032	0.016	0.016	0.019	0.013
Relationship tenure	0.029	0.024	−0.020	−0.027	−0.031	−0.034	−0.038*	−0.037*	−0.038*
DL		0.363**		0.460**		0.355**	0.276**	0.249**	0.265**
EELT					0.377**	0.289**	0.216**	0.257**	0.235**
PM							0.195**	0.185**	0.187**
DL*PM							0.207**		0.174**
EELT*PM								0.151**	0.115*
R_2	0.116	0.196	0.022	0.207	0.203	0.304	0.340	0.336	0.346
ΔR^2	0.116	0.080	0.022	0.186	0.182	0.097	0.036	0.133	0.006
f^2	0.131	0.244	0.022	0.261	0.255	0.437	0.515	0.506	0.529
F	8.327**	13.720**	1.397	14.727**	14.378**	22.111**	21.638**	21.275**	20.465**

$N=517$. DL, distributed leadership; PM, paradox mindset; EELT, exploratory-exploitative learning tension; and BB, bootlegging behavior; * $p < 0.05$, ** $p < 0.01$.

The results showed that the 95% confidence interval [0.083, 0.326] did not contain 0 (the regulating effect was significant), which indicated that the moderating effect of paradox mindset existed.

We also employed a simple slope test to help make certain the moderating effect, and the results showed that when PM was low (M-1SD), the regression slope of DL in predicting BB was 0.142 ($p < 0.05$), with a 95% CI of [0.026,

TABLE 5: Results of mediating effect analysis moderated by PM.

		Effect	SE	95% CI	
				Boot LLCL	Boot ULCL
Mediation		0.085	0.018	0.053	0.123
PM	M-1SD	0.059	0.018	0.027	0.097
	M + 1SD	0.112	0.025	0.066	0.164
	CONTRAST	0.054	0.024	0.006	0.101

0.259], excluding 0, while when PM was high ($M + 1SD$), the regression slope of DL in predicting BB was 0.409 ($p < 0.01$), with a 95% CI of [0.288, 0.531], excluding 0. This forecasts that PM moderates the relationship between DL and BB. Figure 2 shows that when PM is higher, DL has a stronger promoting effect on BB. In conclusion, Hypothesis 5 was supported.

In this study, the moderating effect of PM between EELT and BB was tested. As shown in Table 5, the interaction of PM and EELT ($PM \times EELT$) can significantly predict BB of employees ($\beta = 0.151$, $p < 0.01$). On this basis, we next ran a simpler model with PM as moderator only, using Hayes' (2013) PROCESS 3.3 Model 14. The results displayed that the 95% confidence interval [0.062, 0.236] did not contain 0 (the regulating effect was significant), which indicated that the first-stage moderating effect of paradox mindset existed. We also conducted a simple slope test to help make certain the moderating effect, and the results showed that when PM was low ($M-1SD$), the regression slope of EELT in predicting BB was 0.151 ($p < 0.05$), with a 95% CI of [0.063, 0.240], excluding 0, while when PM was high ($M + 1SD$), the regression slope of EELT in predicting BB was 0.346 ($p < 0.01$), with a 95% CI of [0.235, 0.456], excluding 0. This indicates that PM moderates the relationship between EELT and BB. Figure 3 shows that when PM is higher, DL has a stronger promoting effect on BB. In conclusion, Hypothesis 6 was supported.

4.6. Supplementary Analysis. To further test this second-stage moderated mediation model, we ran a simpler model with PM as second-stage moderator, using Hayes' (2017) PROCESS 3.3 Model 15. The results are displayed in Table 5, and the indirect effect of DL on BB through EELT was various under different PM conditions. Specifically, the indirect effect was significant when PM is lower ($M-1SD$; $b = 0.059$, 95% CI [0.027, 0.097]). When PM was higher, the indirect effect was significant too ($M + 1SD$; $b = 0.112$, 95% CI [0.066, 0.164]). The difference in the conditional indirect effect was significant ($b = 0.054$, 95% CI [0.006, 0.101]). Subsequently, the second-stage moderating mediation effect of PM was tested.

In addition, in order to increase the reliability of the conclusion, the time of individual bootlegging innovation is used as an alternative measure of bootlegging innovation. The measure of individual bootlegging innovation time is to directly calculate the time that individuals have invested in unofficial innovation projects outside the official plan in the past years [17]. Therefore, the ratio of individual bootlegging innovation time to individual normal working time was used

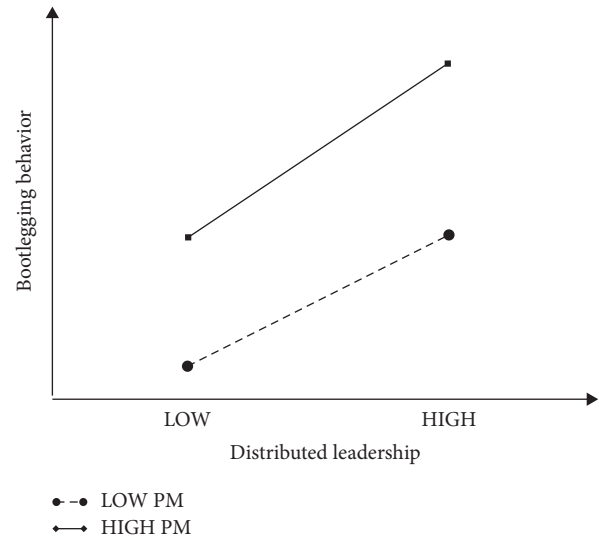


FIGURE 2: The moderating effect of PM on the relationship between DL and BB.

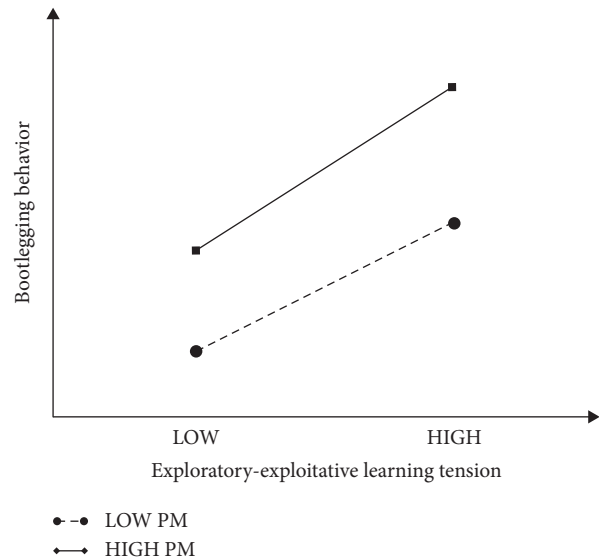


FIGURE 3: The moderating effect of PM on the relationship between EELT and BB.

as a substitute variable of bootlegging innovation. In this paper, a single sequential question was used to measure, that is, "what percentage of your total working time did you devote to bootlegging behavior last year?" Options include

"1 = 0%, 2 = [0, 5%], 3 = [5%, 10%], 4 = [10%, 15%], 5 = [15%, 20%], 6 = more than 20%". The analysis results show that the regression analysis results do not change significantly after using alternative variables, which proves the robustness of the research conclusions.

5. Discussion

Focusing on bootlegging behavior of knowledge-based employees is important, because bootlegging behavior is a particular organic part of organizational innovation, which widely exists in the workplace. We tested a moderated mediation model to explore how distributed leadership has an influence on bootlegging behavior of knowledge-based employees through the holistic perspective of organizational learning theory and paradox theory. Consistent with our expectations, the empirical results displayed that distributed leadership was positively associated with bootlegging behavior of knowledge-based employees, which was mediated by exploratory-exploitative learning tension. Furthermore, the results also showed that paradox mindset moderated the relationship between distributed leadership and bootlegging behavior, as well as the relationship between exploratory-exploitative learning tension and bootlegging behavior.

5.1. Theoretical Implications. This study affords several significant theoretical contributions. First, the study introduces the distributed leadership as the antecedent variable of bootlegging behavior and proposes its underlying theoretical model. Existing studies did not pay a comprehensive and systematic attention to the leader factors in the employee bootlegging innovation mechanism, which relevant researchers have constantly called for enriching [15]. In addition, some scholars believe that the success of bootlegging innovation lies in organization situation, not the bootlegging behavior itself [11]. Furthermore, some scholars suggest that the role mechanism of leaders on employees' bootlegging innovation should be discussed from the perspective of organizational norms [10]. We selected distributed leadership as the antecedent variable of bootlegging behavior, which could be considered as a direct response from three aspects: leader factors, organizational leadership situation, and organizational norms. We believe our research offers a beneficial framework that can be applicable for understanding other marginalized groups' bootlegging behavior.

Second, this study responds to the call of Globocnik and Salomo (2015) [16] to examine new theoretical lenses by which we might conclude the paradoxical nature of bootlegging behavior. There has been controversy about the role of distributed leadership on employee creativity, which is due to the failure to clarify the boundary between bootlegging innovation and in-role innovation [28]. By focusing on the impact of distributed leadership on bootlegging innovation, we respond to the controversy to some extent. Our results not only support the logical reasoning proposed by Globocnik and Salomo [16], but also open a new theoretical lens to go to show the influence of distributed leadership on bootlegging behavior.

Third, this study also has some crucial implications for the organizational learning tension literature. Previous studies believe that distributed leadership can stimulate employees' exploratory and exploitative behavior [28], and distributed leadership can directly promote individual exploratory learning and exploitative learning (the levels of exploratory activities and exploitative activities are both high) [62]; however, there is still a lack of research on distributed leadership and exploratory-exploitative learning tension. Based on the perspective of organizational learning theory, we discuss the mediating role of exploratory-exploitative learning tension between distributed leadership and employees' bootlegging innovation. Our results also show that individuals' conceptions of their exploratory learning and exploitative learning as a kind of tension drive this process. In addition, we consider distributed leadership as a leadership situational factor to stimulate employees to integrate exploratory learning and exploitative learning, which expands the research on the antecedents of exploratory-exploitative learning tension.

Fourth, this study also has implications for the paradox mindset literature. Previous studies have found that individuals can obtain creative value from the paradox framework, and employees with paradox mindset can promote job performance and innovation by using tension [63]; however, there is still a lack of research on the interaction between leadership factors and individual differences from the perspective of paradox. Our research shows that individuals with high paradox mindset are potential to obtain creative value from distributed leadership situations, which is also corresponding with the research results of Berraies et al. [33]; that is to say, employees with high paradox mindset can actively respond to and make use of tension. In addition, we discuss how employees' paradox mindset, as a boundary condition, affects the effectiveness of distributed leadership and conforms to the call for strengthening the study of paradox from an individual perspective [64]. It may also stimulate future research to examine how cognitive processes that are highlighted in paradox mindset illuminate other organizational phenomena.

5.2. Practical Implications. Our findings also have some useful practical implications for individuals and enterprises. First, we recognize that bootlegging behavior of employee does not occur randomly; as a matter of fact, it can be influenced by the organizational leadership pattern. Under the distributed leadership pattern, managers can facilitate bootlegging by granting work autonomy, and prior research has suggested that this restriction may impede all innovative behaviors [16, 65]. On the one hand, formal leaders should increase resource support for employees' innovation; they can also take some measures to promote bootlegging innovation behavior among employees. On the other hand, formal leaders with an encouraging attitude toward bootlegging may stimulate this deviance by providing rewards for innovation accomplishments and improving their failure tolerance, so employees have the freedom and resources to come up with new ideas inside and outside of work.

Second, the results suggest that the distributed leadership pattern can foster bootlegging innovation to a certain extent by encouraging heterogeneous knowledge learning. Formal leaders of the organization should encourage employees to strengthen exploratory learning and exploitative learning. In addition, rather than resorting to one or the other extreme, our results suggest that senior leaders should simultaneously aim to promote both high levels of exploratory learning and high levels of exploitative learning.

Third, our findings are particularly helpful for the recruitment and training of employees in innovation organizations. It can be predicted that paradox mindset will become advocated by enterprises [66]. It is easy for employees with high paradox mindset in the organization to perceive the tension between paradoxical elements and they are good at integrating contradictory elements. Therefore, organization managers should pay attention to selecting employees with high paradox mindset and allocate them to jobs with innovative needs, to promote employees to give full play to the creative value of paradox mindset. In addition, organizations should increase training of informal and potential leaders with heterogeneous knowledge and make them aware of the positive shaping effect of their paradoxical mindset for employees' bootlegging behaviors which can benefit the organization.

5.3. Limitations and Future Research Directions. While our findings have both theoretical and practical implications, we realize that there are still some associated limitations that might be undertaken in the following research. First, the sample relied only on two Chinese large information technology companies. Although data hold all research hypotheses, our findings can only be interpreted within the setting in which they were derived and may not be applicable to organizations in other countries. In the following research, we should add diverse samples from other countries with cultural differences to make the research conclusions universal worldwide.

Second, our study explores the mediating effect of exploratory-exploitative learning tension; it is undeniable that there exist many other possible mechanisms in the relationship between distributed leadership and bootlegging behavior. For example, psychological entitlement plays an important role in the relationship between organizational context and bootlegging behavior of employees [67]. Besides, job autonomy perspective may be a beneficial way to conclude the emergence of employees' bootlegging [68]. Not only that, we cannot ignore that future research also needs to examine the impact of other boundary conditions, and more deep studies can be done to draw the outline of map for the bootlegging behavior literature.

Finally, considering the concealment and social approval of bootlegging behavior, data in this research are collected from the employees' self-statement. Although efforts were made to reduce common method biases, risk still exists. Therefore, further research can utilize other more appropriate methods, such as text analysis, quasi-experimental design, and cross-lagged method to examine the dynamic

relationship between distributed leadership and bootlegging behavior to obtain more robust conclusions.

6. Conclusion

This study was motivated not only to recognize how organizations experience bootlegging innovation in the evolution of organization development, but also to learn about the paradox mindset that drive to resolve these tensions. Based on the integrated perspective of paradox theory and organizational learning theory, this study generalizes bootlegging behavior as a process including the tension between competing learning needs in the context of distributed leadership. While enriching the mediating conditions of the effect of exploratory-exploitative learning tension on employees' bootlegging behavior, this study expands the theoretical application of paradox mindset as a moderating variable. Viewed holistically, our study provides ideas for organizations to correctly deal with employee bootlegging behavior, introduces a new research direction into this field, helps to understand the formation process and action mechanism of bootlegging behavior more deeply, and more comprehensively explains the application value of paradox theory in organizations.

Data Availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

Reorganization Reaction Characteristics between Different Volatile Content and Waste Pyrolysis

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In order to obtain the ideal high-value product and recognize the contribution of various waste components to the final product, each typical single component of domestic waste was pyrolyzed separately, the volatile was reformed with half coke at 600°C, and the yield and components of the reforming gas and liquid were analyzed. The investigation was followed by the results: after reforming, the yield of the gas is the highest, reaching 66.40 wt.% of plastic air-dry weight, 119.74% higher than before reforming, the highest yield, 37.22 wt.% of kitchen waste air-dry weight, only 2.21% lower than before reforming. At the same time, after plastic pyrolysis volatile reforming, H₂ production is the highest, 13.14 mol/kg of air-dry-based plastic, and the largest molar fraction in the reforming gas, 37.33 mol%. Compared with the results of single-component pyrolysis-reforming and multi-component waste copyrolysis-reforming results, the multicomponent copyrolysis-reforming process promotes hydrolysis de-oxidation, electrolyte-water vapor reforming and cracking reaction, chain hydrocarbon looping and aromatic dehydrogenation reaction, hydrogenation gasification reaction and methylation reaction, copyrolysis-reforming H₂, CO₂ production, and less oxygen content in the liquid.

1. Introduction

The diversity of waste pyrolysis products and the difficulty of direct use of oil and carbon, and the unfixed market of products are important reasons that hinder the separate commercialization of the waste pyrolysis process. If simple and effective technologies can be used to improve the quality of oil and gas and use the half coke, the pyrolysis process itself can become an independent waste treatment technology, which will greatly improve the environmental protection and economy of waste disposal. However, the use of hydrolysis and semi-coke is not clear at present. Although there are many reports on hydrolysis, especially the utilization of semi-coke, the overall economical and feasible high-value transformation technology of pyrolysis products is still very lacking. In view of such demand and the current situation, more and more people pay attention to the quality improvement method of pyrolysis products.

The author before the References [1, 2] of the pyrolytic half coke reforming volatile method, already after reforming products, the city waste volatile by homologous waste pyrolytic half coke reforming conditions are selected, but different sources of volatile and half coke reforming products in the process of specific reaction mode and mechanism are not clear [3, 4].

Household waste, as a mixture, its various typical single components due to their own physical and chemical characteristics; the volatiles produced vary widely; it reacts differently between reforming section and half focus at high temperature; and the volatilization produced by different components and the semifocal reaction process will interact, the restructuring process is very complicated.

In this article, based on previous studies, select the appropriate reforming temperature, semi-coke/volatile ratio, and volume airspeed, to study the volatilization produced by the pyrolysis of the typical components of different municipal solid waste, after the reforming reactor, changes

TABLE 1: Typical component element analysis and industrial analysis and calorific value of household waste.

Sample	Elemental analysis (empty dry base, wt.%)				Industrial analysis (empty dry base, wt.%)				HHV (empty dry base, MJ kg ⁻¹)
	C	H	N	O	Water content	Volatile matter	Fixed carbon	Ash content	
Plastics	80.02 ± 0.87	10.71 ± 0.54	0.11 ± 0.01	4.74 ± 0.89	0.85 ± 0.08	90.40 ± 1.54	4.61 ± 0.34	4.14 ± 0.29	30.37 ± 0.88
Cotton cloth	55.62 ± 0.69	5.31 ± 0.45	0.32 ± 0.02	34.04 ± 1.51	3.17 ± 0.14	85.32 ± 2.01	9.97 ± 0.75	1.53 ± 0.11	18.25 ± 0.91
Kitchen waste	40.35 ± 0.55	5.98 ± 0.37	1.92 ± 0.02	20.67 ± 1.15	10.79 ± 0.32	64.73 ± 1.54	4.19 ± 0.28	20.29 ± 0.30	15.36 ± 0.71
Paper products	35.28 ± 0.63	5.36 ± 0.41	0.79 ± 0.01	40.72 ± 1.23	6.16 ± 0.29	70.86 ± 2.17	11.29 ± 0.13	11.69 ± 0.26	14.40 ± 0.59
Sizing remnants	27.74 ± 0.67	2.33 ± 0.22	1.00 ± 0.01	5.43 ± 0.87	10.30 ± 0.43	16.67 ± 1.11	1.63 ± 0.22	57.76 ± 0.47	7.39 ± 0.36

The oxygen element content was calculated by the difference method.

in the reforming product distribution and components, in order to understand the product characteristics of different waste pyrolysis and study the specific reforming effect of waste pyrolysis on different sources as a regulation means to control the final product [5].

In addition, from the previous research, the pyrolysis in the reforming to produce a large amount of gas, the amount of gas can be reduced, and the thick cyclic aromatic hydrocarbons can be removed. In order to understand the difficulty of the lysis and removal of different components in the hydrothermal solution, the thermal electrolyte section was divided into oil and water phases to observe the characteristics of the reaction products [6]. Typical single components of urban garbage include components, including plastic, cotton, kitchen waste, paper, and sorting residue, to conduct the experiment [7].

2. Materials and Methods

Elemental analysis, industrial analysis, and calorific value results of each typical single component of MSW are shown in Table 1.

According to the element analysis, industrial analysis, and calorific value in Table 1, cotton cloth, kitchen waste, and paper are quite similar and quite different from plastic.

The experiment investigated the influence of the volatiles produced by each typical single component of household waste on the volatile process of semi-focus reforming. The experiment was completed on the experimental device system shown in Figure 1. In each group of experiments, plastic, cotton cloth, kitchen waste, paper, sorting residue, and MSW samples were added to the pyrolysis reactor for each component is 100 g, the final temperature of the pyrolysis furnace is still set at 500°C and the nitrogen flow rate is 20 ml/min in the pyrrole reactor. In the pyrolysis/reforming reaction, the guaranteed C/V mass ratio is 1.5, the bulk air velocity is 700 h⁻¹, and the reforming reactor temperature is 600°C. Each garbage fraction was averaged two times.

3. Results and Discussion

3.1. Yield. As shown in Figure 2, the gas and oil output (based on the air dry base quality of the single component) of the typical organic components (plastic, cotton, kitchen

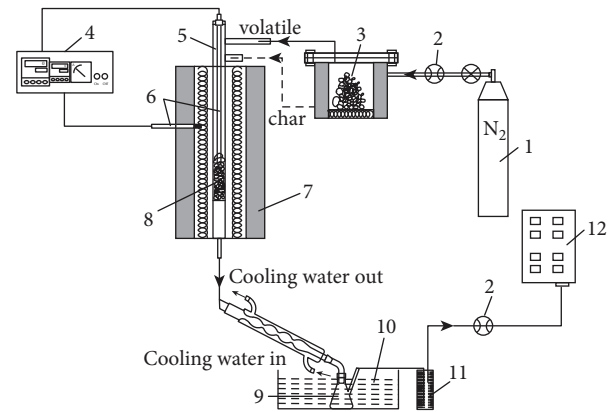


FIGURE 1: Flow diagram of domestic waste pyrolysis-reforming device. (1) Nitrogen bottle; (2) flowmeter; (3) pyrolysis reactor; (4) temperature control device; (5) volatile reforming reactor; (6) thermocouple; (7) heating furnace; (8) half coke from reactor 3; (9) liquid collecting device; (10) ice water mixture; (11) filter; (12) airbag.

waste, paper, and sorting residue) is given, and the gas and oil output of the actual waste is compared.

The calculated value (calculated result) in Figure 2 is weighted by multiplying the yield of each single component by its mass fraction in the actual garbage. The calculation formula is as follows.

In the formula, Y_i is the yield rate of each single component and A_i is the proportion of the corresponding single component in the whole garbage fraction, as shown in Table 1. The calculated values mentioned later in this article are also calculated by this method. In Figure 2, the difference between MSW (actual garbage) and the calculated result indicates the result of each component interaction effect.

Judging from Figure 2, after pyrolysis, sorting the residual volatile production (the sum of gas yield and liquid yield) is 21.57% and cotton is 75.68%, volatile production mainly depends on the material composition and material particle size; all kinds of the single components in this experiment are kept uniform size (10 mm), so the volatile acquisition rate is mainly determined by the component properties.

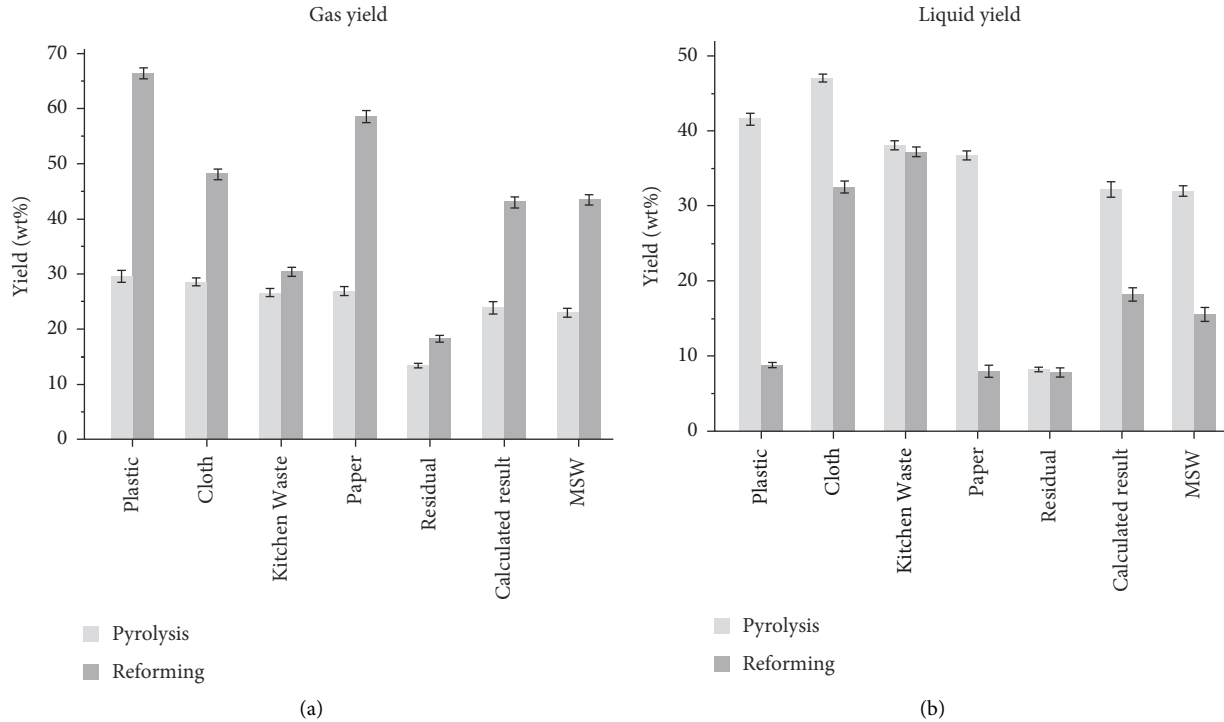


FIGURE 2: Distribution of products before and after volatile reforming of each typical single component of household waste ($T_{\text{reform}} = 600^{\circ}\text{C}$). (a) Gas yield. (b) Liquid yield.

Samples used in this paper-plastic, cotton, kitchen waste, paper, and sorting residual are taken from the actual household garbage, with impurities such as dirt, sorting residual is some small cannot be selected organic matter (including plastic, cotton, kitchen waste, and paper) and muck, ash, fine sand glass, and other inorganic mixture. The inorganic material of cotton cloth selected in garbage has low impurity content and high organic composition, so the yield of volatile content in the pyrolysis process is high, and the sorted residual component contains more impurities such as sand and soil, so the volatile content produced by pyrolysis is less.

Figure 2 also shows the distribution of whole component waste pyrolysis products and the weighted calculation of prediction results are consistent and shows that the single-component pyrolysis conforms the general organic solid waste after pyrolysis distribution, through the single component of volatile and half coke reaction behavior analysis to reveal the whole component of waste volatile and half coke reforming reaction behavior.

According to the single component, half coke yield and quality fraction in the actual garbage can calculate the half coke source, as shown in Figure 3, sorting residual pyrolysis of half coke for more than half (53.57 wt.%), biomass raw materials (paper, kitchen waste, and cotton) pyrolysis half coke accounted for 32.19% of the total half coke, plastic pyrolysis half coke accounted for half coke 14.24 wt.%.

After reforming, the gas yield of each component increases. On the one hand, the increase of the gas yield benefits from the thermal electrolyte component in the volatile process into the gas and the semi-coke reaction, and

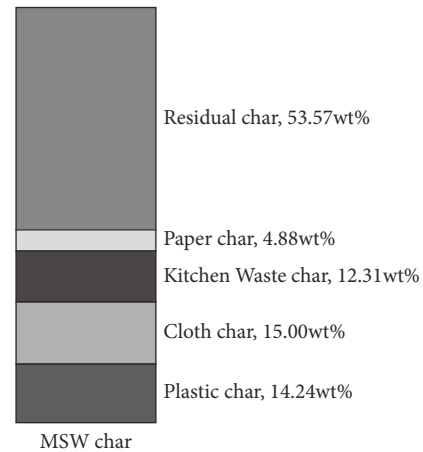


FIGURE 3: Semifocal composition for reforming.

on the other hand, the semi-coke of the reforming section will also produce a part of the gas, as seen in the analysis in Section 3. The gaseous product yield is the highest, reaching 66.40 wt.% of its own mass, which is 119.74% higher than before reforming. This result shows that the condensing components in plastic pyrolysis volatiles are easy to crack in semi-coke catalytic reforming; but for kitchen waste, the volatile liquid product yield is the highest, reaching 37.22 wt.%, only 2.21% lower than before reforming.

The condensing component is difficult to be cracked because plastic volatiles mainly contain long-chain hydrocarbons, as shown in Figure 4, while biomass (kitchen waste mainly living substances) mainly aromatic compounds,

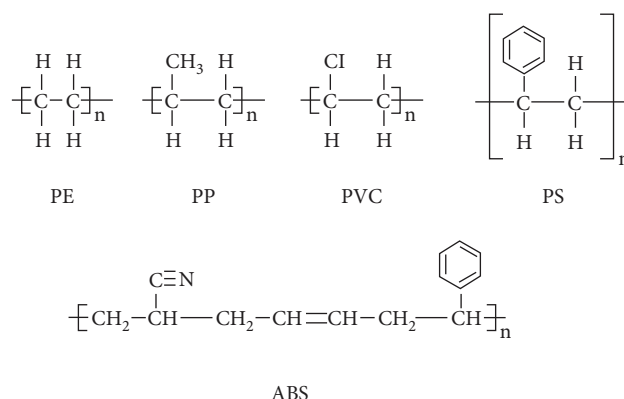


FIGURE 4: Molecular structure of the typical plastics.

long-chain hydrocarbons are easier to break as small molecular gas than aromatic compounds. Therefore, in order to obtain more gas products, the proportion of plastic in the mixed garbage can be increased.

Compared with the distribution of the actual waste products, the gas yield is slightly higher, and the liquid yield is reduced, which may be due to the condensation reaction between some condensable components in the actual waste volatiles to generate carbon and gas.

3.2. Reforming Gas Components. Figure 5 shows the main gas production obtained after the reforming of each typical single component and the calculated value and the actual waste pyrolysis.

After separate pyrolysis: CO₂ production in volatile gas of kitchen waste decreased slightly from 4.68 mol/kg (empty dry base kitchen) to 3.44 mol/kg (empty dry base kitchen); the output of each gas component in sorted residual volatile gas does not change significantly; after the volatilization obtained by separate pyrolysis, the production of all gas components increases.

According to the research results including Wu [8] and Wen Wen[9], biomass components include paper, kitchen waste, and cotton cloth. Because they are mainly composed of cellulose, hemicellulose, and lignin, they are called similar components in the study. In the whole component waste pyrolysis, the thermal effect of the first reaction has an impact on the later reaction, which may make the later reaction pyrolysis at a lower temperature, or even merge the later reaction into the previous reaction [10, 11].

The study [12] by Stöcker showed that under the heating conditions of 10°C/min program, cotton cloth, kitchen waste, and paper occurred in the temperature range of 230–400°C, the plastic weight stage occurred at 350–500°C, and the plastic may be below 350°C, in the whole component waste pyrolysis. Therefore, the first entering the reforming section is the cotton, kitchen waste, and paper pyrolysis volatile mixture, and then the cotton, kitchen waste, paper, and plastic volatile mixture [13]. Finally, when the basic pyrolysis of cotton, kitchen waste, and paper is completed, part of the plastic volatile may enter the reforming section

alone. Therefore, in the volatile reforming section, each single-component pyrolysis volatile will affect each other during the half-focal reaction [14].

The production of H₂, CH₄, C₂H₄, and C₂H₆ increased most significantly after reforming, and these four gases showed a large increase [15, 16], and the specific changes are shown in Table 2. This is because plastic is made up of many monomers by covalent bond polymer, mainly composed of carbon, hydrogen, and other elements, so the pyrolysis volatile components are relatively simple, in the process of reforming, there are some in pyrolysis process decomposition of long-chain hydrocarbons, fracture, C₂H₄, and C₂H₆, at the same time aromatic hydrocarbons dehydrogenation and demethylation reaction.

In this experiment, cotton cloth, kitchen waste, and paper belong to biomass organic solid waste, due to the high oxygen content of biomass raw materials (about 40% quality fraction); therefore, its pyrolysis volatile content contains a large amount of oxygenic organic matter. The production rate of aerobic gases (CO and CO₂) changes significantly, and the output of CO₂ and CO increased from 3.50 mol/kg (air dry paper) and 3.54 mol/kg (air dry paper) to 7.46 mol/kg (air dry paper) and 6.99 mol/kg (air dry paper), respectively. The yield of CO₂ and CO increased from 4.64 mol/kg (air dry-based cotton) and 2.23 mol/kg (air dry cotton) to 4.08 mol/kg (air dry cotton) and 6.42 mol/kg (air dry cotton), respectively. After the reorganization of the kitchen waste volatilization content, the laws of change vary somewhat, CO₂ production decreased from 4.68 mol/kg (empty dry base kitchen) to 3.44 mol/kg (empty dry base kitchen surplus), and CO production increased from 1.69 mol/kg (empty dry base kitchen) to 3.63 mol/kg (empty dry base kitchen). As mentioned above, CO and CO₂ are mainly produced by the decomposition of carboxyl groups and groups in some acids, aldehyde, alcohol, and other components, while CO and CO₂ of biomass components paper, cotton, and kitchen waste change significantly before and after reforming indicating that the content of aerobic organic matter in acids, aldehyde, and alcohols is higher than that of plastics. Comparing the plastic pyrolysis volatile and biomass pyrolysis volatile gas after reforming production can be seen that the yield of plastic volatile gas increased

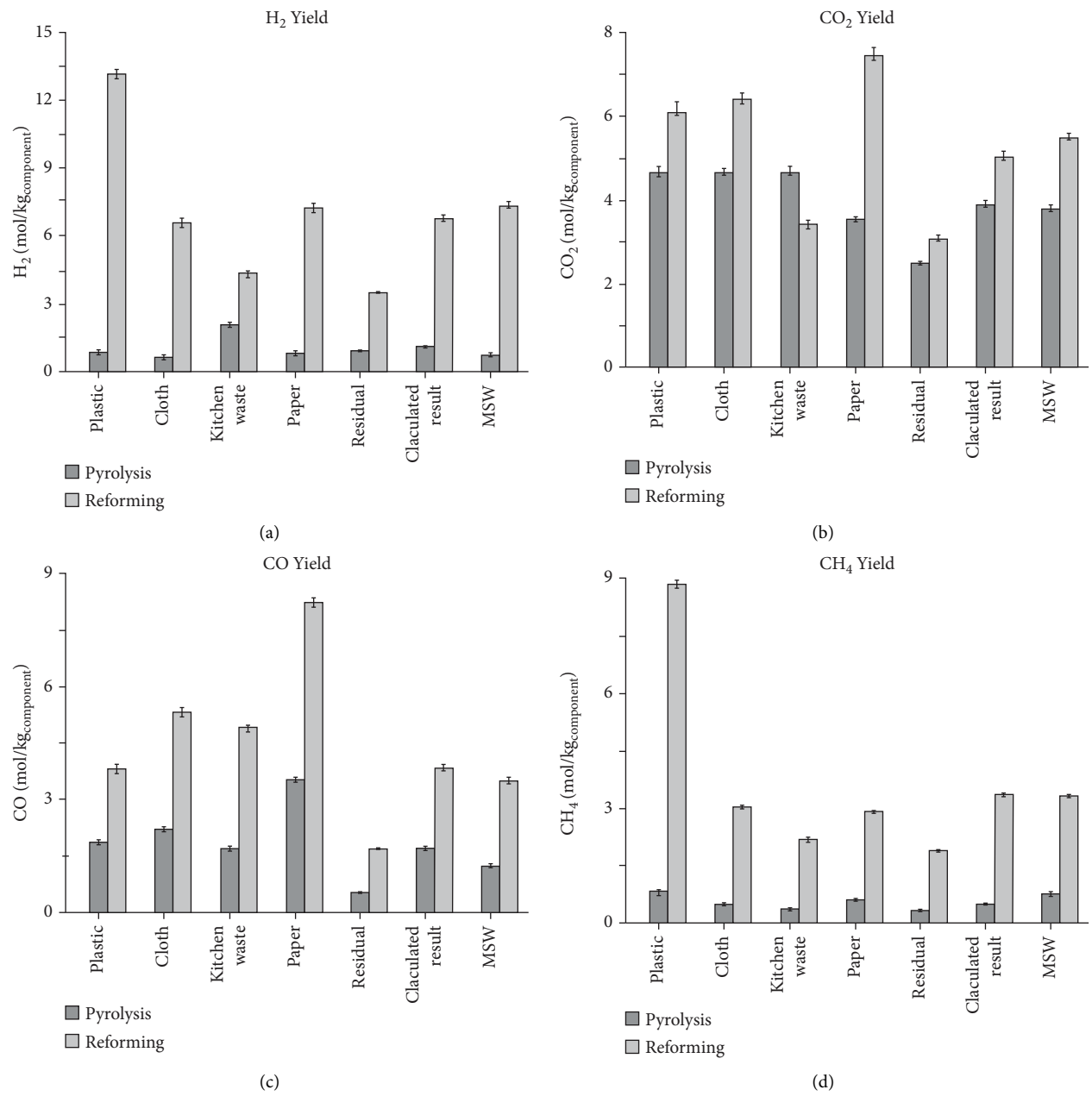


FIGURE 5: Continued.

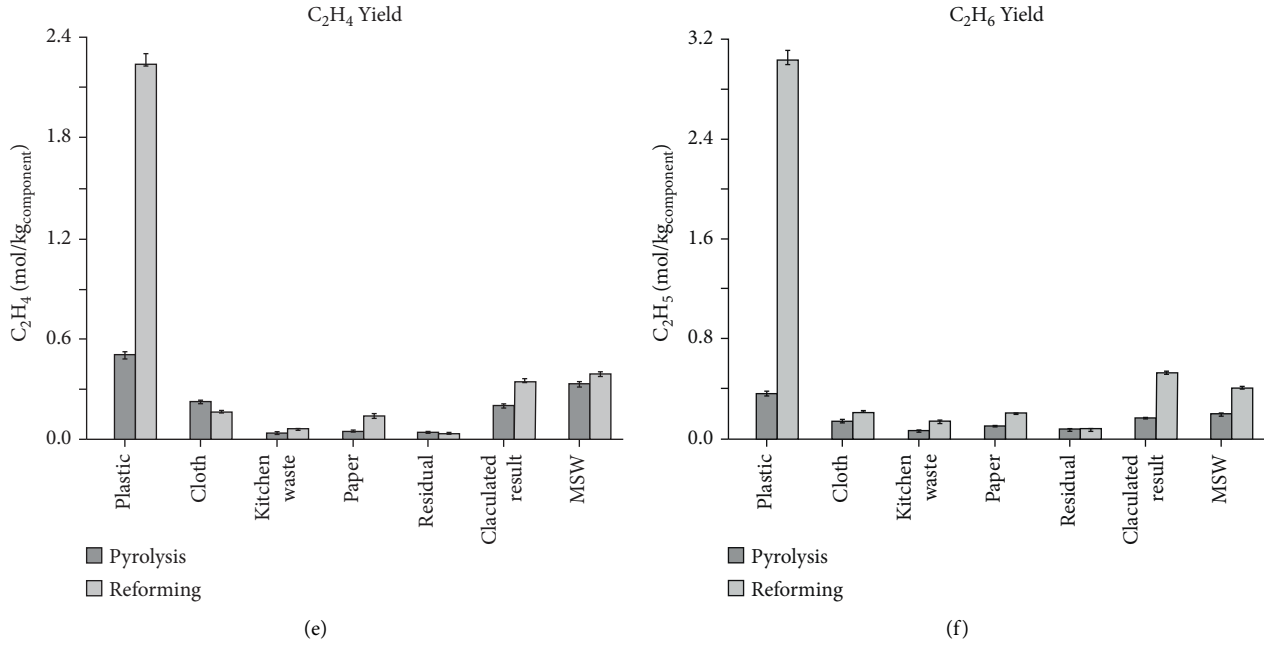


FIGURE 5: Main gas production (mol/kg component) after pyrolysis of waste $T_{\text{reform}} = 600^\circ\text{C}$. (a) H_2 yield. (b) CO_2 yield. (c) CO yield. (d) CH_4 yield. (e) C_2H_4 yield. (f) C_2H_6 yield.

TABLE 2: Changes of main gas production before and after plastic reforming.

Gas component	Before restructuring mol/kg (empty dry base plastic)	After restructuring mol/kg (empty dry base plastic)	Growth rate (%)
H_2	0.88	13.14	1393
CH_4	0.84	8.83	951
C_2H_4	0.50	2.24	348
C_2H_6	0.35	3.04	769

more obviously, indicating that in high temperature and half coke reforming conditions, the reactivity of different components is different, the long-chain fatty hydrocarbons and aromatic hydrocarbons reactivity is higher than oxygen-containing substances [17].

In Figure 5, for pyrolysis gas production, the distribution of waste pyrolysis gas products in the whole fraction is CH_4 high, H_2 low, and low compared with the weighted calculated values of each garbage component. From Figure 2, cothermolysis has little effect on the distribution of the product, so the difference between various gas production alone and copyrolysis is mainly caused by the coexistence of the pyrolysis, such as the low thermal conductivity of plastic, the heating rate of copyrolysis is faster than plastic alone, resulting in high CH_4 , C_2H_4 , and C_2H_6 . The increase in CH_4 production may be due to the reverse reaction of methane water vapor reforming reaction, hydrogenation gasification reaction, and methylation reaction; the increase of C_2H_4 and C_2H_6 production may be inhibited by water vapor reforming reaction, steam reforming cracking reaction, and dry reforming reaction; and the above reaction of CH_4 , C_2H_4 , and C_2H_6 production is suppressed, corresponding to the production of H_2 , CO_2 , and CO .

For reforming gas production, the actual H_2 , CO_2 , and C_2H_4 of the whole component waste pyrolysis-reforming gas product distribution is high, while CO , CH_4 , and C_2H_6 are low compared with the weighted calculated value of each waste component. Compared with the discussion above, the actual waste pyrolysis gas product distribution and the weighted calculated value of the garbage components, H_2 production from low to high, combined with the actual liquid yield in Figure 2, shows that copyrolysis volatile reforming, chain cyclization, and aromatic dehydrogenation reaction is more intense. The CO_2 production from actual high to low indicates that cothermolysis is more sufficient; the actual CH_4 and C_2H_6 production are converted from high to low for reforming and hydrocarbon cracking, and the CH_4 production is converted from high to low indicating that the reforming reaction of methane, hydrogen gasification reaction, and methane are strengthened.

Figure 6 shows the molar concentration of the main gas in the gas obtained after reforming each typical single component, calculated value, and pyrolysis volatilization of the actual garbage, respectively.

After reforming, the volatile content produced by each single component decreases only for the mole fraction of H_2 ,

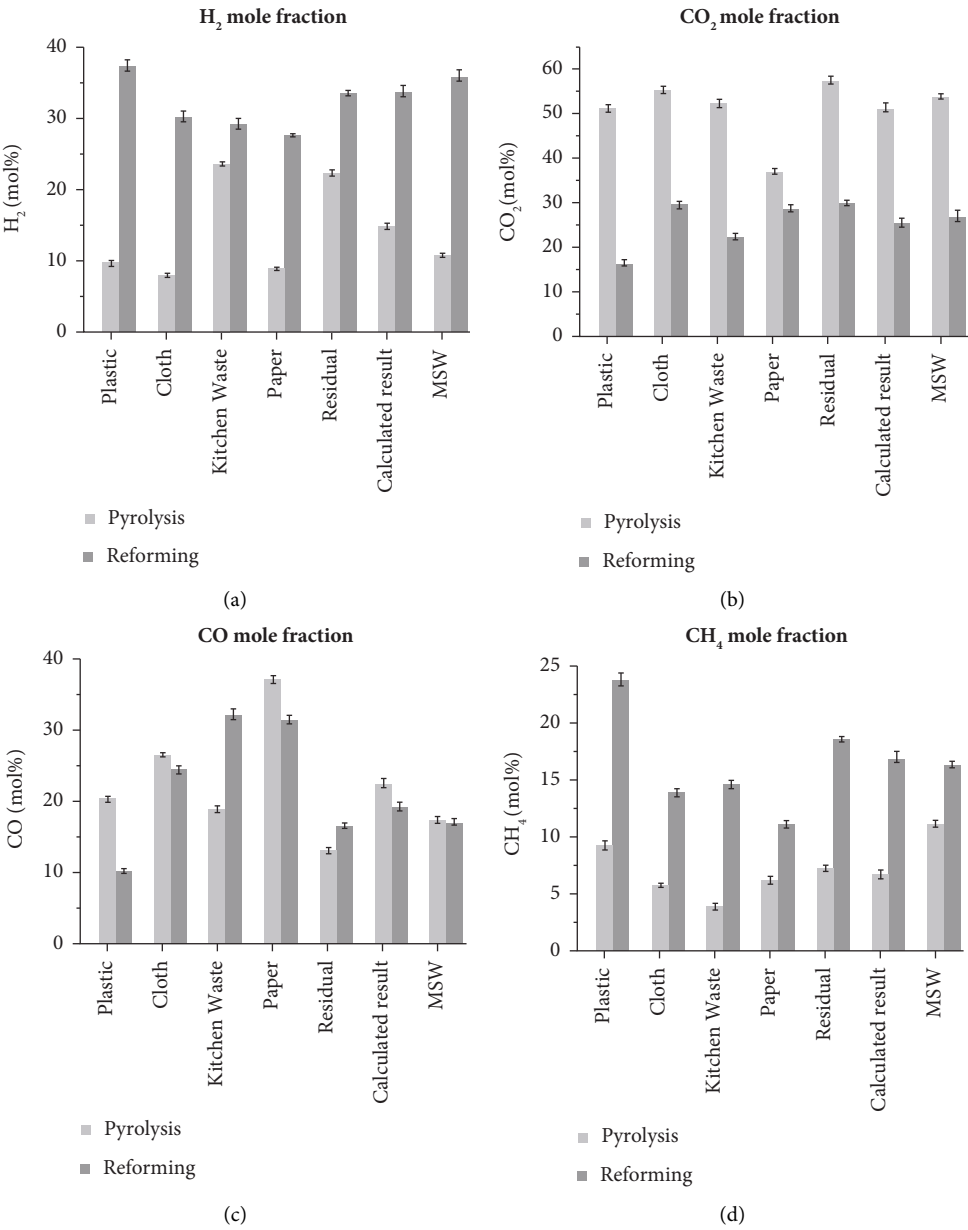


FIGURE 6: Continued.

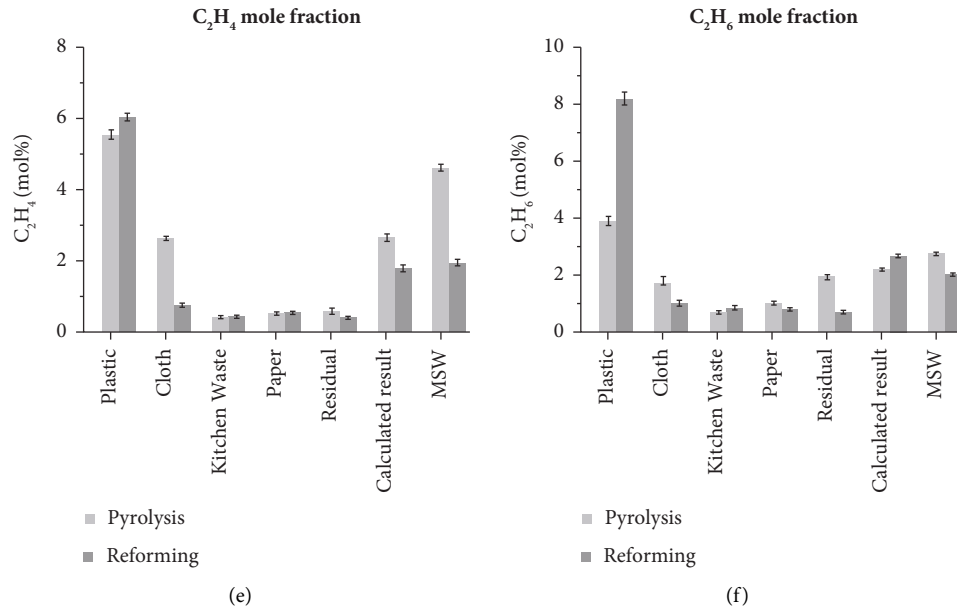


FIGURE 6: Molar fraction (mol%) of main gas after pyrolysis of waste Treform = 600°C. (a) H_2 mole fraction. (b) CO_2 mole fraction. (c) CO mole fraction. (d) CH_4 mole fraction. (e) C_2H_4 mole fraction. (f) C_2H_6 mole fraction.

while the remaining single components increase. Especially for plastics, the H_2 ratio after reforming is 37.33 mol%, increasing by 247.84%, which is 1.60 times the volume concentration of H_2 in the kitchen waste reforming gas. Compared with the CO_2 molar fraction in the reforming gas, the plastic decreased by 62.87%, and the remaining garbage components were also reduced, but the CO_2 reduction of paper and sorting residues was not obvious, reduced by 4.03% and 4.04%, respectively. For the CO mole fraction in reforming gas, only the molar fraction in specific pyrolysis gas is increased after reforming, and the CO mole fraction in kitchen waste reforming gas reaches 35.88 mol%, increasing by 89.37%; the lowest CO mole fraction in sorted residual reforming gas is only 8.70 mol%, 33.49% lower than the molar fraction in pyrolysis gas. The highest molar fraction of CH_4 , C_2H_4 , and C_2H_6 in the reforming gas appeared after the reforming of plastic volatilization, and the most obvious increase in molar fraction compared with pyrolysis gas was mainly due to the high H/C ratio in plastic. After reforming, the molar fraction of CH_4 in cotton, kitchen waste, paper, and sorting residue also increased. Combined with Figure 5, the increase rate of CH_4 in the single component reforming gas mentioned above is greater than the average growth value of its reforming gas. Cotton and sorting residues after reforming, both C_2H_4 and C_2H_6 molar scores decreased. Combined with Figure 5, the production of C_2H_4 and C_2H_6 in cotton also increases, so the molar fraction of C_2H_4 and C_2H_6 decreases because the increase rate of C_2H_4 and C_2H_6 in cotton reforming gas is less than the average value; the residual C_2H_4 and C_2H_6 decrease because the yield of C_2H_4 and C_2H_6 in the sorting residue remains basically unchanged, while the total output of reforming gas is increasing [18].

According to the above results, the most effect on plastic volatile reforming, the volume fraction of H_2 , CH_4 , C_2H_4 , and C_2H_6 ; CO and CO_2 mole fractions significantly reduced. Therefore, the reforming gas with higher H_2 , CH_4 , C_2H_4 , and C_2H_6 mole fractions and lower CO and CO_2 mole fractions can be obtained by increasing the plastic mass ratio in the thermolysis section garbage. After reforming, kitchen waste volatilization is the only component that can increase the CO mole fraction, so the CO volume fraction in the reforming gas can be regulated by adjusting the mass ratio of kitchen waste in the pyrolysis section.

After reforming, the actual waste pyrolysis fraction is reduced from 4.59 mol% to 1.92 mol%, while C_2H_6 is basically unchanged, mainly because during the catalytic lysis of pure hydrocarbons, the same number of carbon atoms is arranged in the following order: alkane > alkane > alkane > aromatics. Because the olefins have double bond electrons, protonic acid with catalytic effect is favored.

3.3. Fractions of the Reforming Fluid. After volatile reforming, the distribution of aqueous and oil phases in the liquid products of each single component is shown in Figure 7. Aqueous phase products are mainly composed of water and some water-soluble organic matter, such as the small molecular weight of aerobic organic matter containing acetic acid, methanol, and acetone.

Because cotton cloth, kitchen waste, and paper are composed of cellulose, hemicellulose, and lignin, they will produce a lot of water in the process of pyrolysis, so the pyrolysis volatile of cotton cloth, kitchen waste, and paper contain a lot of water, and the aqueous content in the final reforming liquid is also higher. In the liquid obtained after

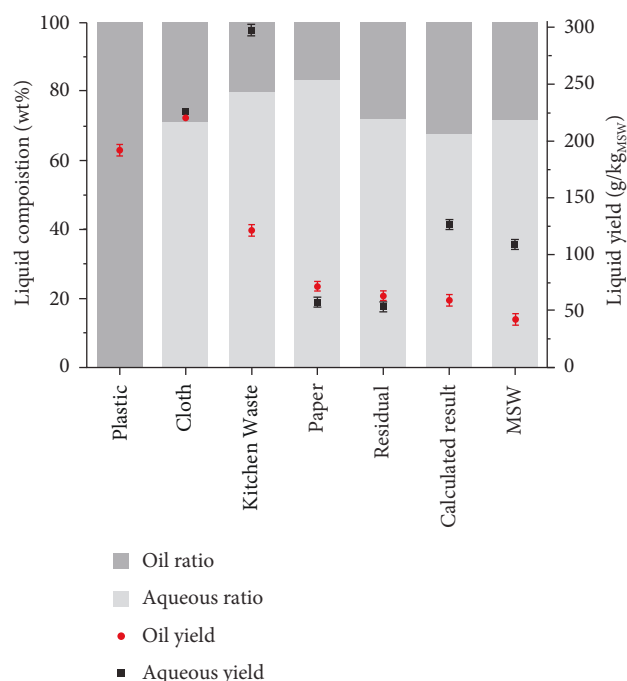


FIGURE 7: Distribution and yield of aqueous and oil phases after reforming of different typical single-component pyrolysis (T_{reform} = 600°C).

reforming of paper, the concentration of the reforming liquid is the highest: 297.39 g/kg (empty dry base kitchen surplus).

The water content of plastic pyrolysis volatiles is relatively low, mainly because plastic is composed of relatively single polymer organic compounds, the water of the thermal electrolyte is a small amount of physical water brought by the plastic sample, so its volatilization after reforming to get the liquid contains no aqueous phase. Although the proportion of the oil phase in plastic pyrolysis and volatile liquid products is high, the liquid yield is low after reforming, and most of the oil phase is decomposed during the reforming process. The yield of the liquid oil phase is the highest at 218.68 g/kg (empty dry-based cotton cloth).

The reforming fluid and oil phase component is still divided into six categories as described in the previous chapter: (1) aerobic heterocyclic rings, mainly including phenol, alcohol, lipids, ketones, and carboxylic acids; (2) light aromatic (1 benzene ring), usually single-ring light hydrocarbons, which do not constitute a problem about condensation and solubility. Main components include benzene, toluene, ethylbenzene, xylene, and styrene; (3) nitrogen ring, mainly including pyridines, amines, nitrile, and amides; (4) light polycyclic aromatic compounds (2–3 benzene rings), usually contain 2–3 benzene rings, even at a very low concentration, will be concentrated at low temperature. Main components are ind, naphthalene, methyl naphthalene, biphenene, ene, and anthracene; (5) fat hydrocarbon compounds, mainly including alkanes, alkenes, and cycloalkanes. (6) Heavy polycyclic aromatic hydrocarbon compounds (4–7 benzene ring), attributes greater than 3 benzene ring, these

compounds will also condense in low concentration, high temperature conditions. The main ingredients are phenanthrene, pyrene, flexion, and hexabenzene. The GC-MS measurement is performed by qualitative measurement method, so the percentage of a liquid component refers to the proportion of the peak area of the substance in the total ion flow map to the total area of all detected objects.

Figure 8 shows the proportion of the resulting oil phase components in the typical single-component pyrolysis volatilization after reforming.

After reforming, the pyrolysis volatilization of plastic oxygenation in the liquid completely disappeared, only hydrocarbons, mainly aromatic hydrocarbons, among which the single-cyclic aromatic hydrocarbons contain the highest content, reaching 70.48 area%, which increased by 420.53% compared with before reforming. Next by fatty hydrocarbons containing 14.16 area%; besides light polybenzene ring (2–3) 13.36 area%, while heavy polybenzene ring components completely disappeared. The reforming solution does not contain nitrogen compounds, because the plastic itself contains almost no nitrogen elements.

Kitchen waste in this experiment mainly includes all kinds of fruit shells and leaf and other biomass components, the nitrogen content is high, so the electrolyte nitrogen compounds quality fraction is the highest, after reforming nitrogen compounds absolute value also decreased, but the mass fraction still rose slightly, from before reforming 18.30 area% to 19.19 area%, mainly because the reaction activity of nitrogen compounds and other components, so nitrogen compounds removal efficiency is lower than the overall removal level.

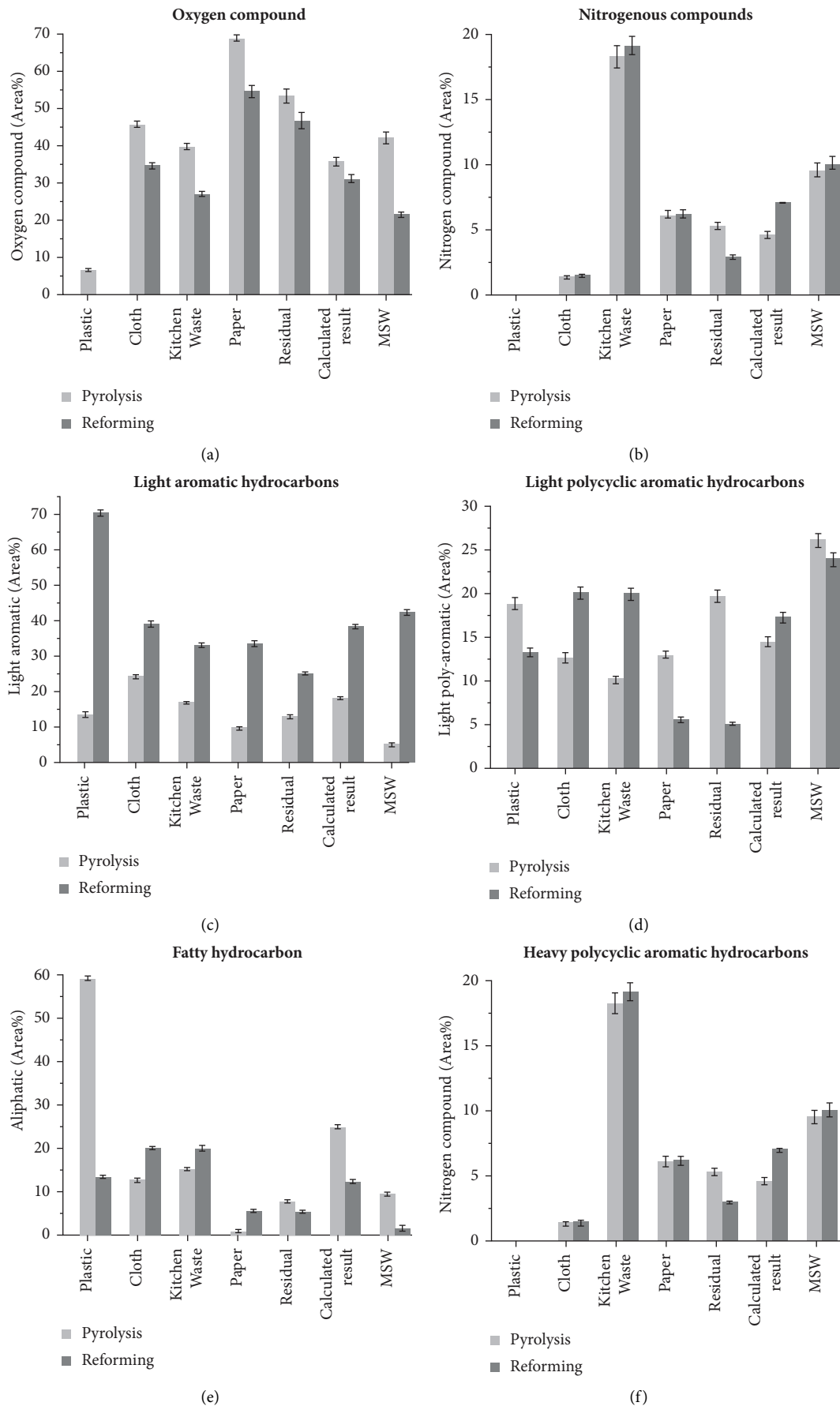


FIGURE 8: The portion of each component (area%) in the oil phase after typical single component $T_{\text{reform}} = 600^\circ\text{C}$. (a) Oxygen compound. (b) Nitrogenous compounds. (c) Light aromatic hydrocarbons. (d) Light polycyclic aromatic hydrocarbons. (e) Fatty hydrocarbon. (f) Heavy polycyclic aromatic hydrocarbons.

TABLE 3: The liquid pH after reforming of pyrolysis of waste.

Working condition	Classification					
	Plastics	Cotton cloth	Kitchen waste	Paper products	Select the remnants	Rubbish
Before restructuring	2.73 ± 0.10	1.46 ± 0.05	9.11 ± 0.06	1.84 ± 0.05	6.79 ± 0.11	4.30 ± 0.11
After restructuring	9.03 ± 0.13	8.37 ± 0.07	9.33 ± 0.07	8.28 ± 0.06	8.55 ± 0.08	8.45 ± 0.09

TABLE 4: Liquid calorific value (M J/kg) before and after reforming of typical single-component pyrolysis.

Working condition	Classification					
	Plastics	Cotton cloth	Kitchen waste	Paper products	Select the remnants	Rubbish
Before restructuring	43.16 ± 2.19	13.15 ± 1.04	9.32 ± 0.62	10.25 ± 0.58	12.17 ± 0.70	19.81 ± 1.21
After restructuring	27.58 ± 0.93	8.55 ± 0.79	6.83 ± 0.57	5.84 ± 0.43	9.34 ± 0.52	14.31 ± 0.87

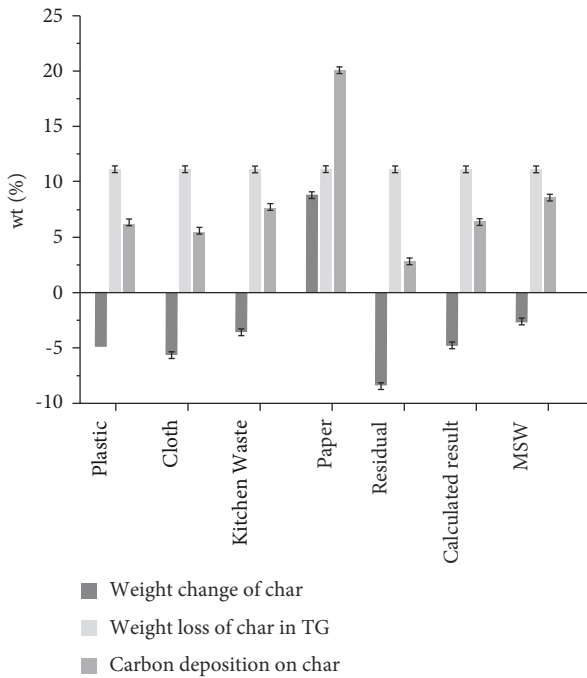


FIGURE 9: Change of semi-coke mass and carbon deposition in the process of pyrolysis.

After reforming paper pyrolysis volatiles, the resulting liquid oil phase contains no fatty hydrocarbon and very little aromatic hydrocarbon, only 1.27 area%, as high as 54.52 area %, and 6.21 area%. Paper is mainly composed of cellulose, but also includes various additives added in the paper-making process. Gao [19] study found that cellulose molecules in the process of pyrolysis first decomposition into cellulose monomer, then cellulose monomer hydroxyl functional group priority removal, the intermediate product of liquid products, so paper reforming volatile will contain a large number of hydroxyl functional group, finally after reforming the liquid, oxygenation content is still relatively high. These findings in this article have potential application prospects in the manufacturing industry [20–27].

Oxygenic compounds [28–30] in biomass thermal electrolyte mainly contain carboxyl, base, and hydroxyl

groups, and the reduction of oxygenic compounds is mainly due to the removal reaction of these three groups.

3.3.1. Decarboxylation Reaction. As shown in equation (1), mainly the fracture of $-\text{COOH}$ bond, mainly organic acids, including acetic acid, oleic acid, and palmitate, which will produce methane or ethylene; oleic acid and palmitate are usually saturated alkane. But the decarboxylation process produces a large amount of residual carbon, causing the catalyst to rapidly inactivate.



3.3.2. Unbased Reaction. It is mainly the fracture of $\text{C}=\text{O}$ bond. The substances in the thermal electrolyte mainly include ketones, aldehydes, and furans, and the branched chains are mostly hydrocarbons, mainly including alkanes and aromatic hydrocarbons. Therefore, the above substances mainly produce alkanes and aromatic hydrocarbons after removing the radicals.

3.3.3. Dehydroxy Group Reaction. It is mainly the breakage of $-\text{OH}$ bonds, including phenyl and alcohol hydroxyl groups. The hydroxylic functional group mainly includes alcohols and phenols. The generation of aromatic hydrocarbons mainly comes from the dehydroxy reaction of alcohols.

Pyrolysis solutions contain some furan derivatives, and these compounds are thought to be typical of hemicellulose pyrolysis, while hydroxy and hydroxyl groups are thought to arise from thermal lysis of cellulose, whereas phenols and methoxy groups are resulting from thermal lysis of lignin.

Compared with the calculated value and the actual waste pyrolysis liquid, it can be found that the actual waste pyrolysis liquid does not contain aromatic hydrocarbons, the content of oxygen and nitrogen heterocyclic ring decreased, the content of aromatic hydrocarbons increased, the proportion of light polybenzene ring aromatic hydrocarbons reached 397.09% of the calculated value, and the content of single benzene ring also increased by 303.87%. It shows that when mixed together, the volatiles produced by different single components will react with each other during the reforming process, and will affect each other, making more

oxygen and nitrogen elements into the gas and solid products.

After reforming each single component and the actual waste pyrolysis volatilization, the resulting liquid no longer contains heavy PAH compounds, indicating that heavy PAHs will be decomposed during restructuring.

Because the components are complex and contain water, pyrolysate is difficult to use directly. But hydrothermal electrolyte is actually an important industrial chemical raw material, such as the main components of thermal electrolyte benzene, styrene, toluene, ind, and so on.

The pH values of the pyrolysis volatilization of the liquid products obtained before and after reforming are shown in Table 3. For the hydrothermal electrolyte pH value, only the kitchen waste hydrothermal electrolyte is alkaline, and the remaining single components and the actual waste hydrothermal electrolyte are acidic. This is because kitchen waste has a high content of nitrogen compounds, while nitrogen compounds such as amines and pyridines are all alkaline. The rest of the hydrolysate is acidic mainly contains acidic substances such as methoxy derivatives and phenols. The liquid obtained after reforming increases with the liquid obtained before reforming, with the pH value greater than 8. The liquid pH value of volatile reorganization of kitchen waste is still the highest, and the liquid pH value of paper volatiles is the lowest. After reforming, the content of oxygen compounds in each single component reforming liquid decreases, so the pH value of the reforming liquid will increase.

The pH value of hydrothermal electrolyte is another important parameter to measure its chemical properties. The pH value of hydrothermal electrolyte is small and the acidity is large, which is not conducive to its storage and transportation, and it is corrosive as a fuel, which needs to be refined to be used.

Under the coupled treatment condition of pyrolysis at 500°C, the calorific value changes of liquid products before and after volatile reforming of the typical single-component pyrolysis at 600°C are shown in Table 4.

The calorific value of volatile liquid product after reforming of each single-component pyrolysis is lower than before reforming, with the paper dropping by 43.02%; the absolute value of plastic falling is the most, decreasing by 15.58 MJ/kg compared with before no reforming. The reason may be that after reforming, most of the oil component in the hydrothermal solution can be catalyzed cracked, the water component is difficult to be consumed or the substances dissolved in water cannot be catalyzed decomposed, the water will increase, and the proportion of the oil phase decreases, so the calorific value decreases.

3.4. Changes of the Half Focus after Reforming. After the volatilization of each typical single component of the reforming waste, the mass change and carbon deposition of the pyrolysis of the domestic waste are shown in Figure 9.

The differences in the composition, structure, and properties of different sources of thermal electrolyte make the catalytic transformation process different. The more the

aromatic thermal electrolyte, the more serious the treatment process, and the removal of the carboxyl group will also produce a large amount of carbon deposition. Obviously, in the reforming process of paper pyrolysis, the carbon accumulation is 20.03 wt.%, and the sorting residual carbon accumulation is only 2.64 wt.%. This is mainly because the paper is mainly composed of cellulose and hemicellulose and the aromatic component in the reforming section is high (Figure 8). According to Table 2, the pH value of paper electrolyte before reforming is only 1.84, so it contains a lot of carboxylic acids and is easy to produce carbon accumulation, and the residual organic component is less and the total volatile amount is less. In addition to paper, other typical single components and actual waste pyrolysis volatilization and semi-coke, the net quality of semi-coke is reduced, indicating that carbon gasification and volatilization are in the reforming process. However, the amount of volatile carbon deposition for paper is greater than its volatile amount.

4. Conclusion

This article studies the product characteristics of volatile and semifocal reforming of separate pyrolysis of each typical single component of domestic waste and compares them with the products of overall pyrolysis and reforming. To explore the effects of the different components in the hydromolate, the products of the aqueous and oil phase reforming of the hydromolate were studied separately. The following conclusions are obtained from the experiment.

(1) Product distribution: after reforming of plastic pyrolysis, the highest gas yield is 66.40 wt.%, 119.74% higher than before reforming; the liquid product yield of kitchen waste is the highest, only 2.21% lower than before reforming. At the same time, after the reforming of plastic pyrolysis, the highest yield of H_2 is 13.14 mol/kg (air dry-based plastic), and the largest molar fraction in the reforming gas is 37.33 mol%. (2) The liquid obtained after reforming of plastic pyrolysis no longer contains aqueous phase (including water and organic components soluble in water), and aerobic compounds completely disappear, only hydrocarbons, mainly aromatic hydrocarbons, among which the monocyclic aromatic hydrocarbons have the highest content, reaching the 70.48 area% of the oil phase component after reforming. The liquid obtained after paper pyrolysis volatile reforming has the largest aqueous proportion, reaching 83.30 wt%, and the content of oxygenated in the oil phase component is still 54.52 area%. The liquid obtained after the yield of the highest oil component reaches 218.68 g/kg (empty dry base cotton cloth). The liquid obtained after the reorganization of the aqueous component yield is the highest, reaching 297.39 g/kg (empty dry base kitchen surplus). To reduce the content of the aqueous phase in the pyrolysis oil, it is suitable to separate the biomass components before the pyrolysis. (3) After reforming, the liquid is obtained with the liquid obtained before reforming, pH value increases, pH value is greater than 8. The calorific value of volatile liquid product after reforming of each single component is lower than before reforming, with the paper

dropping 43.02% and the absolute value of plastic 15.58 MJ/kg compared with before no reforming. The pyrolysis of paper is 20.03 wt%. According to the above results, after semi-coke reforming, plastic pyrolysis volatilization can get more gas, and the H_2 production is the largest, the obtained liquid product quality is also the best. For biomass components, semi-coke reforming can significantly reduce the acidity of the liquid products and reduce their corrosion. (4) By each component, separate pyrolysis volatile reforming results and garbage overall pyrolysis-reforming results comparison: each component coexistence of the reforming process promotes the hydrothermal molecular deoxygenation reaction and other cracking reaction, make the liquid product oxygen compound content reduced, and H_2 and CO_2 production increase.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Design and Implementation of a Medical Question and Answer System Based on Deep Learning

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Medical services play a pivotal role in people's lives and in the national economy. Although the number of healthcare facilities is currently growing every year, there are still major problems in terms of access and pressure on the flow of people. Therefore, there is an urgent need for complementary medical services to alleviate the flow of patients and their psychological burden and to enable them to receive timely medical advice. This article designs and implements a medical Q&A system based on deep learning. We took a retrieval-based approach, using crawler technology that has been manually reviewed to build the Q&A database, and the Seq2Seq algorithm and the TF-IDF model to build the answer generation model. The medical question and answer system developed enable effective Q&A and relevant medical advice to be given. The algorithm proposed in this paper can quickly provide users with accurate answers compared to conventional search methods in real datasets.

1. Introduction

Artificial intelligence technologies, represented by machine learning, are currently being used in large numbers in various industrial sectors. Deep learning is a key technology in machine learning that has made great breakthroughs in computer vision, natural language processing, and speech processing, some of which surpass those of human professionals. However, the medical industry is more traditional and outdated than social media and e-commerce, and the development of modern medical technology can greatly improve people's quality of life.

With the rapid development of medical information technology, technologies such as deep learning and natural language processing have also developed rapidly, and intelligent diagnostic technology based on artificial intelligence will bring about a huge change to the medical industry. Answering users' questions quickly, accurately, and concisely in natural language is an important problem to be solved in medical Q&A systems. Traditional database

search methods are unable to meet the demands of search efficiency and accuracy, and Q&A using natural language can quickly provide users with accurate answers compared to conventional search methods. This algorithm will improve the efficiency of medical services, promote the development of medical question and answer systems, and provide users with more accurate and faster answers to everyday medical questions.

The rest of the paper is organized as follows: Section 2 introduces the relevant materials and methods. The general design, key technologies of the medical Q&A system, and application results and data analysis are explained in Section 3. Finally, Section 4 concludes the work of this paper.

2. Materials and Methods

2.1. Related Studies. In the late 1980s, the discovery of new neural network propagation algorithms gave impetus to the development of machine learning and sparked a machine learning frenzy based on statistical models. This frenzy

continues to this day. In the 1990s, machine learning models such as the vector machine, boosting, and maximum entropy methods were developed and achieved good results in both theory and practice. Research on shallow artificial neural networks has been in limbo during this time due to the difficulties of theoretical analysis and the fact that training methods also take time to hone. The rapid growth of the Internet since 2000 to date has greatly necessitated intelligent parsing and prediction of massive amounts of information, but shallow learning models have achieved good results online. Some of the most relevant applications are as follows: CTR prediction, content-oriented recommendations, web search sorting, spam filtering, etc. Deep learning is the most active field of artificial intelligence and has achieved fruitful results in the fields of speech recognition, computer vision, and natural language processing in recent years [1]. One of them is artificially intelligent customer service.

Now, companies are launching their own intelligent Q&A systems. Examples include Google's GoogleAssistant and Apple's Siri. They can answer some basic natural language questions and can also follow simple user instructions. In China, many manufacturers have developed their own smart quiz software, such as Huawei's HiAssistant and Xiaomi's "Xiaoai classmate." Another commonly used Q&A system is a type of intelligent voice audio, such as the Tmall Genie developed by Alibaba, which solves basic natural language problems and can perform some basic commands. This voice interaction-based Q&A can solve some of the problems of everyday life, but they rely more on their own experiences on the Internet and face open-ended questions rather than medical ones.

Most of the current medical Q&A uses knowledge graphs to store medically relevant knowledge in a nonrelational database in an entity-relational way [2] and to present medical advice in a search and reasoning manner. Izcovich et al. [3] developed a graphical GRADE-based medical Q&A system based on GRADE. Oyelade et al. [4] collected relevant information based on the patient's symptom profile in order to conduct an initial specialist consultation. In addition, there have been many achievements in this field in China in recent years. For example, Xin [5] built a community health Q&A system using natural language processing techniques and various machine learning methods, while Chao [6] used big data analysis and deep learning techniques to build a disease guidance system that can be very helpful for patients for consultation and guidance. Elytai et al. [7] used a joint learning model to perform knowledge extraction and a stack-propagation framework to recognise medical input interrogatives and quickly feed the user with accurate medical answers. Hu [8] implemented CMQA, a Chinese medical Q&A system that understands user semantics well and generates SPARQL queries.

However, natural language processing techniques in Chinese are complex, and existing theories and industrialized results are not yet well suited to address the intolerance that exists in medical problems. Therefore, further research in the field of medical Q&A is still to be conducted. The Seq2Seq model is often used in machine translation, chat robots, text summarization, automatic generation of picture

descriptions, and creation of ancient poems. In addition, the Seq2Seq model can also be applied to speech recognition, search intent completion, and recommendation. In the search recommendation scenario, when the user inputs the first half of the keyword, through the idea of interesting writing, the user inputs the first half of the vocabulary as the model input, predicts the possible search content in the second half, and improves the search efficiency. On this basis, we propose a medical Q&A system based on deep learning and build a sequence-order (Seq2Seq) architecture.

2.2. General Design of the Medical Q&A System. The medical Q&A system developed in the thesis uses a hierarchical architecture consisting of four layers: data layer, model layer, functional layer, and interaction layer. The advantages of using a layered architecture are that it reduces the correlation between layers and facilitates the standardisation of work; specific layers can be replaced, and analysis can be carried out from one level without too much knowledge of other levels, thus enhancing the repeatability and modifiability of the system. The architecture of the medical Q&A system based on deep learning [9–11] is shown in Figure 1.

The data layer managed and processed the data for the training corpus, laying a solid foundation for the design of an appropriate training set for the model layer. The training corpus was recorded this time in the form of questions with the title being the symptom of a condition and the answer being the name of a condition, combining the symptoms of these conditions sequentially and in reverse order to form a series of question responses.

At the model layer, secondary processing of the completed training set is completed with segmentation of the text, similarity operations, and feature extraction of the text. The Seq2Seq model is learnt so that the value of loss gradually decreases to achieve better accuracy.

At the functional layer, using natural language processing technology, the medical Q&A system is achieved by extracting text features from the input text and analysing the results to output predictive text, which is then subjected to secondary operations on the generated text via TF-IDF to improve accuracy.

The interaction layer provides access to the underlying layers for the purpose of meeting user requirements. This part consists mainly of the front-end interface and the human-computer interaction, which displays and receives the user's interactive actions through the terminal. The interaction layer is the top layer of the whole system and is the level that is directly accessible to the user.

2.3. Key Technologies for Medical Q&A Systems

2.3.1. The Seq2Seq Model. The intelligent quiz developed in this thesis uses the Seq2Seq model based on the encoder-decoder architecture [12, 13]. The Seq2Seq model is essentially an encoder-decoder construct: it transforms a series of long variables of data into a fixed vector; the decoder converts this fixed-length vector into a larger sequence of data. The difficulty of obtaining the true meaning in the case

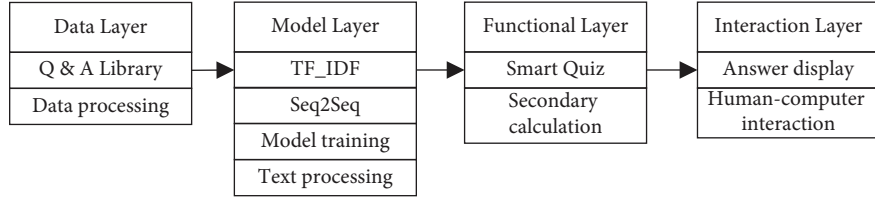


FIGURE 1: Medical Q&A system architecture.

of long input sequences can be well overcome by introducing the attention mechanism. The workflow of the Seq2Seq model is shown in Figure 2.

When doing the experiment, the first step is to obtain names, aliases, sites, infectiousness, population, symptoms, complications, departments to which they belong, and clinical management, treatments, common drugs, etc., of different diseases in the emergency department from one of the health sites, using crawlers. The data were analysed and filtered to obtain 3600 sets of questions and answers, which were then put into lists and then saved in data files for easy correction and training.

The model was built using the TensorFlow 2.0 framework. This model is a variant of the RNN that improves the neural network's ability to extract long text information [14], achieving better results than using the LSTM alone.

2.3.2. TF-IDF Model. TF-IDF is a statistical method for assessing the importance of words to a document set or corpus. TF-IDF has two values, one for TF (term frequency) and the other for IDF (inverse document frequency). It is calculated as follows:

$$TF-IDF = tf * idf,$$

$$tf_{i,j} = \frac{n_{i,j}}{\sum_k n_{k,j}}, \quad (1)$$

$$idf_i = \log \frac{|D|}{|\{j : t_i \in d_j\}|}.$$

The basic concept of IDF is that if the smaller number of files includes t , which means that n is smaller and the IDF is larger, it means that t has a better classification function. If the number of documents including t is m and the number of all documents of other classes containing t is k , it is clear that the number of all documents containing t , $n = m + k$, is large when m is large and n is also large, then the smaller value will be obtained by the IDF, indicating that t does not have good classification performance. In practice, however, when a word is used multiple times in a category of documents, it indicates that it can denote the character of the text, and such words should have a higher weight and be used to distinguish other documents.

2.3.3. Bahdanau Attention. TensorFlow provides two attention mechanisms, a Bahdanau attention mechanism (additive accumulation) and a Luong attention mechanism

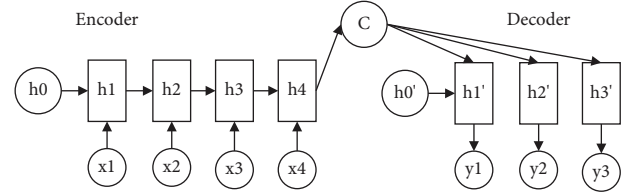


FIGURE 2: Workflows.

(multiplicative multiplication), and the former is used in this system [15, 16].

Bahdanau, an additive attention mechanism, uses a linear combination to output the hidden layer of the decoder and the full position of the encoder, thus improving the decoding pattern of the queue [17, 18]. It is essentially a two-layer fully connected network with an activation function of tanh and an output layer of dimension 1. The advantages are that the encoder generates a hidden state vector for each input vector; the alignment score is calculated at each encoder output x_i using the hidden state s_{t-1} of the previous moment; this alignment score can be converted into a probability distribution vector by softmax; according to the probability distributed alignment score, the context vector c_t can be derived by weighing the encoder outputs at each position; the context vector c_t and the embedding corresponding to the previous moment's encoder output y_{t-1} are spliced as the current moment's encoder input, and the new output and hidden state are generated by the RNN network, with the real target sequence $y=(y_1, y_m)$ in the training process, and more y_{t-1} is used instead of \hat{y}_{t-1} as the decoder input at moment t . At time t , the hidden state of the decoder is denoted as $s_t = f(s_{t-1}, c_t, y_{t-1})$, and the attention fraction of the hidden state s_{t-1} for all outputs X of the encoder at each t is

$$\alpha_t s_{t-1}, X = \text{softmax}(\tanh(s_{t-1} W_{\text{decoder}} + X W_{\text{encoder}} W_{\text{alignment}}), c_t = \sum_i \alpha_{ti} x_i. \quad (2)$$

As shown in Figure 3, the blue one is an encoder and the red one is a decoder. Based on traditional encoding and decoding algorithms, the attention mechanism requires more context vectors to generate the corresponding context vectors. Each context vector is a weighted sum of each word x of Input_Sentence, where the weight vector is the attention vector, indicating the importance of each word x of Input_Sentence at this point in time when word y produces Output_Sentence. Eventually, the current text vector is combined with the current y , and it is taken as the final result.

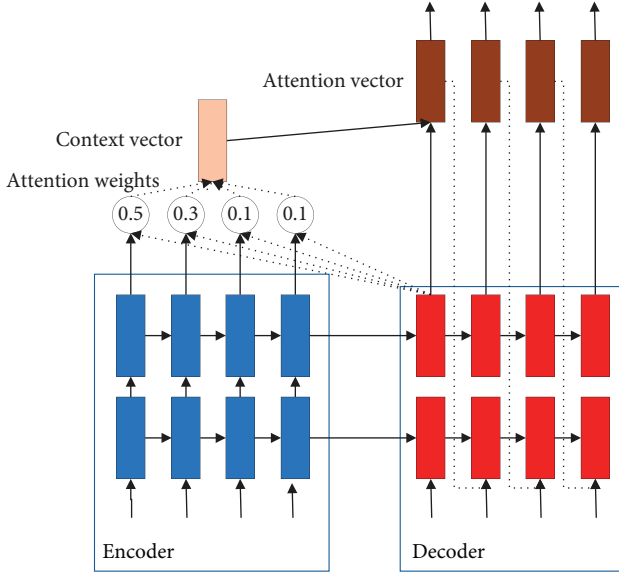


FIGURE 3: Attention mechanism.

The rules for calculating attention mechanisms are as follows:

$$\begin{aligned}
 \alpha_{ts} &= \frac{\exp(\text{score}(h_t, \bar{h}_s))}{\sum_{s'=1}^S \exp(\text{score}(h_t, \bar{h}_{s'}))}, \\
 c_t &= \sum_s \alpha_{ts} \bar{h}_s, \\
 a_t &= f(c_t, h_t) = \tanh(W_c [c_t; h_t]), \\
 \text{Score}(h_t, \bar{h}_s) &= \begin{cases} h_t^T W \bar{h}_s \\ v_a^T (W_1 h_t + W_2 \bar{h}_s) \end{cases}.
 \end{aligned} \tag{3}$$

2.4. Application Results and Data Analysis

2.4.1. Experimental Evaluation Indicators. The trained model can be used to predict new text, and it is not possible to determine whether the results are satisfactory. No model is as good as it should be, and we are always looking for better. When the model has finished training, in order to determine how good or bad it is, we can make predictions based on the available information and compare the predictions with reality as a way to judge how good the model is [19]. Therefore, we need some metrics to measure how similar the actual predicted results are to the expected results.

Common evaluation metrics for text classification tasks include accuracy, precision, recall, and F1-score to name a few.

(1) *Accuracy.* Accuracy is the most basic evaluation metric, which is the percentage of correctly classified test samples of the total test samples. The advantages are that it is simple to

calculate, easy to understand, and can be used for both dichotomous and polyphenolic classes. However, when the data are unbalanced, it is not a good measure of how good the model is. The formula is as follows:

$$\text{Accuracy} = \frac{\text{answer}_{\text{true}}}{\text{answer}_{\text{all}}}. \tag{4}$$

(2) *Precision.* In the classification model, there exists an outcome with an output, which is a prediction. Assume that A is predicted by Class_1. There are only two cases of A: A is Class_1 (prediction is correct) and A is not Class_1 (prediction is wrong). If all data are predicted, then Class_1 data will appear to be incorrectly predicted in relation to Class_1 and the other non-Class_1 will be considered to be Class_1. The confusing evidence is shown in Table 1.

The denominator of precision is all test samples classified as Class_1, and the numerator is the number of test samples that are predicted to be Class_1 test samples that are actually positive classes.

$$\text{Precision} = \frac{TP}{(TP + FP)}. \tag{5}$$

(3) *Recall.* Recall is also derived from the above table, and its denominator is all test samples that are positively true to Class_1; its numerator is predicted to be a test sample of Class_1, as is precision.

$$\text{Recall} = \frac{TP}{TP + FN}. \tag{6}$$

(4) *F1-Score.* In practical experiments, we all want both precision and recall to be high, but in reality, you cannot have both, so there is something that combines them both, the F1 value. The larger the F1 value, the better the model.

$$\text{F1Score} = \frac{2PR}{P + R}. \tag{7}$$

The similarity is the result of a similarity calculation between the predicted answer by the model and the original test data.

2.4.2. Algorithm Description. When designing the Q&A system, we initially used the TF-IDF algorithm, which calculates the similarity between user input and existing statements in the database and then returns the answer corresponding to the value with the highest similarity, but the algorithm takes longer to calculate as the data grow. Later, after reviewing the information, the Seq2Seq model, which is currently the most used, was chosen for implementation. Seq2Seq is generative, predicting possible output values from a trained model and getting one word or text per prediction.

Since the most likely value is predicted each time, the value is not necessarily what the user wants or the correct value. If the predicted result is a value within a certain range, it is possible to control the content of the output and also

TABLE 1: Confusing evidence.

Actual/Forecast	Predicted as Class_1	Predicted for other categories
Actual class is Class_1	TP: the number of test data items that are actually predicted correctly even for Class_1	FN: the number of test entries that are actually Class_1 but are predicted to be other classes
Actual class is other class	FP: the number of data items that are not actually Class_1 but are predicted to be Class_1	TN: the number of data entries that are not actually Class_1 and are not predicted to be Class_1

improve the accuracy of the output. Thus, the two methods can be combined, and result A predicted by Seq2Seq can be then calculated by TF-IDF to output result B that is most similar to A from the existing database, as shown in Figure 4.

2.4.3. Results. The model first classifies the dataset questions with a batch_size of 128 and an epoch of 7. The questions are classified into two categories, symptom and name, and the results of recall, precision, and F1 of the classification results are shown in Table 2.

Secondly, all test datasets were manually tested, and a total of 410 test datasets were counted; it was found that a total of 361 datasets could be predicted by the model, a rate of 88.0488%.

Because the Seq2Seq model is called based on the textual properties of the sentence, if the information in the training set is not precise enough, or if the user's text does not correspond to the input to the model, then this can lead to inaccurate results. On this basis, a simple algorithm of TF-IDF is introduced to perform text similarity analysis. We take the output of Seq2Seq and recall TF-IDF to perform a secondary operation so that the output belongs to the data already used in the database. For example, the Seq2Seq model predicts "exercise-induced asthma" for "coughing and dry cough after strenuous exercise" (a symptom of cough variant asthma), although this condition is not named in the database, and then the TF-IDF algorithm outputs "cough variant asthma" to improve the accuracy of the output. The comparison results are shown in Table 3.

As the information used in this system is taken from the emergency department, it is very useful for emergency management of emergencies. The medical information provided to the user by the system comes from the medical knowledge base, and this database is rigorously hand-selected, its answers are output based on the data available in the database, so the accuracy of its answers can be guaranteed. As calling the model consumes a long time, the files for model calculation are placed on Tencent Cloud servers, which improve the rate of model calculation and reduces the time for Q&A. Simulations of the calculations show that the method gives a relatively good answer.

Given the specific nature of the system's model training set, which requires user input of symptoms to most accurately invoke the model, a guided input module was added to the system. The initial values in the module are the twenty most common symptoms for the user to select. For each symptom selected, the symptom is added to the input box, and the value in the guided input module change to all the remaining symptoms that have the symptomatic disease. The input box monitors the user's input in real time, and if the

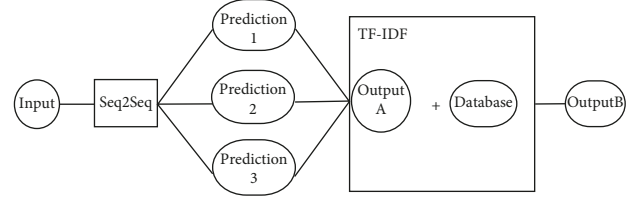


FIGURE 4: Algorithm description diagram.

TABLE 2: Classification results.

Type of question	Recall	Precision	F1
Symptom	0.894737	0.772727	0.829268
Name	0.842105	0.727273	0.780488
All questions	0.804878	0.804878	0.804878

TABLE 3: Models comparison results.

Models	F1
TF-IDF	0.731707
Seq2Seq	0.804878
Fusion model	0.880488

user enters symptoms themselves, the value of the guided input module will change accordingly. It is recommended that the user selects 3–5 symptoms before choosing to send, as this will make the answers more accurate. After sending, the symptoms on the right revert to their initial values.

3. Conclusions

This article designs and implements a medical Q&A system based on deep learning. The algorithm proposed in this paper can quickly provide users with accurate answers compared to conventional search methods in real datasets. The system has been validated through several experiments and has achieved excellent results [20]. The added guided input enables the user to select the information accurately, which in turn helps the user to quickly locate disease information and know how to administer medicine. However, this system has some limitations in certain aspects. Due to the specificity and high quality requirements of the medical question and answer content and the system's ability to learn autonomously is not yet optimal, in practice, the user is currently limited to selecting or entering symptoms in order to use the system most effectively. In terms of modelling, the accuracy of the model has not been maximised, and modifications to certain values could be considered in the future. In terms of data, the quality of the training set would need to

be improved by consulting a professional and modifying it manually due to the small amount of first aid data; in addition, a library of common question and answer statements could be added to diversify user input [21]. Intelligent diagnostic techniques based on artificial intelligence will bring great changes to the healthcare industry [21]. The intelligent diagnostic technology based on artificial intelligence will bring about a huge change to the medical industry [22, 23].

Data Availability

No data were used to support the findings of this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Promotion Path and Application of Enterprises Sustainable Competitive Advantage: Perspective of TMT Behavior Integration

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The role of the sustainable competitive advantage of enterprises is becoming increasingly prominent. Taking TMT behavior integration, enterprise sustainable competitive advantage, absorptive capacity, and critical reflection as independent, dependent, intermediary, and regulatory variables, respectively, and 223 enterprises as an empirical research sample, through theoretical analysis and empirical research, this paper reveals the influence of TMT behavior integration on sustainable competitive advantage of enterprises and intermediary role of absorptive capacity and the regulatory role of critical reflection. The empirical results show that the behavior integration of top management team can promote the sustainable competitive advantage of enterprises. The potential absorptive capacity plays a partial intermediary role between TMT behavior integration and enterprise financial performance and a complete intermediary role between TMT behavior integration and enterprise strategic performance. Realistic absorptive capacity can partially mediate the behavioral integration of TMT and the sustainable competitive advantage of enterprises. Critical reflection plays a positive regulatory role between TMT behavior integration and enterprise strategic performance. The research shows that in order to improve enterprises sustainable competitive advantage, enterprises should take the following measures: ① Enterprise executives must attach importance to TMT behavior integration. ② Enterprise executives should focus on critical thinking. ③ Enterprise executives should take cultivation of absorptive capacity seriously and give full play to the intermediary effect of absorptive capacity. Research model provides a new path to build sustainable competitive advantage, and can be applied to enhance enterprises sustainable competitive advantage from the perspective of TMT behavioral integration.

1. Introduction

In recent years, the theory of enterprise sustainable competitive advantage has attracted extensive attention in academic circles. Sustainable competitive advantage is related to the survival of enterprises. Promoting the sustainable competitive advantage of enterprises has become an important issue for enterprise development. The top management team (TMT) is very important in the development of enterprises and is an important competitive resource of enterprises [1]. As an important variable in the field of TMT, TMT behavior integration is receiving increasing attention. Guo pointed out that the behavior integration of TMT can promote the innovation performance of enterprises [2]. Hu and others pointed out that the behavior integration of the TMT has a positive impact on the innovation of enterprise business model [3]. Wang and Feng [4] pointed out that the

behavior integration of TMT is conducive to the balance between the two types of technological innovation. Research shows that the behavior integration of the TMT is conducive to promoting enterprise dual innovation and it can promote the innovation performance of enterprises. Peng and others pointed out that the breakthrough innovation is conducive to the improvement of enterprises' sustainable competitive advantage [5].

However, there is still a lack of research on the relationship between the behavior integration of TMT and the sustainable competitive advantage of enterprises. The author believes that the behavior integration of the TMT can promote the improvement of the absorptive capacity of an enterprise, and absorptive capacity can promote the sustainable competitive advantage of enterprises. In view of this, this paper brings TMT behavior integration, absorptive capacity, and enterprise sustainable competitive advantage

into an overall framework, explores the relationship between TMT behavior integration and enterprise sustainable competitive advantage, and examines the intermediary role of absorptive capacity. In addition, since the role of TMT behavior integration is closely related to critical reflection, this paper includes critical reflection and examines the regulatory role of critical reflection between TMT behavioral integration and enterprise sustainable competitive advantage.

This paper constructs an overall research framework of TMT behavior integration, enterprise sustainable competitive advantage, absorptive capacity, and critical reflection, that is, the research focuses on the antecedent variables, intermediary variables, and regulatory variables of sustainable competitive advantage, so as to provide a new path to bring about sustainable competitive advantage of enterprises. The research clarifies the relationship between TMT behavior integration, absorptive capacity, critical reflection, and enterprises sustainable competitive advantage. The research conclusion provides a new idea for enterprises to establish competitive advantage, that is, to enhance the sustainable competitive advantage of enterprises from the perspective of TMT behavior integration. It provides a reference for enterprises to construct sustainable competitive advantage.

The remainder of the paper is organized as follows. Firstly, it introduces the theoretical basis and research assumptions, and constructs the research model of this paper. Then, 223 samples are used to do empirical research on the research hypothesis. Finally, research conclusions, applications, and future research prospects are discussed.

2. Theoretical Basis

2.1. TMT Behavioral Integration. Hambrick [6] first put forward the notion of TMT behavior integration in 1994. He believed that the TMT behavior integration has three dimensions: open communication, decision-making participation, and team cooperation. Open communication refers to the extent to which the resources are shared among TMT members. Decision participation is a process in which TMT members fully discuss and participate in organizational decision-making around decision-making objectives on the basis of fully understanding the problems they face. Teamwork refers to behavior whereby TMT members actively carry out mutual assistance, clarify responsibilities, and complete organizational tasks through cooperation. For the above three dimensions, teamwork is the social attribute required for a TMT to produce cohesion and trust, and open communication and decision-making participation are the task attributes needed for a TMT to achieve its goals [7]. Simsek, Veiga, and Lubatkin further proposed that the behavior integration of TMTs can promote better enterprise development [8].

2.2. Sustainable Competitive Advantage of Enterprises. The sustainable competitive advantage of an enterprise refers to the ability accumulated by an organization to surpass its

competitors in the process of long-term competition [9]. In terms of business conditions, enterprises with a good sustainable competitive advantage have good performance in financial performance, growth, and market value, which can reflect better cash flow creation abilities [9]. An enterprise's sustainable competitive advantage includes both better financial returns and better strategic performance [10]. Therefore, financial and strategic performance are regarded as two important dimensions of enterprises' sustainable competitive advantage [11]. This study explores the above two dimensions.

2.3. Absorptive Capacity. Cohen and Levinthal defined absorptive capacity as "the ability to absorb and identify the value of external new knowledge and apply it to commercial terminals" [12]. Zahra and George classified absorptive capacity as potential absorptive capacity and realistic absorptive capacity; potential absorptive capacity contains knowledge acquisition and absorptive capacity, while realistic absorptive capacity contains knowledge transformation and utilization capacity [13].

2.4. Critical Reflection. Critical reflection is a core concept in the field of philosophy. Since it was introduced to the field of management, the interpretation of its connotations has not been consistent [14]. Because critical reflection can effectively address loopholes in work, it has received more attention in the field of management [14]. At first, critical reflection was defined as the synthesis of a series of knowledge fields, attitudes, and skills [15]. Meyers regards critical reflection as the cognitive ability of individuals to ask questions and find solutions to problems [16].

3. Research Hypothesis and Conceptual Model

3.1. TMT Behavior Integration and Sustainable Competitive Advantage of Enterprises. According to the process theory of the TMT, when facing dynamic and complex decision-making problems, which are limited to the decision-making information, knowledge base, and cognitive ability obtained by individuals, group decision-making from a TMT helps improve decision-making quality and organizational performance [8, 17]. The behavior integration of TMT is a feasible means for enterprises to deal with complexity and dynamics and a key factor necessary to improving performance [18]. Some studies have pointed out that the behavioral integration refers to TMT members solving conflicts, reaching consensus, and implementing decisions through the open and free exchange of information to promote the better development of enterprises [8]. Good communication among TMT members can reduce team decision-making differences, promote the exchange of new organizational knowledge and ideas, improve decision-making quality, and promote organizational performance. Information sharing among TMT members can effectively alleviate the decision-making pressure caused by members' differences of opinion [19], improve the transparency of the decision-making process and organizational decision-

making efficiency, and promote the improvement of enterprise financial performance and strategic performance. TMT cooperation is conducive to organization members' mining and use of organizational innovation resources, improves the use efficiency of innovation resources, and promotes organizational dual innovation [6], which has a great influence on the sustainable development of enterprises [10]. Decision-making participation of TMT members facilitates the discussion organizational objectives and consensus on organizational objectives and helps an organization achieve better financial and strategic performance.

H1a: TMT behavior integration has a positive impact on financial performance.

H1b: TMT behavior integration has a positive impact on strategic performance.

3.2. Intermediary Role of Absorptive Capacity. Open communication among TMT members can enhance a team's personal knowledge, broaden the vision of members, create a good knowledge exchange atmosphere for an organization [21], and promote the improvement of absorptive capacity. The participation of TMT members in decision-making can clarify organizational objectives, mobilize the enthusiasm of TMT members, and improve scientific decision-making. The decision-making participation of a TMT deepens the TMT's understanding of decision-making needs and improves the TMT's ability to obtain and absorb information [22]. High-level cooperation among the members of a TMT helps TMT members respect each other's values and opinions; share resources and knowledge [18]; fully integrate the team's knowledge, resources and creativity; accumulate organizational knowledge, and lay the foundation for the improvement of absorptive capacity.

H2a: TMT behavior integration has a positive impact on potential absorptive capacity.

H2b: TMT behavior integration has a positive impact on realistic absorptive capacity.

Potential absorptive capacity includes knowledge acquisition capacity and digestion capacity [13]. Potential absorptive capacity helps better grasp and meet customer needs [23], which is helpful to the enhancement of enterprise financial performance. In the meantime, potential absorptive capacity can help enterprises update their knowledge base in time, effectively avoid repetitive work, and promote the improvement of organizational innovation performance [24] to improve strategic performance.

Enterprises with strong absorptive capacity in reality can integrate knowledge more smoothly and realize the transformation of external knowledge to improve innovation ability to improve innovation output [25]. Khan et al. found that enterprises with high absorption capacity often have strong knowledge creation and application abilities, which are conducive to the timely launch of new products that can meet market demand [26]. Through the transformation and utilization of knowledge, realistic absorptive capacity can realize the improvement of existing products and promote

the improvement of enterprise financial performance. Realistic absorptive capacity enhances enterprises innovation capacity, enables them to launch new products in time, and promotes the improvement of enterprise strategic performance.

H3a Potential absorptive capacity has a positive impact on financial performance.

H3b Potential absorptive capacity has a positive impact on strategic performance.

H3c Realistic absorptive capacity has a positive impact on financial performance.

H3d Realistic absorptive capacity has a positive impact on strategic performance.

Based on the above analysis, the author posits the following paths for the impact of TMT behavior integration on enterprises sustainable competitive advantage; that is, TMT behavior integration promotes the improvement of absorptive capacity (including potential and realistic absorptive capacity). The improvement of absorptive capacity helps enterprises obtain internal and external innovation knowledge resources and lays a good innovation knowledge foundation for the improvement of their sustainable competitive advantage to promote enterprise financial and strategic performance.

H4a Potential absorptive capacity plays an intermediary role between TMT behavioral integration and financial performance.

H4b Potential absorptive capacity plays an intermediary role between TMT behavioral integration and strategic performance.

H4c Realistic absorptive capacity plays an intermediary role between TMT behavior integration and financial performance.

H4d Realistic absorptive capacity plays an intermediary role between TMT behavior integration and strategic performance.

3.3. The Moderating Role of Critical Reflection. A TMT with high critical reflection can break through the traditional thinking mode and cognitive framework and create conditions for organizational innovation [27]. Critical reflection can enrich organizational knowledge [28]; create excellent conditions for TMT members to communicate, collaborate, and make joint decisions; and promote the improvement of innovation efficiency. Critical reflection can cause TMT members to move away from a thinking framework and adopt a new and better, unique, and bold way of achieving organizational innovation goals, which is conducive to the development of organizational dual innovation activities and further promotes enterprise financial and strategic performance. Therefore, the higher the level of critical reflection is, the stronger the positive impact of TMT behavior integration on enterprise financial performance and enterprise strategic performance becomes.

H5a Critical reflection positively regulates TMT behavior integration and financial performance.

H5b Critical reflection positively regulates TMT behavior integration and strategic performance.

3.4. Research Conceptual Model. According to the above theories and research hypotheses, we constructed a research model on the relationship between TMT behavioral integration, critical reflection, absorptive capacity, and sustainable competitive advantage, as shown in Figure 1.

4. Research Methods

4.1. Research Samples and Data Collection. Taking enterprises in Jiangsu, Shanghai, Zhejiang, Shandong, and Anhui as research samples, the questionnaire was distributed on-site and online, and the research object was enterprise top managers. The questionnaire was distributed from early June 2021 to early January 2022 for nearly 7 months. The details are as follows: 280 sets were distributed on-site, with 201 sets recovered and 180 sets deemed effective; 338 sets were distributed online, with 50 sets recovered and 43 sets deemed effective. A total of 618 sets were distributed, and 251 sets were recovered. Of these, 223 were deemed effective, and the effective recovery rate was 36.08%. In terms of nonresponse bias, we tested the significance of the first 25% and last 25% of the questionnaires on the nature, growth scale, and industry attributes of the companies and found no significant differences at the 5% level.

4.2. Variable Measurement. To ensure that the scale of the four variables has high reliability and validity, the measurement of TMT behavior integration, enterprise sustainable competitive advantage, absorptive capacity, and critical reflection mainly referred to the maturity scale applied domestically and abroad. The measurement of the scale adopts a Likert 7 scale, where 1 means “very inconsistent” and 7 means “very consistent”. The measurement items of research variables are shown in Table 1.

4.2.1. TMT Behavior Integration. Referring to the measurement method [29] of Yao and Sun, the three dimensions of decision-making participation, open communication, and teamwork are used for measurement, and each dimension is measured by three items.

4.2.2. Enterprises Sustainable Competitive Advantage. The measurement of an enterprise’s sustainable competitive advantage is based on the research of Hill, Jones [10], Barney [30], etc., and with reference to [31], starting from the two dimensions of financial performance and strategic performance. The variable is measured by five items.

4.2.3. Absorptive Capacity. Absorptive capacity refers to the research of Zhao et al. [32] and is measured by two

dimensions: potential absorptive capacity and realistic absorptive capacity; each dimension is measured by three items.

4.2.4. Critical Reflection. Using the measurement scale [33] developed by scholars Jiang and Yang for reference, five measurement items are used for critical reflection.

4.2.5. Control Variables. To ensure the robustness of the results and prevent reasoning deviation caused by the results being affected by some variables, as the age and size of an enterprise may affect the accumulation and acquisition of knowledge and then affect the absorptive capacity and enterprises sustainable competitive advantage, the age and size of an enterprise are used as control variables and the logarithm is used to convert the variable values.

4.3. Reliability and Validity Test. To test the reliability and validity of the questionnaire, we conducted a factor analysis of variables such as TMT behavior integration, enterprises sustainable competitive advantage, absorptive capacity, and critical reflection. The results are shown in Table 2. The KMO value of each variable is between 0.701 and 0.889, meeting the requirement of more than a critical value of 0.7. The Bartlett sphere test result is significantly different from 0, meeting the requirements of factor analysis. The reliability and validity analysis results of the variables show that the Cronbach’s α coefficient is between 0.796 and 0.917, and the combined reliability (CR) value is between 0.881 and 0.938, meeting the requirement of a critical value greater than 0.7, indicating that the scale is highly reliable. The factor load of each item is between 0.776 and 0.899, meeting the requirement of a value greater than 0.7, indicating that the research scale has good aggregate validity. The AVE value is between 0.660 and 0.754, which is higher than the critical value of 0.5, proving the discrimination validity of each research scale.

5. Analysis Methods and Results

For the test involving regulation, this study uses multiple linear regression with more reliable research conclusions to test the overall model and applies SPSS 23.0 for data processing.

5.1. Correlation Analysis. The mean value and correlation analysis of the research variables are carried out to preliminarily verify the research hypothesis. According to Table 3, the average values of TMT behavior integration, potential absorptive capacity, realistic absorptive capacity, financial performance, strategic performance, and critical reflection are between 4.34 and 4.68; that is, the average value of the survey sample is better than expected and meets the requirements of this study. From the correlation coefficient between the main research variables, there is a significant positive correlation between the variables, which preliminarily verifies some of the research hypotheses proposed in this paper.

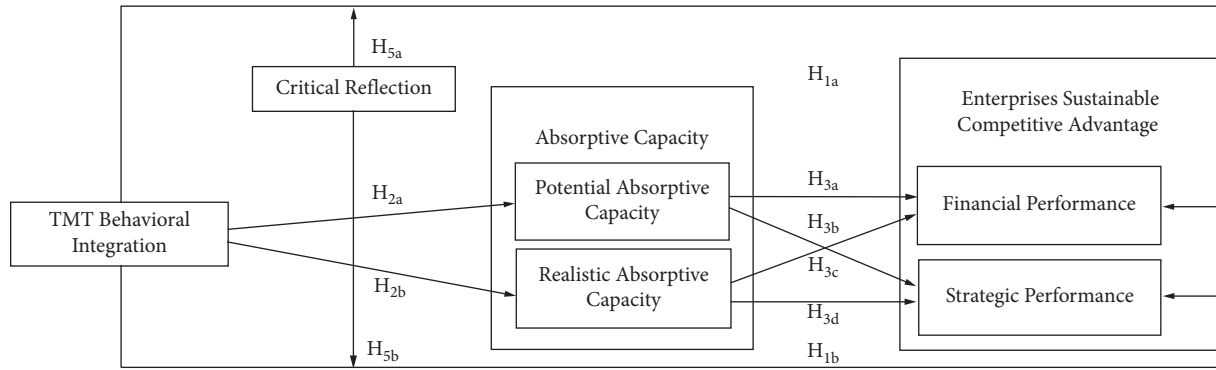


FIGURE 1: Conceptual model of this paper.

5.2. A Test of the Relationship between TMT Behavior Integration, Critical Reflection, and Enterprise Sustainable Competitive Advantage. The two models in Table 4 involve three steps. Step 1 measures the impact of age and scale on enterprises sustainable competitive advantage. Step 2 measures the impact of TMT behavior integration on sustainable competitive advantage. Step 3 adds the interaction items of TMT behavior integration, critical reflection, and TMT behavior integration to the research model at the same time to test the regulation effect. The D-W values of all models in Tables 4–6 are close to 2, and the VIF values are less than 3, indicating no autocorrelation or multicollinearity between the variables. The coefficients of the control variables are not significant, indicating that the enterprise size and age do not affect the results. Step 2 in Table 4 shows that the regression coefficients of TMT behavior integration on enterprise financial performance and enterprise strategic performance are ($\beta = 0.409$, $P < 0.001$) and ($\beta = 0.379$, $P < 0.001$), the coefficients are significant, and H1a and H1b thus are assumed to be valid.

The moderating effect test of critical reflection is shown in step 3 in Table 4. The interaction term coefficient of step 3 of Model 1 is ($\beta = 0.093$, $P > 0.05$), and the coefficient is not significant; thus, H5a is not confirmed. The interaction term coefficient of step 3 of Model 2 is ($\beta = 0.092$, $P < 0.01$), and the coefficient is significant; thus, H5b is proven. To clearly show the regulatory effect of critical reflection, a regulatory effect diagram is drawn according to the procedure proposed by Aiken and West [34]. As shown in Figure 2, under highly critical reflection, there is a strong relationship between TMT behavior integration and strategic performance ($\beta = 0.135$, $P < 0.01$), while under little critical reflection, the relationship between behavioral integration and the strategic performance of a TMT is relatively weak ($\beta = 0.109$, $P < 0.01$) but reaches a significant level, consistent with our expectations.

5.3. Regression Analysis of TMT Behavior Integration, Absorptive Capacity, and Enterprises Sustainable Competitive Advantage

5.3.1. Test of the Relationship between TMT Behavior Integration and Absorptive Capacity. The impact of TMT behavior integration on potential absorptive capacity and

realistic absorptive capacity is shown in Table 5. The coefficients of TMT behavior integration (independent variable), potential absorptive capacity (dependent variable), and realistic absorptive capacity (dependent variable) are ($\beta = 0.604$, $P < 0.001$) and ($\beta = 0.301$, $P < 0.001$); H2a and H2b thus are confirmed.

5.3.2. Testing the Relationship between the Absorptive Capacity and the Sustainable Competitive Advantage of Enterprises. The relationship between the absorptive capacity and the sustainable competitive advantage of enterprises is shown in Models 3–6 in Table 6. The impact of potential absorptive capacity on financial performance and strategic performance is shown in Model 3 and Model 5, and the regression coefficients are ($\beta = 0.402$, $P < 0.001$) and ($\beta = 0.524$, $P < 0.001$), respectively. Hypotheses H3a and H3b are thus confirmed. The impact of realistic absorptive capacity on financial performance and strategic performance is shown in Model 4 and Model 6, and the regression coefficients are ($\beta = 0.336$, $P < 0.01$) and ($\beta = 0.310$, $P < 0.001$); thus, H3c and H3d are confirmed.

5.3.3. Intermediary Effect Test of Absorptive Capacity. Regression analysis requires that the samples conform to a normal distribution. In this paper, a process program and bootstrapping method are used to test the intermediary effect of absorption capacity, which cannot be limited by the normal distribution of samples. The sample size is set to 5000, and the confidence level is set to 95%. The results are shown in Table 7.

The indirect effect of TMT behavior integration—potential absorptive capacity—enterprise financial performance is 0.1973, $P < 0.001$, and the confidence interval is [0.0652, 0.3543]. The indirect effect of TMT behavior integration—potential absorptive capacity—enterprise strategic performance is 0.4900, $P < 0.001$, and the confidence interval is [0.3296, 0.6867]. The indirect effect of TMT behavior integration—realistic absorptive capacity—enterprise financial performance is 0.0946, $P < 0.001$, and the confidence interval is [0.0343, 0.1829]. The indirect effect of TMT behavior integration—realistic absorptive capacity—enterprise's strategic performance is 0.1146, $P < 0.001$, and the confidence interval is [0.0460, 0.2198]. The above

TABLE 1: Measurement items.

Variables	Item	Measurement
Enterprises sustainable competitive advantage	FP11	In the past two years, the return on assets of enterprises has increased rapidly
	FP12	In the past two years, the market share of enterprises has increased rapidly
	FP13	In the past two years, the net profit of the enterprise has increased rapidly
	FP14	In the past two years, the rate of return on sales of enterprises has increased rapidly
	FP15	In the past two years, the sales of enterprises have increased rapidly
	SP11	In the past two years, the consumer satisfaction of enterprises has increased rapidly
	SP12	In the past two years, the long-term competitiveness of enterprises has increased rapidly
	SP13	In the past two years, the product quality of enterprises has increased rapidly
	SP14	In the past two years, the products or services of enterprises have increased rapidly
	SP15	In the past two years, the company's comprehensive performance has increased significantly
	CR11	Carefully consider the background of the problem and make a careful judgment
	CR12	Take targeted strategies according to the problems
	CR13	Seek alternative solutions to the problem
	CR14	Dare to challenge difficulties affecting the job performance
Critical reflection	CR15	Willing to adopt possible solutions beyond the existing procedures or rules and regulations
	PA11	The knowledge types of enterprise and cooperative network spillovers are in the same or close field
	PA12	Enterprises have a keen ability to identify, acquire, utilize, and develop new knowledge
	PA13	Enterprises have the ability to analyze and explain the changes of knowledge needs of cooperative networks
Absorptive capability	Enterprises take the initiative to consider the impact of cooperative network knowledge needs on their products, and can store relevant knowledge for future use	
	RA11	Enterprises often share the practical experience of knowledge acquisition and knowledge creation
	RA12	Enterprises regularly discuss the knowledge change trend of cooperation network and new product development
	RA13	The team encourages everyone to put forward their different opinions
Decision participation	DP11	The different opinions of the team members can be taken seriously
	DP12	Team members can argue when they have different opinions
	DP13	Team members can fully share relevant information when making decisions
	OC11	Team members often have informal exchanges
Open communication	OC12	Team members often discuss each other's expectations and requirements
	OC13	When a member is busy, other members will help him share his work tasks
	TW11	Team members often support each other in their work
	TW12	When there are problems in the cooperation between members in charge of fields, they often inform each other
TMT behavioral integration	TW13	

TABLE 2: Test results of variable reliability and validity.

Variable	Item	Loading	KMO	Cronbach's α	AVE	CR
TMT behavioral integration	Decision participation	DP11	0.883	0.701	0.815	0.737
		DP12	0.814			
		DP13	0.876			
	Open communication	OC11	0.835	0.708	0.796	0.711
		OC12	0.836			
		OC13	0.859			
	Team work	TW11	0.899	0.703	0.837	0.754
		TW12	0.824			
		TW13	0.881			
Sustainable competitive advantage of enterprises	Financial performance (FP)	FP11	0.870	0.761	0.905	0.730
		FP12	0.875			
		FP13	0.843			
		FP14	0.885			
		FP15	0.797			
	Strategic performance (SP)	SP11	0.829	0.746	0.866	0.660
		SP12	0.835			
		SP13	0.781			
		SP14	0.839			
Absorptive capacity	Potential absorptive capability (PA)	PA11	0.835	0.713	0.808	0.724
		PA12	0.862			
		PA13	0.855			
	Realistic absorptive capability (RA)	RA11	0.884	0.708	0.821	0.739
		RA12	0.827			
		RA13	0.867			
Critical reflection		CR11	0.856	0.889	0.917	0.752
		CR12	0.859			
		CR13	0.867			
		CR14	0.878			
		CR15	0.875			

TABLE 3: Correlation coefficients of variables.

	Avg	S.D.	1	2	3	4	5	6	7
1	2.48	0.54	1.00						
2	5.41	1.02	0.527**	1.00					
3	4.68	0.71	-0.054	0.003	1.00				
4	4.38	0.93	0.024	0.015	0.350**	1.00			
5	4.50	0.53	0.069	0.109	0.404**	0.377**	1.00		
6	4.44	0.71	0.039	0.017	0.399**	0.524**	0.599**	1.00	
7	4.40	0.56	0.029	0.035	0.335**	0.310**	0.301**	0.390**	1.00
8	4.34	0.84	0.039	-0.005	0.153**	0.770**	-0.049	0.219**	0.206**

Note: 1. age, 2. scale, 3. TMT behavioral integration, 4. potential absorptive capacity, 5. realistic absorptive capacity, 6. financial performance, 7. strategic performance, 8. critical reflection, ** $P < 0.05$, *** $P < 0.01$, **** $P < 0.001$, the same below.

TABLE 4: Regression results of TMT behavior integration, critical reflection, and enterprises sustainable competitive advantage.

	Model 1 financial performance			Model 2 strategic performance		
	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
1. Age	-0.077	-0.083	-0.089	0.022	0.016	-0.026
2. Scale	0.043	0.002	0.005	0.004	-0.035	-0.013
3. TMT behavioral integration		0.409***	0.438***		0.379***	0.438***
4. Critical reflection			0.061**			0.797***
5. Critical reflection * TMT behavioral integration			0.093			0.092**
R^2	0.004	0.170	0.209	0.001	0.143	0.775
Adjusted R^2	-0.005	0.158	0.191	-0.008	0.131	0.770
F	0.469	14.901***	11.464***	0.066	12.166***	149.426***

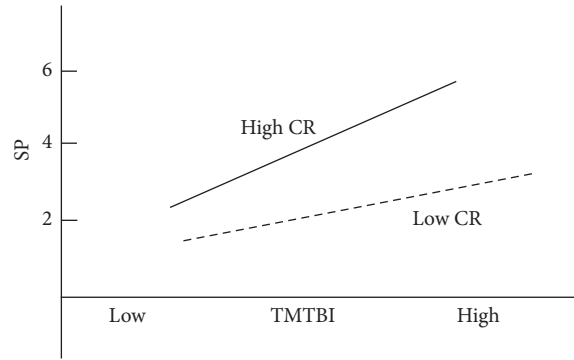


FIGURE 2: Moderating effect of critical reflection on the relationship between TMT behavior integration and enterprise strategic performance. Note: TMTBI, SP, and CR, respectively, refer to TMT behavioral integration, strategic performance, and critical reflection.

TABLE 5: Regression analysis of the impact of TMT behavior integration on absorptive capacity.

Variable	Potential absorptive capacity		Realistic absorptive capacity	
	β	VIF	β	VIF
TMT behavioral integration	0.604 * * *	1.012	0.301 * * *	1.012
R^2	0.362		0.091	
Adjusted R^2	0.353		0.078	
F	41.451 * * *		3.132 *	

TABLE 6: Relationship test between absorptive capacity and enterprises sustainable competitive advantage.

	Financial performance		Strategic performance	
	Model3	Model4	Model5	Model6
Control variable				
Age	-0.093	-0.081	0.000	0.018
Scale	0.045	0.034	0.006	-0.005
Independent variable				
Potential absorptive capacity	0.402 * * *		0.524 * * *	
Realistic absorptive capacity		0.336 * *		0.310 * * *
R^2	0.166	0.117	0.274	0.097
Adjusted R^2	0.154	0.105	0.264	0.084
F	14.512 * * *	9.675 * * *	27.600 * * *	7.798 * * *

TABLE 7: Bootstrapping analysis results of mediating effect.

Path	Effect value	Bootse	BOOT LLCI	BOOT ULCI
TMTBI PAC FP	0.1973	0.0728 * * *	0.0652	0.3543
TMTBI PAC SP	0.4900	0.0900 * * *	0.3296	0.6867
TMTBI RAC FP	0.0946	0.0370 * * *	0.0343	0.1829
TMTBI RAC SP	0.1146	0.0428 * * *	0.0460	0.2198

Note: TMTBI, PAC, RAC, FP, and SP, respectively, refer to TMT behavioral integration, potential absorptive capacity, realistic absorptive capacity, financial performance, and strategic performance.

indirect effect confidence intervals do not contain 0; that is, potential absorptive capacity mediates the relationship between TMT behavior integration and financial performance and strategic performance, and realistic absorptive capacity plays an intermediary role between TMT behavior integration and financial performance and strategic performance. In addition, after controlling the potential absorptive capacity of intermediary variables, the confidence interval of the direct effect of TMT behavior integration on enterprise strategic performance includes 0; that is, a direct effect does not exist, and potential absorptive capacity completely mediates the relationship between TMT behavior

integration and enterprise strategic performance. It is assumed that H4b passes the test. The direct effect of TMT behavior integration on enterprise financial performance does not include 0; that is, a direct effect exists, and potential absorptive capacity plays a partial intermediary role between TMT behavior integration and enterprise financial performance. It is assumed that H4a passes the test. After controlling the realistic absorptive capacity of the intermediary variable, the confidence interval of the direct effect of TMT behavior integration on an enterprise's sustainable competitive advantage does not contain 0, and it is significant; that is, a direct effect exists. The realistic absorptive capacity

partially mediates the relationship between the behavioral integration of TMT and the sustainable competitive advantage of enterprises; thus, H4c and H4d are supported.

6. Research Conclusions, Application, And Prospects

6.1. Research Conclusions. This paper reveals the impact of TMT behavior integration on the sustainable competitive advantage of enterprises, the intermediary role of absorptive capacity (including potential and realistic absorptive capacity), and the regulatory role of critical reflection. Except for H5a, our research hypotheses are confirmed. The regulatory effect of critical reflection on TMT behavior integration and enterprise financial performance failed to pass our test. It may be that the critical reflection helps senior managers think thoroughly about the future of their enterprises, contributes to longer-term strategic planning, and tends to promote strategic performance but has no significant effect on financial performance.

The research shows that TMT behavior integration has a significant positive impact on financial and strategic performance; that is, the improvement of TMT behavior integration, as an important antecedent variable of enterprises sustainable competitive advantage, is conducive to promoting financial performance and strategic performance, which fully reflects the important role of TMT behavior integration in improving enterprises sustainable competitive advantage. Critical reflection has a significant positive regulatory effect between TMT behavior integration and strategic performance, which means that improving the critical reflection (level) will enhance the positive effect of TMT behavior integration on strategic performance.

Potential absorptive capacity completely mediates the relationship between TMT behavior integration and strategic performance, while it plays a partial mediation role between TMT behavior integration and financial performance, and realistic absorptive capacity plays a partial intermediary role between TMT behavior integration and the sustainable competitive advantage of an enterprise (including financial and strategic performance), indicating that the intermediary roles of potential and realistic absorptive capacity should be brought into full play to promote enterprises sustainable competitive advantage.

6.2. Application of the Model. Based on theories of TMT behavior integration, absorptive capacity, enterprise sustainable competitive advantage, and critical reflection, this paper presents a theoretical analysis and empirical research on the relationships between TMT behavior integration (independent variable), enterprise sustainable competitive advantage (dependent variable), absorptive capacity (intermediary variable), and critical reflection (regulatory variable). The empirical results show that there are two ways for TMT behavior integration to affect enterprises sustainable competitive advantage: First, TMT

behavior integration directly affects the enterprises sustainable competitive advantage. Second, TMT behavior integration affects enterprises sustainable competitive advantage through absorptive capacity. In addition, critical reflection can positively regulate the relationship between TMT behavior integration and enterprises strategic performance. The research conclusion can be used to enhance enterprises sustainable competitive advantage from the perspective of TMT behavior integration. Specific measures are as follows:

First, we must attach importance to the TMT behavior integration. The measures are as follows: ① Strengthen the internal knowledge exchange of TMT, reduce decision-making differences, and improve decision-making efficiency. ② Pay attention to information sharing and improve the utilization and efficiency of decision-making information. ③ TMT members should strengthen cooperation, work as a team, and improve their decision-making ability.

Second, enterprise executives should focus on critical thinking. Enterprise executives should be fully aware of the important role of critical reflection in enterprise strategic performance, strengthen their critical reflection, and promote the improvement of enterprise strategic performance. Specific measures can involve: ① Creating a positive organizational atmosphere and conditions for critical reflection. ② Encouraging the critical reflection of TMT members and give better play to the positive role of critical reflection. ③ Introduce critical reflection into the work assessment of TMT members and strengthen the investigation, training, and reuse of members with high critical reflection abilities.

Third, enterprise executives should take the cultivation of absorptive capacity seriously and give full play to the intermediary role of absorptive capacity to promote the continuous improvement of enterprise competitive advantage. Specific measures to improve absorptive capacity can involve: ① Building a learning organization, as the construction of learning organizations creates a strong organizational learning atmosphere and promotes the improvement of organizational absorptive capacity, and ② paying attention to collective rewards and encouraging organization members to carry out high-level knowledge sharing, improve organizational knowledge accumulation and application abilities, and promote the improvement of absorption ability by adopting collective rewards.

6.3. Research Limitations and Future Directions. The limitations of the paper are as follows: ① The selection of samples is limited to enterprises in Jiangsu, Shanghai, Zhejiang, Shandong, and Anhui. Therefore, whether the research conclusions drawn are suitable for enterprises in other regions and industries needs further empirical testing. ② This research only examines the intermediary effect of absorptive capacity and the regulatory effect of critical reflection. Future research can examine the impacts of other intermediary (e.g., learning ability, dual innovation) and regulatory variables (e.g., environmental uncertainty, environmental turbulence).

Data Availability

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

Conflicts of Interest

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

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Research Article

Fault Diagnosis of Double Pitch Time-Sharing Meshing Toothed Conveyor Chain Transmission System Based on Neural Network

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With the rapid development of industry, the production and demand of automobiles have increased significantly. The generation of cars often requires tens of thousands of processes, consisting of hundreds of assembly lines to complete. Chain conveyors are widely used in the transportation of automobile assembly lines. The existing conveyor chains are roller chains. With the improvement of the requirements for conveyor reliability, synchronization, and environmental friendliness, the characteristics of roller conveyor chains restrict the further development of chain conveyors. It is urgent to study a new conveyor chain system to improve the synchronization, reliability, and environmental friendliness of chain conveyors on hundreds of assembly lines. In this paper, the mathematical modeling, meshing analysis, reliability, and environmental friendliness of the parameters of the components of the double pitch time-sharing meshing toothed conveyor chain system are studied. In addition, a novel fault diagnosis method of double pitch time-sharing meshing toothed conveyor chain transmission system based on neural network model is proposed in this paper.

1. Introduction

A car consists of more than 5000 parts, excluding interchangeable and universal standard parts (such as bolts, nuts, and gaskets). For the automobile assembly process is complex, the output of a car often requires a lot of labor, which is completed through hundreds of assembly lines composed of tens of thousands of processes. The integrity, reliability, and service life of the automobile require a high degree of specialization, strong continuity, and coordinated flow production.

At present, the conveyor system of automobile assembly line mainly adopts roller conveyor chain transmission and belt transmission. Due to the polygon effect in the transmission process of roller conveyor chain, there will be a large instantaneous impact in the meshing process of chain and sprocket. This impact process will produce large noise and serious wear, resulting in large wear elongation. In serious cases, tooth skipping and fracture will occur, which will seriously affect the continuity and rhythm coordination of the assembly line. Under heavy load and variable load, the belt

transmission has low transmission efficiency and service life, and slip will occur. When the tension is too large, the joint or weak link of the belt will be broken. The most important thing is that the belt will deviate during the transmission process, which will seriously affect the normal operation of the assembly line. It is found that the noise of toothed chain is almost the same as that of belt drive. The toothed chain is limited by the guide plate, so there will be no deviation in the transmission process. At the same time, the toothed chain is meshed transmission and has a constant average transmission ratio. It can be seen that the toothed chain can better ensure the continuity and rhythm coordination of the automobile assembly line. However, the toothed chain with the same pitch is heavier than the roller chain, and the weight of the conveyor itself will affect the conveying performance. Therefore, it is difficult for the traditional toothed chain to meet the increasing requirements of the conveyor. With the rapid development of automobile manufacturing industry, there is an urgent need to study a new chain conveyor system with better conveying performance and higher transmission efficiency, which is suitable for conveyor applications.

As one of the basic parts of mechanical transmission [1–5], toothed chain has stronger bearing capacity and lower noise. For the working conditions of large center distance and variable speed and load, its transmission performance is better than that of toothed belt transmission, gear transmission, and roller chain transmission. Toothed chains are divided into external meshing toothed chains, internal meshing toothed chains, internal and external meshing toothed chains, and other toothed chains. The existing standards are the design standards of transmission toothed chain, which are not suitable for the conveyor chain on the assembly line, and there is little research on the conveyor toothed chain. In this paper, the multibody dynamics model of the double pitch time-sharing meshing toothed conveyor chain system is established, and the kinematics and dynamics characteristics of the double pitch time-sharing meshing toothed conveyor chain system are studied. When conveying and transmitting the same force, the chain transmission system has stable meshing and meshing, low impact vibration and noise, less consumables, high motion accuracy, and good reliability. The new double pitch time-sharing meshing toothed transmission chain system has a very broad application prospect in various assembly lines, especially in automobile assembly lines. Finally, a novel fault diagnosis method of double pitch time-sharing meshing toothed conveyor chain transmission system based on neural network model is constructed in this paper.

2. Related Work

2.1. Research on Toothed Chain Transmission System. Because the meshing mode of toothed chain transmission system is different from that of roller chain transmission, the structural parameters are more complex. There is relatively little research on toothed chain transmission system. Because of its great manufacturing difficulty and high production technology content, only a few manufacturers can produce toothed chain internationally. Bucknor N.K makes static and dynamic analysis of Hy-VO toothed chain with external meshing mechanism, adds the influence of link clearance, establishes the quasi-static equation of roll pin toothed chain on the basis of analyzing the influence of the parameters of chain plate and pin shaft on the transmission performance of toothed chain, and calculates the maximum torque value under the condition of static balance. It is concluded that the extreme torque is related to the corresponding center distance and the design parameters of the chain drive system [6, 7]. Based on the finite element method, Adnan et al. analyzed the fatigue strength of the toothed chain plate of the external meshing mechanism under cyclic load, and proposed corresponding improvement methods according to the research conclusions. Weber, Stephenson, and others used telemetry to continuously observe a series of parameters such as wear, noise, and dynamic characteristics of timing chain system under different engine working conditions [8, 9]. Heinz Heisler put forward a relatively complete design scheme for V-type engine, in which the design layout of camshaft, installation position of chain tensioner, and oil pump drive chain were studied in detail [10]. Masakazu Wada, Shouchiro

IDE, and others proposed a toothed chain product with a pitch of 6.35 mm, which was successfully applied to a single camshaft timing transmission system. Based on the dynamic analysis of external meshing circular pin toothed chain by using Adams/engine module, some researchers obtained the characteristic equivalence of tight edge tension and contact force between driving and driven sprocket and chain plate in the process of chain transmission and simulated and analyzed the calculation results. In order to solve the wear problem of toothed chain sprocket, Jeffrey et al. started with the material and processing technology of toothed chain and used powder metallurgy technology to manufacture the timing round pin toothed chain sprocket of engine. In addition, some scholars improved the wear resistance of toothed chain by coating the surface of toothed chain plate and pin shaft.

2.2. Application of Chain Drive System in Conveyor. The chain is the bearing and traction component of the chain conveyor. The bearing capacity and running length of the conveyor mainly depend on the conveyor chain system. Therefore, whether the design of the conveyor chain system is reasonable not only is related to the productivity, reliability, and service life of the conveyor, but also affects the driving power of the conveyor and the consumption of steel for manufacturing the conveyor chain. Industrial developed countries attach great importance to the design and standardization of the conveyor chain system. For example, Germany, France, Finland, Sweden, and other countries have developed their own national standards din8167, nfe26-106, sfs2380, and sms2083 based on iso/r1977 recommended by international standards. Through these standards, the conveyor chain systems of the same model produced by these countries can be used universally, and there will be no obstacles in technology, trade, or academic exchanges. Compared with other types of conveyors, the chain conveyor has low energy consumption and high efficiency, and the energy consumption of the same conveying length and volume is 50% lower than that of the screw conveyor. With simple structure and light weight, it can ensure stable transmission ratio, convenient maintenance, and low operation cost and can work normally in various environments, including corrosive, flammable, and explosive working conditions, as well as transporting hot materials. It is commonly used in building materials, chemical industry, mechanical assembly, metallurgy, grain, hydropower, light industry, ports, mines, transportation, and other departments and is suitable for transportation density of $0.2 \sim 1.8 \text{ t/m}^3$ and powdery, granular, or small loose materials with temperature $\leq 80^\circ\text{C}$. At present, the commonly used chain conveyors mainly include KS double chain scraper conveyor, DTS chain conveyor, Fu chain conveyor, and SFC chain conveyor.

2.3. Problems in the Application of Toothed Chain in Conveyor. With the development of industrial automation, the performance requirements of conveyors are becoming higher and higher. In addition to ensuring transmission accuracy, service life, and reliability, environmental friendliness has also been put on the agenda. Therefore, it has been difficult

for the chain conveyor of roller chain drive system to meet the demand. We need to have the environmental friendliness of belt transmission system and the reliability of roller chain transmission system at the same time. Only the toothed chain transmission system has the common advantages of belt transmission and roller chain transmission system at the same time. Due to the complexity of toothed chain transmission system, there is no international standard at this stage. The research on toothed chain mainly focuses on the tooth profile and tooth profile design method of round pin toothed chain and roller pin toothed chain used in high-speed transmission methods of reducing polygon effect, establishment of kinematic model, establishment of dynamic model, transverse and longitudinal vibration of chain, noise source, software simulation, development of test equipment, etc. Through the research, it is found that the toothed chain has many advantages, but it is not used in the conveyor, because the self-weight of the chain drive system affects the working performance of the conveyor. Based on the development needs of mechanical automation and the advantages of toothed chain transmission system, this paper proposes a double pitch time-sharing meshing toothed conveyor chain system. It is hoped that, through the establishment and research of this project, some theoretical and methodological problems of the application of toothed chain in conveyors, that is, the double pitch time-sharing meshing toothed conveyor chain system, can be effectively solved.

3. Simulation Analysis of Double Pitch Time-Sharing Meshing Toothed Conveyor Chain System

In the process of double pitch time-sharing meshing toothed conveying chain, polygon effect is an inherent attribute in the process of chain transmission, and it is also the main factor causing the horizontal and vertical fluctuations of the chain. Therefore, to evaluate the advantages and disadvantages of the new double pitch time-sharing meshing toothed conveyor chain, it is necessary to carry out dynamic simulation analysis in kinematics. In order to analyze the influence of the characteristic parameters of the new double pitch time-sharing meshing toothed conveyor chain on the polygon effect, the kinematic simulation analysis of the chain and sprocket of the double pitch time-sharing meshing toothed conveyor chain is carried out based on the multibody dynamics simulation software Adams [11–13] without considering the chain plate hole and pin shaft clearance. The vibration generated by the meshing impact excitation between the chain and the sprocket is the main source of noise. In order to evaluate the noise reduction characteristics of the double pitch time-sharing meshing toothed conveyor chain, a dynamic model is established on the premise of considering the chain plate hole and the pin shaft clearance, and the multibody dynamics technology is used to study the contact meshing impact force between the double pitch time-sharing meshing toothed conveyor chain and the sprocket teeth.

3.1. Theoretical Basis of Multibody Dynamics. In multibody dynamics, three rectangular coordinates and rotational coordinates in the inertial coordinate system of the center of mass of each rigid body are selected as Cartesian generalized coordinates, and the multibody system equation is derived by using the first kind of Lagrange equation with Lagrange multiplier. The multibody system includes the inertial coordinate system and the follow-up coordinate system. The follow-up coordinate system is fixed on the component and moves with it. In the process of establishing and solving the dynamics of the multibody system, the motion of the rigid body in the inertial coordinate system can be determined by establishing the position of the center of mass of the rigid body in the follow-up coordinate system and then establishing the position relationship between the follow-up coordinate system and the inertial coordinate system with the azimuth angle.

3.1.1. Establishment of Kinematic Equation. In a multirigid body system, rigid bodies are connected in the form of kinematic pairs. These kinematic pairs are expressed as algebraic equations through generalized coordinates, which can be holonomic constraints, steady constraints, and unsteady constraints.

$$\Phi^k(\vec{q}) = [\Phi_1^k(\vec{q}), \Phi_2^k(\vec{q}), \dots, \Phi^k(\vec{q})]^T = 0. \quad (1)$$

In the above formula, the constraint equation is a time function, which is called unsteady constraint; if the constraint equation contains an integrable velocity term, it is called incomplete constraint. The motion constraint equation and the driving constraint equation together form the position equation of the system:

$$\Phi(\vec{q}, t) = \begin{bmatrix} \Phi^k(\vec{q}) \\ \Phi^D(\vec{q}, t) \end{bmatrix} = 0. \quad (2)$$

By differentiating the above formula, the velocity constraint equation can be obtained:

$$\dot{\Phi}(\vec{q}, \dot{\vec{q}}, t) = \Phi_q(\vec{q}, t)\dot{\vec{q}} + \Phi_t(\vec{q}, t) = 0. \quad (3)$$

Continue to differentiate the above formula to obtain the acceleration constraint equation:

$$\ddot{\Phi}(\vec{q}, \dot{\vec{q}}, \ddot{\vec{q}}, t) = \Phi_q(\vec{q}, t)\ddot{\vec{q}} + \left[\Phi_q(\vec{q}, t)\dot{\vec{q}} \right]_q \ddot{\vec{q}} + 2\Phi_{qt}(\vec{q}, t)\dot{\vec{q}} + \Phi_{tt}(\vec{q}, t) = 0. \quad (4)$$

The above equation is solved by Calahan method:

$$\left\{ \begin{aligned} \ddot{\vec{q}} &= -\Phi_q^{-1}\Phi_t, \ddot{\vec{q}} = -\Phi_{q-1} \left[\left(\Phi_q \dot{\vec{q}} \right) \dot{\vec{q}} + 2\Phi_{qt} \dot{\vec{q}} + \Phi_{tt} \right]. \end{aligned} \right. \quad (5)$$

3.1.2. Establishment of Dynamic Equation. The coordinate transformation matrix of the follow-up coordinate system and inertial coordinate system of the component centroid is

$$\begin{bmatrix} \cos \psi \cos \varphi - \sin \psi \cos \theta \sin \varphi & -\cos \psi \sin \varphi - \sin \psi \cos \theta \cos \varphi & \sin \psi \cos \theta \\ \sin \psi \cos \varphi + \cos \psi \cos \theta \sin \varphi & -\sin \theta \sin \varphi + \cos \psi \cos \theta \cos \varphi & -\cos \psi \sin \theta \\ \sin \theta \sin \varphi & \sin \theta \cos \varphi & \cos \theta \end{bmatrix}. \quad (6)$$

Then define an Euler axis coordinate system. The coordinate transformation matrix from this coordinate system to the component centroid follow-up coordinate system is

$$\vec{B} = \begin{bmatrix} \sin \theta \sin \varphi & 0 & \cos \theta \\ \sin \theta \cos \varphi & 0 & -\sin \theta \\ \cos \theta & 1 & 0 \end{bmatrix}. \quad (7)$$

Then the kinetic energy of the multirigid body system is

$$\vec{T} = \frac{1}{2} \dot{\vec{R}}^T \vec{M} \dot{\vec{R}} + \frac{1}{2} (\vec{B} \dot{\vec{r}})^T \vec{J} (\vec{B} \dot{\vec{r}}). \quad (8)$$

The Euler Lagrange equation of the multirigid body system is

$$\begin{bmatrix} \vec{M} & \vec{\Phi}_q^T \\ \vec{\Phi}_q & 0 \end{bmatrix} \begin{bmatrix} \ddot{\vec{q}} \\ \ddot{\vec{\lambda}} \end{bmatrix} = \begin{bmatrix} \vec{Q}^A \\ \vec{\eta} \end{bmatrix}. \quad (9)$$

3.2. 3D Model Establishment. The multibody kinematics and dynamics of the double pitch time-sharing meshing toothed conveyor chain system are analyzed in Adams simulation software. First, carry out geometric modeling. The double pitch time-sharing meshing toothed conveyor chain system is a newly designed structure, which cannot be directly obtained in the Adams Geometric Modeling Toolbox, and there are many structural parameters of the chain plate. Therefore, the three-dimensional modeling and virtual assembly of chain and sprocket are carried out in pro/e first.

The design parameters of the chain and sprocket of the double pitch time-sharing meshing toothed conveyor chain are designed. Taking the single pitch of the chain as 15.875 mm, the number of sprocket teeth as 45, and the sprocket pitch as 15.875 mm, the component models of the linear tooth profile double pitch time-sharing meshing toothed chain sprocket and the corresponding double pitch time-sharing meshing toothed conveyor chain are established in pro/e, respectively. We designed the negative modification involute tooth profile sprocket and modified the parameters of the double pitch time-sharing meshing tooth profile conveyor chain plate. Similarly, we established the component model of the double pitch involute tooth profile sprocket and the corresponding modified double pitch time-sharing meshing tooth profile conveyor chain in pro/e.

In the process of simulation and analysis, the double pitch roller conveyor chain should have the same pitch as the new double pitch time-sharing meshing toothed conveyor chain. Therefore, when the double pitch time-sharing meshing toothed conveyor chain has a single pitch of 15.875 mm and the number of sprocket teeth is 45, the model parameters of the double pitch roller conveyor chain and sprocket are based on the standard. The model of the chain is

210a, and the number of sprocket teeth is 45, and the pitch is 15.875 mm standard roller chain sprocket.

3.3. Kinematic Simulation Analysis of Double Pitch Time-Sharing Meshing Toothed Conveyor Chain System

3.3.1. Initial Condition Analysis. After entering the 3D model and establishing constraints, Adams will analyze the initialization conditions to ensure that the simulation model meets all constraints. The initial condition analysis is achieved by solving the minimum value of the corresponding position, velocity, and acceleration objective function.

3.3.2. Meshing Simulation Model. When the double pitch time-sharing meshing toothed conveyor chain is meshed with the sprocket, the tooth shape parameters of the chain plate and the number of teeth of the sprocket have a great impact on the conveying characteristics of the double pitch time-sharing meshing toothed conveyor chain system. The more the number of teeth of the sprocket is, the more stable the transmission of the chain drive system is. In order to analyze the influence of the extension of the internal tooth profile of the chain plate on the meshing polygon effect of the double pitch time-sharing meshing toothed transmission chain, when the number of sprocket teeth is certain, the influence of the extension of the internal tooth profile on the tight side wave momentum of the double pitch time-sharing meshing toothed transmission chain system is established, respectively. Without considering the chain plate hole and pin shaft clearance, a three-dimensional parametric simulation model of the double pitch time-sharing meshing toothed conveyor chain system and the double pitch roller conveyor chain system is established by using Adams simulation software.

3.3.3. Influence of Tooth Profile Extension in Chain Plate on Tight Side Wave Momentum of Chain Drive System. The single pitch of the chain is 15.875 mm, the number of driving and driven sprocket teeth is 45, the pitch of the sprocket is 15.875 mm, and the protrusions are 0.05 mm, 0.10 mm, 0.15 mm, 0.20 mm, 0.25 mm, 0.30 mm, 0.35 mm, and 0.40 mm, respectively. The simulation model of the double pitch time-sharing meshing toothed conveyor chain system is analyzed. In the initial setting, the driving wheel speed is $4\pi/Z$ per second, and the simulation runs for 1s. In a meshing cycle, the fluctuation of the tight side center of the double pitch time-sharing meshing toothed conveyor chain is within a certain range. The larger the extension, the smaller the fluctuation of the tight side of the chain center, which is in line with the function of the extension of the inner tooth profile. The extension of the inner tooth profile can reduce the polygon effect. However, when the extension value is too large, the whole meshing is completely double

pitch time-sharing meshing, and the inner tooth profile of the toothed conveyor chain is meshed. During meshing rotation, the inner tooth profile cannot shrink into the outer tooth profile of the adjacent chain link, and the meshing impact is large when meshing with the intermediate tooth. When the extension is very small, in the meshing process, the internal tooth profile meshing is transformed into the external tooth profile meshing of adjacent links in a very short time, so the effect of reducing the polygon is not obvious. Therefore, for the calculation example, the best internal tooth profile elongation is $\delta = 0.25$ mm.

3.3.4. Comparative Analysis of Tight Edge Fluctuation between Double Pitch Roller Conveyor Chain System and Double Pitch Roller Conveyor Chain System. For the double pitch time-sharing meshing toothed conveyor chain system with a single pitch of 15.875 mm and double pitch of 31.67 mm and the double pitch roller conveyor chain system with a single pitch of 15.875 mm and double pitch of 31.75 mm, the number of teeth of the driving and driven wheels of the two conveyor chain systems is 45. In order to show generality, the extension is 0.15 mm. The simulation models of the two conveyor chain systems are analyzed. In the initial setting, the driving wheel speed is $4\pi/Z$ per second, and the simulation runs for 1 s. In a cycle, two conveyor chains fluctuate around the center. The simulation analysis shows that the transverse wave momentum of the double pitch time-sharing meshing toothed conveyor chain is 113.19–113.53 mm, and the fluctuation range is 0.34 mm. The transverse wave momentum of the double pitch roller conveyor chain is 113.08–113.91 mm, and the fluctuation range is 0.83 mm. It can be concluded that the transverse fluctuation of the tight side of the double pitch time-sharing meshing toothed conveyor chain is 59% lower than that of the double pitch roller conveyor chain.

3.4. Dynamic Simulation Analysis of Double Pitch Time-Sharing Meshing Toothed Conveyor Chain System. Dynamics is to study that the vibration and noise of the double pitch time-sharing meshing toothed conveyor chain system change with the evolution of time under the action of meshing impact force, and the polygon effect of the double pitch time-sharing meshing toothed conveyor chain is the main cause of meshing impact. By studying the meshing impact force, Newton's law of motion is used to study the influence on the double pitch time-sharing meshing toothed conveyor chain system.

3.4.1. Contact Force Model. The double pitch time-sharing meshing toothed conveyor chain system is composed of a driving and driven sprocket, a chain, and a tensioning device. The chain extends due to wear, and the tensioning device compensates for the wear elongation. Therefore, in the process of simulation, it is only necessary to establish a double pitch time-sharing meshing toothed conveyor chain system composed of driving and driven sprocket and chain. The driving and driven wheels in the simulation model carry

out the predetermined relative motion through the contact force and friction between the chain and sprocket teeth, and the driving wheel sets the driving constraint of constant speed. Each section of the double pitch time-sharing meshing toothed conveyor chain is connected by multiple rows of chain pieces through pin shafts, and there is a guide plate in the middle of every other section. The guide plate plays a role in horizontal positioning and adjusting the strength between chain links and does not play a major role in the meshing process. Without affecting the calculation results, simplify the contact force simulation model and establish $5 \times$ Model 6 double pitch time-sharing meshing toothed conveyor chain link simulation model. In the practical application of toothed chain for inner guide conveying, the outer chain plate and the pin shaft are interference fit, while all the other chain plates and guide plates are clearance fit with the pin shaft. Therefore, in order to make the simulation results true, we establish the geometric model of the link. The pin shaft of 6 chain links and two outer chain plates form one part, and the clearance between the inner chain plate and the pin shaft is considered, with a unilateral clearance of 0.01 mm.

The meshing contact force of the double pitch time-sharing meshing toothed conveyor chain system is mainly considered in the simulation model, using the search algorithm. The search process is as follows: define a boundary circle whose center coincides with the center of the sprocket, then search the chain for the starting link and the ending link that may contact the sprocket, and then search the starting link and the ending link in the boundary circle in detail to observe the direct contact of the chain link. For the double pitch time-sharing meshing toothed conveyor chain and the linear tooth profile, there are three possible contacts between the sprockets of the double pitch time-sharing meshing toothed conveyor chain, namely, the circular arc linear contact between the inner tooth profile of the chain plate and the linear tooth profile of the sprocket, the linear point contact between the outer tooth profile of the chain plate (middle tooth profile) and the linear tooth profile of the sprocket, and the circular arc circular arc contact between the hole of the chain plate and the pin shaft. The double pitch roller conveyor chain conveying system is mainly arc-arc contact.

3.4.2. Contact Impact Analysis. In order to verify the rationality of the structure of the double pitch time-sharing meshing toothed conveyor chain and the reduction of the meshing impact by the tooth profile structure, the double pitch time-sharing meshing toothed conveyor chain with a single pitch of 15.875 mm and a sprocket tooth number of 45 and the double pitch roller conveyor chain are compared and analyzed. To analyze the meshing contact impact, only one meshing cycle needs to be analyzed, so the simulation model can be simplified.

In the process of establishing the simulation model, the unilateral clearance between the chain plate hole and the pin shaft is considered to be 0.01 mm. The sprocket is the driving wheel, which rotates counterclockwise and rotates at a speed

of $4\pi/Z$ degrees per second. In order to obtain the meshing impact between the chain plate and the sprocket and the tension of the tight chain during the operation of the chain drive system, it is necessary to establish contact pairs between the chain plate and the sprocket, and between the chain plate and the pin shaft. In addition, in order to make the simulation process close to the running state of the conveyor chain system in reality, that is, to realize the horizontal movement state of the tight side chain, a 2Kn fixed tension is applied to the center of the chain plate pin to simulate the tension of the tight side chain. The extension of the tooth profile in the chain plate is 0.15 mm, 0.20 mm, 0.25 mm, and 0.30 mm, respectively. When the sprocket rotates at a constant speed of $4\pi/Z$ degrees, the contact force between the chain plates 2 and 3 of the double pitch time-sharing meshing toothed conveyor chain and the sprocket can be seen. When the extension of the tooth profile in the chain plate increases within a certain range, the meshing impact contact force decreases, but when it reaches a certain value, contact is found with the increase of the extension. 3. There is no meshing impact force, and the meshing impact force is all in contact_2. At this point, explain contact_3. It does not participate in meshing. According to the simulation results, it conforms to the role of the inner tooth profile of the chain plate. When the extension is very small, the meshing of the inner tooth profile will soon be transformed into the meshing of the outer tooth profile, and the contact impact force will soon be changed from contact_2 convert to contact_3. As the extension increases, the conversion time increases, and it is consistent when the extension is 0.15–0.25 mm. However, when the extension reaches a certain value, the internal engagement cannot be converted to the external engagement. There is no contact impact on contact 3.

The contact force of the double pitch time-sharing meshing tooth profile transmission link can show that, at the beginning of operation, the impact force of the contact between the inner tooth profile of link 2 and the sprocket is large, and link 1 and the sprocket do not contact without impact force. When the operation is 0.13s, link 1 and link 2 participate in the meshing at the same time and gradually transition to the meshing of the outer tooth profile of link 1. The impact force of link 1 is slightly greater than that of link 2. However, they are much smaller than the impact force of link 2 when it just runs. When it runs to about 0.5s, the external tooth profile meshing of link 1 is transformed into the internal tooth profile meshing of adjacent link 2. Link 1 disengages without impact force, while the impact force of link 2 in contact with the sprocket is instantaneous large, and link 2 gradually engages and locates to complete one-time meshing. The meshing impact force of the roller and sprocket of the double pitch roller chain is instantaneous contact meshing, and the initial meshing impact is large. The simulation results show that the maximum meshing impact force of the double pitch time-sharing meshing toothed conveyor chain is 4542.6N, and the maximum meshing impact force of the double pitch roller conveyor chain is 8726.5 N. The meshing of the double pitch time-sharing meshing toothed conveyor chain system is stable, and the maximum impact force is

51.9% of the double pitch roller chain. Considering the influence of the internal tooth profile extension on the tight side wave momentum and the meshing impact force of the double pitch time-sharing meshing toothed conveyor chain system, the internal tooth profile extension of the double pitch time-sharing meshing toothed conveyor chain system with a single pitch of 15.875 mm and a sprocket tooth number of 45 is taken as 0.25 mm.

4. Construction of Diagnosis Model Based on Deep Neural Network

With the continuous improvement of the complexity of data processing, artificial neural network has natural advantages in signal processing. Its excellent nonlinear characteristics, adaptive characteristics, the ability to learn from the environment in a supervised or unsupervised manner, and extensive global approximation ability make it a natural tool to solve adaptive and nonlinear signal processing problems. It has good fault tolerance, strong parallel computing capability, and distributed information storage capability. It has a wide range of applications, such as smart medicine [14–16], smart finance [17, 18], and smart transportation [19, 20]. At present, there are many neural network models, and RBF neural network is a popular application in fault diagnosis and prediction. This paper is based on RBF neural network for fault diagnosis.

4.1. Neural Network

4.1.1. Artificial Neural Network. Artificial neural network belongs to one of the application branches of artificial intelligence. Artificial neuron is an important component of artificial neural network. Its function is to sum the input signals of neurons through the connection weight and then compare them with the fixed threshold through the activation function. If the value after the sum is less than the threshold, it will output 0; otherwise it will output 1. The common neural network is a forward network structure, and the training value is transferred to the hidden layer through the network. In the network, the input vector and output vector are in one-to-one correspondence. When the state of the network is updated, the output vector is obtained from the output layer.

4.1.2. RBF Neural Network. RBF neural network belongs to local approximation network, which has strong pattern classification and self-learning ability. For local areas, the selection of the number of nodes and connection weights of only hidden layers affects the output of the network. In terms of structure, RBF neural network is a three-layer feedforward network with a hidden layer. The essence of its learning process is to find the best fitting hyperplane with the training data set in the weight space. RBF neural network is more suitable for online monitoring and diagnosis because of its shorter time to achieve the best fitting and higher real-time performance when training data sets.

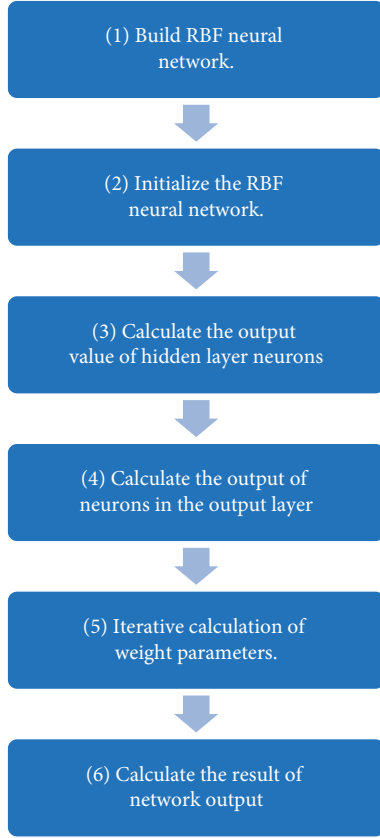


FIGURE 1: Method flowchart.

4.1.3. Construction of RBF Neural Network. The training process of the network first takes the number of extracted feature vectors as the number of nodes in the input layer and transmits them to the RBF neural network for training through the input layer. Secondly, by adjusting the relevant parameters between the hidden layer unit and the output unit to realize the corresponding relationship between input and output, the information of the network can be fully reflected. Figure 1 shows the network training steps:

- (1) Build RBF neural network. The numbers of input layers, output layers, and hidden layers are selected according to the vector dimension of the extracted feature vector and the number of selected fault types.
- (2) Initialize the RBF neural network.
- (3) Calculate the output value of hidden layer neurons.
- (4) Calculate the output of neurons in the output layer.
- (5) iterative calculation of weight parameters.
- (6) Calculate the result of network output.

4.1.4. Experimental Result. RBF neural network is used to train the data to achieve the purpose of fault diagnosis and state trend prediction. First, we construct samples according to the signal data obtained after feature extraction. Then we will divide the constructed data samples into training data set and test data set. After the division, we can start to create RBF neural network and set the parameters of RBF neural

TABLE 1: Comparison of results.

	MAE	RMSE
SVM	0.16	0.32
RF	0.10	0.24
RBF	0.04	0.10

network. Before we input the data samples into the RBF neural network, we also need to normalize the training data and test data with the same parameters. Then the output value of our data samples after RBF neural network training should also be denormalized with the same parameters as the input. After completing the above series of operations, we can get the prediction value we need based on RBF neural network. We calculate the error index of RMSE and Mae to measure the prediction accuracy and compare the prediction accuracy of fault diagnosis and prediction combined with other intelligent control algorithms. Table 1 shows that the proposed method achieves the best classification performance.

5. Conclusion

In this paper, three-dimensional modeling of the newly designed double pitch time-sharing meshing toothed conveyor chain and linear tooth profile sprocket is carried out by using three-dimensional software. Through the interface between Adams and pro/e, the assembled double pitch time-sharing meshing toothed conveyor chain, linear tooth profile sprocket system, and double pitch roller conveyor chain system are introduced into Adams, respectively. The kinematic model and meshing impact dynamic model of the two chain transmission systems are established by using multibody dynamics technology, and the influence of internal tooth profile elongation parameters on the system and the superior performance of the new conveyor chain system and the traditional conveyor chain system are analyzed. In addition, a novel fault diagnosis method of double pitch time-sharing meshing toothed conveyor chain transmission system based on neural network model is proposed in this paper.

Some achievements have been made in the parameter design, meshing theory, simulation analysis, and bench test of the double pitch time-sharing meshing toothed conveyor chain system, and the laboratory research stage has been completed. The double pitch time-sharing meshing toothed conveyor chain system can be further studied in the following aspects, so that the toothed chain system can be more perfectly applied to the chain conveyor. In the process of structural design of double pitch time-sharing meshing toothed chain, the pin shaft of variable pitch time-sharing meshing toothed chain is further designed, so that the excellent characteristics of toothed chain are widely used in conveyors. The test of the double pitch time-sharing meshing toothed conveyor chain system made in this paper is carried out on the closed force flow chain test-bed. By increasing the load to simulate the self-weight and the friction generated by the load, the actual working conditions can be simulated. However, if conditions permit in the

future, the noise test and durability wear test of the double pitch time-sharing meshing toothed conveyor chain system will be further carried out on the workshop conveyor [21–23].

Data Availability

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

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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Retraction

Retracted: Psychological Adjustment and Emotional Health Care Strategies in the Teaching Process of College Music Teachers Based on Big Data Analysis

Mathematical Problems in Engineering

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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] S. Ma and Y. Liu, "Psychological Adjustment and Emotional Health Care Strategies in the Teaching Process of College Music Teachers Based on Big Data Analysis," *Mathematical Problems in Engineering*, vol. 2022, Article ID 4501189, 10 pages, 2022.

Research Article

Psychological Adjustment and Emotional Health Care Strategies in the Teaching Process of College Music Teachers Based on Big Data Analysis

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In music teaching in high schools, teachers should not only impart corresponding music knowledge to students but also focus on cultivating students' comprehensive quality and quality. In the process of music teaching in universities, we should focus on students' psychological adjustment and emotional health care. In order to quantify the application effect of big data technology in music teaching reform, this paper takes piano teaching in universities as an example to conduct research and mainly analyzes the physiological and psychological prediction effects involved in the teaching process. This paper introduces three typical big data technologies to predict and analyze the data involved in the existing piano teaching in universities. The analysis results show that the prediction effect based on the fuzzy neural inference system is the best. In addition, the three-dimensional display of the prediction data shows that the prediction effect obtained by big data technology shows good consistency and continuity, which indicates that the prediction method based on big data technology is suitable for psychological adjustment and emotional health care in music teaching in universities.

1. Introduction

Music, as an independent art, is aesthetic [1, 2]. In people's aesthetic activities, the artistic image is born out of emotion, which makes the aesthetic subject feel the same, and evokes various emotional experiences of the appreciator. Studies [3, 4] have confirmed that the melody and timbre changes and rhythm and beat movements of music can radiate the unique charm of the human spiritual world. When it mobilizes various factors such as memory, association, and imagination of people's thinking, it can arouse people's sympathy and resonate. The study pointed out that music therapy is a method based on the theory of psychological diagnosis and treatment. It uses the physical and psychological reactions produced by music, with the help of music therapists, using established music interactions and then relying on the influence of music perception, so that

patients can regain confidence and gain a healthy mind. As shown in Figure 1, in the current era, there are generally the following types of music therapy methods that have more appeal in the world: psychodynamic music therapy, cognitive music therapy, behavioral music therapy, guided imagery music therapy, etc. First of all, the concert brings the audience a happy mood, which is the process of psychodynamic therapy. Music can then change the perception and behavior of the audience through their characteristic melodies. Finally, through the above operations, music can make the audience have a reasonable imagination space.

In addition to these types of therapy, it also includes transpersonal music therapy and personality-oriented music therapy. These scientific music therapy methods can provide a model for college students' mental health education as a reference.

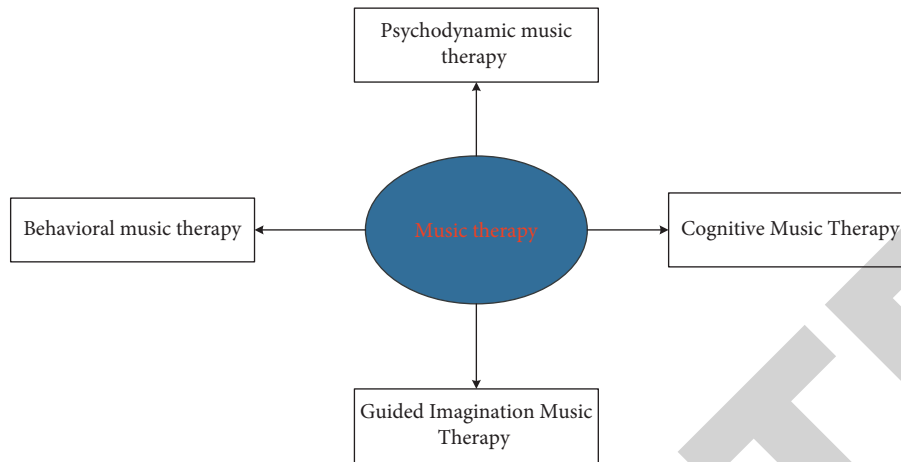


FIGURE 1: Components of college music therapy.

At present, in some developed countries abroad, music has achieved obvious therapeutic effects on the treatment of mental health diseases. Therefore, the subject exploration of music therapy abroad has developed into a practical subject with strong clinical application, that is, music therapy. Music therapy became an independent subject in universities and first appeared in the United States, so the United States also occupies a leading position in the global music therapy industry [5, 6]. Up to now, music therapy has been widely used in many countries around the world. According to statistics from the Global Music Therapy Federation, music therapy has been implemented in 45 countries in the world, and 150 universities have carried out music therapy teaching. In recent years, with the rapid development of China's social economy, the teaching mode and teaching methods and means of universities are constantly maturing. Therefore, music therapy education has gradually been incorporated into the teaching system and teaching management of Chinese universities. However, China is still in its infancy, mainly learning from the West, with less original research on its own. In the actual teaching work, music education in Chinese universities still faces a series of practical problems. Therefore, the effective implementation of music therapy in universities still needs continuous improvement.

For the specific group of college students, how to combine the psychological characteristics of college students and integrate music therapy into the daily study and life of college students is a problem we should focus on.

As we all know, music is a romantic word. As far as most people are concerned, the music teaching process in universities is more about singing and laughing, singing, and dancing, keeping away from worries and troubles and making people mentally healthier. However, on the contrary, according to the scientific research statistics in recent years, it is found that the mental health problems of music teachers in universities are relatively serious. At the same time, music teachers and musicians are groups with distinct industry characteristics and special psychological states. Therefore, how to understand the psychological activities and psychological states in the process of music teaching and

how to break the bottleneck of mental health of music teachers in universities and further improve the quality of teaching in universities are issues worthy of consideration at this stage.

In order to explore the real cause of this problem, it is necessary to deeply understand the psychological phenomena and psychological characteristics of music workers, especially music teachers who are engaged in music careers in universities. Musicians have their own unique psychological characteristics. First of all, as an art major, music has relatively high requirements on people's image thinking ability, creativity, and overall sensitivity. Moreover, it will be honed in the teaching practice process. At the same time, the training of musical skills requires enduring loneliness alone. Workers in the music business require long hours of individual training and pondering every day. Therefore, the groups engaged in teaching and learning in this area are more critical. In addition, musicians tend to be simpler and more easily injured because they have less contact with people. Moreover, their character appears to be aloof, arrogant, and self-conscious.

In addition, the music group has a strong sense of musical hearing, explicitness, and expressiveness required by music. At the same time, the direct communication characteristics of music, especially professional skills, such as instrumental music, dance, vocal music, and conducting, will require stage performance and emotional appeal. This will naturally lead to differences in the overall character and psychological process of music lovers from other art groups. However, these differences often manifest as excitability, emotionality, and high ups and downs. Therefore, their overall performance is more extroverted.

In the fusion of these talents and professional characteristics, teachers and students have a lot of emotional ups and downs in the classroom. When the class is exciting, everyone is enthusiastic and impulsive, even dancing, and the music and singing are very loud. However, when there is no feeling in the classroom, teachers and students may be free and loose, lacking the basic process and discipline of regular teaching. In terms of music teaching methods, due to the characteristics of visualization and creative thinking,

teachers prefer to use perceptual methods such as metaphors, inspiration, and feelings. Moreover, each teacher will have a relatively distinct teaching image thinking and language system, and it is easy to seek changeable and new forms of expression. This requires students to learn more by relying on comprehension. However, once you cannot adapt to this learning rhythm, it becomes difficult.

2. Psychological Adjustment and Mental Health in the Teaching of Music Major in Universities

In the teaching process, according to the unique psychological characteristics of music groups, as a music teacher, we should strive to achieve psychological stability and emotional peace for ourselves and students. On the one hand, teachers engaged in music teaching should change their cognition, accepting the setbacks and twists and turns in teaching are in line with the natural law of the development of things, rather than excessively pursuing extreme effects. When facing students with low talent or when teachers and students do not cooperate well in class, they should pay attention to each other's emotions, so as not to affect teaching due to temporary emotions or even lead to students' cognitive errors. On the other hand, in order to effectively improve the literacy of educational psychology, teachers and students should read more books on pedagogy and psychology and participate in courses and lectures in this area. Only in this way, can we be more sensitive to the ability to perceive and respond to their own psychological conditions in the teaching process.

At the same time, in order to achieve the goal of psychological and emotional health care [7, 8], professional music teachers should not only pay attention to psychological and emotional adjustment in the process of music teaching but also consider the impact of psychological health outside the process of music teaching in universities on teaching. Music education is the inheritance education of the highest ideology of human spiritual culture, and it is the most essential and indispensable field of human civilization. The physical and mental health of teachers in music education in universities should be paid attention to. This requires us to improve the survival and growth conditions of music teachers in universities, introduce high-level psychological assistance programs, broaden the psychological knowledge of music teachers, make more use of psychological methods for self-care, and improve teaching efficiency. This is an important way to improve music education in universities in the future.

It must be admitted that music appreciation is also an emotional activity, which contains distinct psychological factors. Music aesthetic psychology includes the listener's music perception, aesthetic attitude, emotional experience, basic cognition, and associative imagination. Specifically, music appreciation is a highly subjective activity, which requires listeners to generate psychological emotional resonance from the perspective of hearing and further stimulate their own associative ability, so as to realize the appreciation

of the essence of music. The aesthetic psychology of music includes aesthetic psychological factors such as musical perception, imaginative association, intuition, and insight. These factors are closely related to the acquisition of the appreciator's aesthetic experience and reflect the essential laws of music everywhere. They are interactive and inseparable, which is a dynamic process of emotional fluctuations.

In the specific teaching process in the initial stage of music appreciation, teachers need to mobilize students' aesthetic attention and arouse their aesthetic expectations. In the specific teaching process in the initial stage of music appreciation, teachers need to mobilize students' aesthetic attention and arouse their aesthetic expectations. In order to achieve the psychological adjustment and emotional health care of music teaching, teachers engaged in music education need to have the following professional skills or professional qualities.

First, in music teaching, teachers should focus on creating teaching situations to stimulate students' interest in music learning. Music teaching in universities should change the single and boring form of music teaching in the past. Teachers should focus on setting up corresponding teaching situations. They can strengthen students' audio-visual experience through PPT, microlectures, short videos, etc., enrich students' appreciation levels, and help students acquire different forms of musical beauty. While maintaining students' interest in music learning, music teaching should focus on letting them express their own feelings and comprehension and stimulate students' creative inspiration. Only in this way can students fully display their talents in the process of interaction with teachers.

Second, in music teaching, teachers should continuously improve educational methods so that students can improve their aesthetic ability in practice. Teachers should return the dominant position of learning to students. This requires adding some interactive links in the classroom and allowing students to learn from each other's skills. Teachers should return the dominant position of learning to students. This requires adding some interactive links in the classroom and allowing students to learn from each other's skills. In addition, universities can hold more concerts and famous music performances for teachers and students to observe. In the process of appreciating everyone's demeanor, students can accumulate music perception ability and professional theoretical knowledge.

Third, in music teaching, teachers should improve their ability to appreciate music aesthetics and guide students scientifically and effectively. Teachers are the main guides of teaching activities, and they should have high musical literacy and aesthetic ability. Based on this, music teachers in universities should regularly participate in teaching seminars and business training, appreciate world famous songs, and broaden their horizons and minds, so as to better guide students in music learning and establish a good cultural connotation and music professional quality. Universities should conduct performance appraisals on teachers and urge teachers to improve their teaching ability in order to make more outstanding achievements in educational positions.

With the third wave of artificial intelligence sweeping the world, artificial intelligence has once again become the focus of the whole society [9, 10]. With the third wave of artificial intelligence sweeping the world, artificial intelligence has once again become the focus of the whole society. With the advent of the era of big data, various application fields are inseparable from the assistance and blessing of artificial intelligence technology. In particular, big data technology [11, 12] has the unique advantages of not being limited by time and space, fast copying and dissemination, and rich in presentation effects. Therefore, the improvement method based on big data technology has important research significance. As we all know, big data technology is actually a special form of artificial intelligence, that is to say, big data technology is included in the link of artificial intelligence. The difference between the two is that big data technology is based on huge data sources to carry out prediction research.

However, the application of big data technology enables a quantitative description, which is the elaboration of specific solutions to specific problems. In order to quantify the impact of big data technology on college music teaching, this paper introduces a specific example in college music teaching for quantitative research. College piano teaching is an important part of college music teaching. However, there are still many problems in the current stage of piano teaching in universities. These problems are mainly manifested in the strong randomness of curriculum education, the backward teaching mode, and the differences in students' cognitive ability. In the piano teaching of universities, the law of playing breathing has the functions of making the player's mood more stable, improving the coordination of the strength of various parts of the body, improving the level of the work, and improving the image of the music work. For this reason, based on the perspective of big data, this paper conducts relevant research on the laws of performance breathing in piano teaching in universities. For ordinary piano lovers, the breathing changes during the performance directly affect the performance. Therefore, based on the processing angle of big data, the variation law of breathing vibration during piano training is studied in detail. Specifically, by introducing several commonly used big data technology, this paper conducts a prediction study based on the corresponding value of the breathing law of performance

in piano teaching, in order to provide some theoretical suggestions for psychological adjustment and emotional health care solutions in music teaching in universities.

3. Methods of Big Data Analysis

3.1. Multidimensional Support Vector Prediction. Extending the one-dimensional insensitive loss function to a multidimensional space, the loss function is defined, and the expression of the loss function is [13, 14]

$$L(u_i) = \begin{cases} 0, & u_i < \varepsilon, \\ (u_i - \varepsilon)^2, & u_i \geq \varepsilon, \end{cases} \quad (1)$$

where $u_i = \|e_i\| = \sqrt{e_i^T e_i}$; $e_i^T = y_i^T - \phi^T(x_i)W - b^T$; $W = [w^1, \dots, w^Q]$; and $b = [b^1, \dots, b^Q]^T$, where ϕ is the nonlinear mapping kernel function; x_i is the sample input row vector; y_i is the sample output row vector; $i = 1, \dots, n$, n is the number of samples; and Q is the dimensionality of the output variable.

Based on the loss function shown in the above equation, we construct the optimization objective function with the expression:

$$L_P(W, b) = \frac{1}{2} \sum_{j=1}^Q \|\omega^j\|^2 + C \sum_{i=1}^n L(u_i). \quad (2)$$

In the formula, W and b represent the independent variables related to the support vector machine, respectively.

To solve the mathematical optimization problem of the multidimensional output support vector regression model, this paper introduces the use of iterative reweighted least squares (IRSL) to solve the problem.

In the optimization objective function of (2), the loss function is approximated by replacing it with a first-order Taylor expansion:

$$L'_P(W, b) = \frac{1}{2} \sum_{j=1}^Q \|\omega^j\|^2 + C \left(\sum_{i=1}^n L(u_i^k) + \frac{dL(u_i)}{du_i} \Big|_{u_i^k} \frac{(e_i^k)^T}{u_i^k} [e_i - e_i^k] \right). \quad (3)$$

Constructing a quadratic approximation of (3) instead, the approximation formula we use expresses the following relation.

$$L''_P(W, b) = \frac{1}{2} \sum_{j=1}^Q \|\omega^j\|^2 + C \left(\sum_{i=1}^n L(u_i^k) + \frac{dL(u_i)}{du_i} \Big|_{u_i^k} \frac{u_i^2 - (u_i^k)^2}{2u_i^k} \right) = \frac{1}{2} \sum_{j=1}^Q \|\omega^j\|^2 + \frac{1}{2} \sum_{i=1}^n a_i u_i^2 + CT. \quad (4)$$

The reason for using this approximation formula is that W and b are decoupled in this formula, the optimization solution does not need to be iterated, and the approximate solutions of W and b can be calculated by taking the partial derivatives of W and b equal to 0 directly. The optimization objective is solved to obtain W and b that minimize the overall loss of the sample set, and the multioutput support vector regression model is established.

In (4), an engineering parameter can be expressed as follows:

$$a_i = \frac{C}{u_i^k} \frac{dL(u_i)}{du_i} \Big|_{u_i^k} = \begin{cases} 0, & u_i^k < \varepsilon, \\ \frac{2C(u_i^k - \varepsilon)}{u_i^k}, & u_i^k \geq \varepsilon. \end{cases} \quad (5)$$

CT is a constant term that does not depend on W and b .

In the research process, the objective function can be introduced into the generalized Lagrange multiplier. At this time, the optimization problem can be re-expressed as follows.

$$\max \sum_{i=1}^n \alpha_i - \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \alpha_i \alpha_j y_i y_j k(x_i, x_j), \quad (6)$$

where α_i is the Lagrangian coefficient. Then, the final optimized hyperplane can be expressed as follows.

$$f(x) = \sum_{i=1}^n \alpha_i y_i k(x_i, x_j) + b, \quad i = 1, 2, \dots, N. \quad (7)$$

3.2. Prediction Based on the Fuzzy Neural Inference System.

The neural reasoning system is a system composed of three components, which mainly include (1) rule base, (2) database, and (3) reasoning system. In the fuzzy neural inference system, the input parameters consider different fuzzification and defuzzification methods and strategies and have various rules. This intelligent algorithm can choose from many sets of member functions to ensure the effect of fuzzy logic on the input data. The fuzzy inference system can be divided into three inference modes according to the “if-then rule” inference operation. These inference modes are Mamdani system, Sugeno system, and Tsukamoto system, respectively. Sugeno system is considered to be the most popular candidate for sample-based fuzzy modeling and facilitates the use of adaptive techniques. In a one-dimensional Sugeno system, a typical rule set with two computational rules for fuzzy inference can be expressed as follows [15, 16].

Fuzzy comprehensive evaluation is carried out from the second level of factors. We can set the evaluation object to be the factor UIJ in the second level, the membership degree of the k th element in the evaluation set to be r_{ijk} , and then the single-factor membership degree matrix of the second level is

$$R_i = \begin{bmatrix} r_{i11} & r_{i12} & L & r_{i1p} \\ r_{i21} & r_{i22} & L & r_{i2p} \\ M & M & M \\ r_{im1} & r_{im2} & L & r_{imp} \end{bmatrix}. \quad (8)$$

Then, the first-level fuzzy comprehensive evaluation model can be expressed as follows:

$$R = \begin{bmatrix} B_1 \\ B_2 \\ M \\ B_m \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & L & r_{1p} \\ r_{21} & r_{22} & L & r_{2p} \\ M & M & M \\ r_{m1} & r_{m2} & L & r_{mp} \end{bmatrix}. \quad (9)$$

3.3. Elman Neural Network. tElman neural network is widely used for its large-scale parallel distributed structure and learning ability and generalization ability.

The main advantages include nonlinear analysis capability, convenient input/output mapping, adaptive capability, evidence response, background information, strong fault tolerance, and VLSI (very large scale integrated) implementation. The key to the nonlinear ability and learning ability of neural network lies in the continuous modification of weights. There are two methods for recurrent network training, one is batch mode and the other is online mode. Like the BP neural network, the Elman neural network uses the ordered chain rule for learning and derivation. The output layer weights can be expressed as follows [17, 18].

For the input layer, the Elman network can be represented as follows:

$$x_i^0 = x_i(k). \quad (10)$$

For the hidden layer, the Elman network can be expressed as follows:

$$\begin{cases} s_i^1 = \sum_{j=1}^{n^0} w_{ij}^0 x_j^0(k) + \sum_{j=1}^{n^1} w_{ij}^2 c_j^0(k), \\ x_i^1 = f1(s_i^1(k)). \end{cases} \quad (11)$$

For the association layer, the Elman network can be expressed as follows:

$$\begin{cases} s_i^2(k) = x_i^1(k-1), \\ c_i(k) = s_i^2(k). \end{cases} \quad (12)$$

For the output layer, the Elman network can be represented as follows:

$$\begin{cases} s_i^3(k) = \sum_{j=1}^{n_1} w_{ij}^1 x_j^1(k), \\ y_i(k) = f2(s_i^3(k)), \end{cases} \quad (13)$$

$$-\frac{\partial E(k)}{\partial w_{ij}^1} = -\frac{\partial E(k)}{\partial y_i(k)} \cdot \frac{\partial y_i(k)}{\partial w_{ij}^1} = e_i(k) \cdot f2'(s_i^3(k)) \cdot x_j^1(k).$$

Similarly, the implicit value in the network can be expressed as follows.

$$\begin{aligned} -\frac{\partial E(k)}{\partial w_{ij}^0} &= -\sum_{l=1}^r \frac{\partial E(k)}{\partial y_l(k)} \cdot \frac{\partial y_l(k)}{\partial w_{ij}^0} \\ &= \sum_{l=1}^r e_l(k) \cdot f2'(s_l^3(k)) \cdot w_{ij}^1(k) \cdot \frac{\partial x_i^1(k)}{\partial w_{ij}^0}. \end{aligned} \quad (14)$$

Through comprehensive calculation, we can get

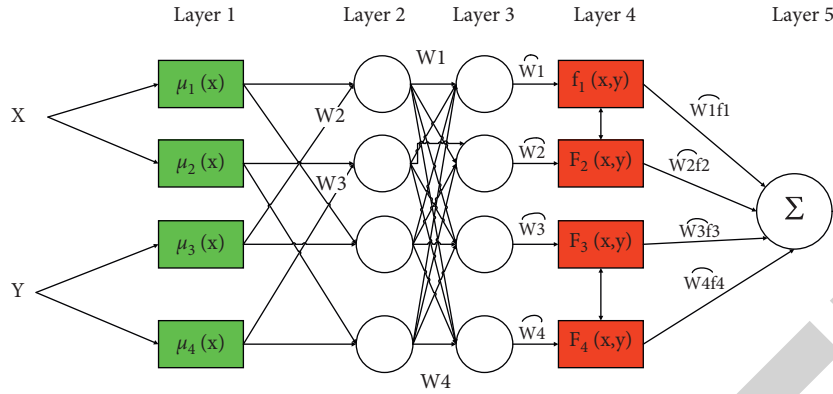


FIGURE 2: The calculation flow chart of the Elman neural network.

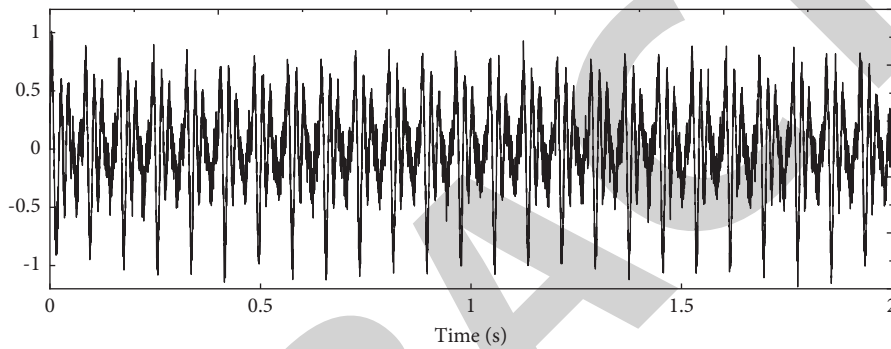


FIGURE 3: Typical breathing vibration signal.

$$\begin{cases} \frac{\partial E(k)}{\partial w_{ij}^0} = \sum_{l=1}^r e_l(k) \cdot f_2'(s_l^3(k)) \cdot w_{ij}^1(k) \cdot \chi_{ij}^i(k), \\ \chi_{ij}^i(k) = f_1'(s_i^1(k)) \cdot \left(x_j^0(k) + \sum_{m=1}^{n_1} w_{im}^2 \cdot \chi_{ij}^m(k-1) \right). \end{cases} \quad (15)$$

In the actual operation process, the neural network algorithm can be used to replace the traditional BP neural network for research. At the same time, the correlation and difference between the two can also be reflected in the prediction process. Figure 2 is a flow chart of the calculation process of the neural network.

4. Psychological Adjustment and Emotional Health Care in Music Teaching Based on Big Data Analysis

4.1. The Application of Wavelet Packet Analysis in Music Teaching. In the specific piano performance teaching, in addition to requiring the performer to deeply understand the composer's emotions and inner world when shaping the music image, the performer also needs to recreate the piano works based on their own characteristics. Only in this way can the musical composition match the characteristics of its own performance, which can allow the audience to produce

the best musical experience. In this process, performance breathing is also a very important part of the content, and students must have a deep understanding of the performance works in the performance. On this basis, students should fully understand the breathing law of performance and then make secondary creations on this basis.

Combining with specific teaching examples, it can be seen that students' breathing is affected by their own emotions. When they are more panicked when playing, they may produce nervous emotions, which will affect their breathing during performance. This requires students to accumulate certain breathing experience in specific training. In the process, studies have demonstrated that it is possible to perform quantitative studies using the collected signals of breathing vibrations. Figure 3 is a player's breathing vibration signal collected during a certain piano performance. As shown in Figure 3, the player's breathing vibration signal exhibits the regularity of continuous oscillation with time.

As an unsteady vibration signal, the player's breathing vibration signal shows strong nonlinearity and randomness. It is well known that the signal intrinsic characteristics of such nonstationary signals can be obtained by means of signal analysis [19, 20]. The existing signal analysis methods mainly include Fourier transform, wavelet analysis, wavelet packet analysis, and Hilbert transform. Among them, the Fourier transform is suitable for the processing of steady-state signals, which can transform the signal from the time domain to the frequency domain representation through the

corresponding window function. However, this transformation method is not suitable for the processing of non-stationary signals. Wavelet analysis can optimize the Fourier transform principle by changing the size of the window function. It can decompose the original signal into multiple layers of components. However, in the decomposition process of wavelet analysis, the high-frequency part of the signal is deleted and the resolution of high frequency is reduced. In order to overcome the defects of wavelet analysis, wavelet packet analysis [21, 22] also decomposes the high-frequency part of the signal, which effectively improves the high-frequency resolution of the signal.

The Daubechies wavelet series has good compactness, smoothness and symmetry, so it is widely used in unsteady signal processing. For the same color signal, db5~db10 are used for 9-layer decomposition, respectively, and the reconstruction error is shown in Figure 4. As shown in Figure 4, the reconstruction error of db10 is the smallest, so this paper uses db10 as the wavelet basis function for subsequent research.

Assuming that an n -level decomposition of the signal with frequency w results in $2n$ sub-bands, with each sub-band width being $w/2n$:

$$x(t) = \sum_{j=0}^{2^n-1} x_{n,j}, \quad (16)$$

$x_{n,j}$ is the reconstructed signal corresponding to the j th frequency band of the n th layer, $j = 1, 2, 3, \dots, 2^n - 1$.

Let $E_{n,j}$ represent the signal energy value corresponding to the frequency band of $x_{n,j}$ gives

$$E_{n,j} = \int |x_{j,i}(t)|^2 dt = \sum_{k=1}^m |z_{i,k}|^2, \quad (17)$$

where $z_{i,k}$ is the amplitude corresponding to the discrete points of the sub-band, k is the number of discrete points, and m is the length of the collected data.

The total vibration energy of the signal can be expressed as [23, 24]

$$E = \sum_{j=1}^{2j} E_{n,j}. \quad (18)$$

The energy percentage of each frequency ($T_{n,j}$) band can be expressed as follows:

$$T_{n,j} = \frac{E_{n,j}}{E}. \quad (19)$$

The signal is decomposed into 9 layers using the “db10” basis function. According to formulas (1–4), the wavelet packet energy calculation is carried out through the MATLAB platform. The energy percentages of the sub-bands are shown in Figure 5.

4.2. The Specific Application of Big Data Analysis Technology. Secondly, it is also very important to adjust the breathing from the physiological and psychological aspects. First,

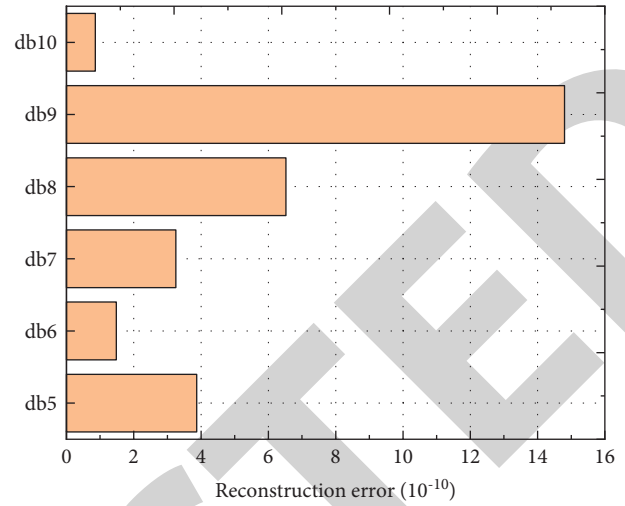


FIGURE 4: Reconstruction errors of different wavelet basis functions.

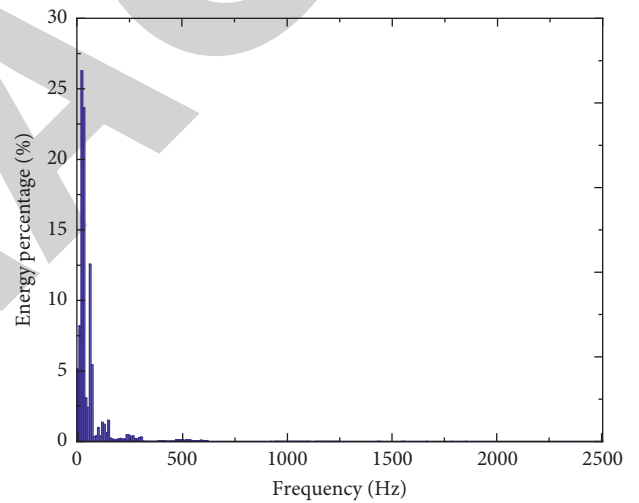


FIGURE 5: Spectrogram of the player's breathing signal.

breathing is a physiological characteristic. In specific piano performances, it is not enough for students to maintain normal breathing. For example, some students may feel physical tension or muscle fatigue when playing, and the brain and thinking cannot be connected, which makes the performance unsatisfactory. To a certain extent, this is related to the unnatural breathing adjustment of students, and teachers need to take the initiative to help students relieve tension. This teaching mode can enhance students' confidence and return to normal breathing. In this way, the normal breath and the breath during performance can be effectively integrated to ensure that a good breathing state is always maintained during the specific performance. In addition, teachers should guide students to coordinate breathing and performance when carrying out piano teaching activities, so that students can adjust their breathing independently during performance. Many students often have the problem of arm soreness in specific performances.

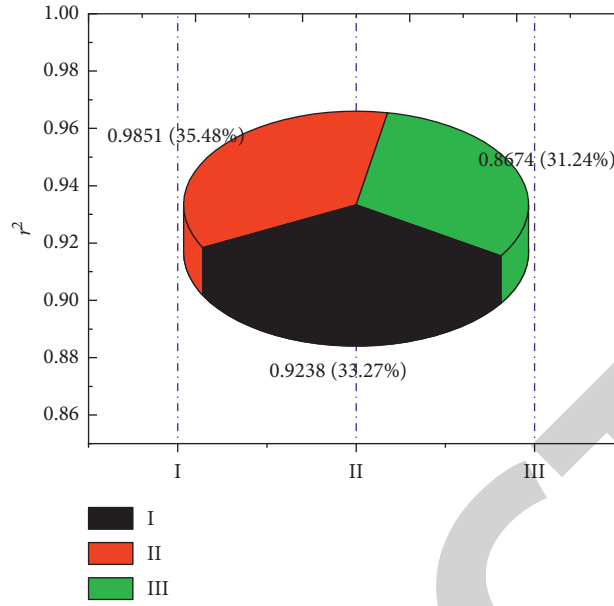


FIGURE 6: The square of the correlation coefficient corresponding to the three big data technologies.

Teachers should help students to correct their movements in time, so that students can master the correct breathing method. Through this operation mode, it can accurately adjust the breathing rhythm and bring out the normal performance level. At the same time, the psychological impact cannot be ignored. Psychological factors have a direct impact on students' piano performance. Students can perform normally in daily practice. However, when it comes to the exam, it will be affected by nervousness, and various emergencies will appear one after another, such as shortness of breath, playing wrong sounds, etc., which seriously affects the performance of the normal level. Therefore, teachers should encourage students to adjust their mentality, enhance their confidence in playing, and accurately identify playing and notation. This adjustment mode can eliminate the interference of bad psychology in time, stabilize one's own emotions, and lay the foundation for smooth piano performance.

Based on the characteristics of breathing changes in the process of piano performance in universities as the research object, this paper uses the three big data processing technologies introduced above to predict and study the physiological and psychological factors involved in the process of piano performance, in order to complete the purpose of quantitative prediction analysis.

It is well known that the closer the square of the correlation coefficient (r^2) is to 1, the smaller the root mean square error (RMSE), the median absolute error (MAPE), and the mean absolute percentage error (MEDAE), indicating higher prediction accuracy [25]. Among them, RMSE can be obtained by the following formula:

$$\text{RMSE} = \sqrt{\frac{1}{n} \times \sum_{i=1}^n (y_i - x_i)^2}. \quad (20)$$

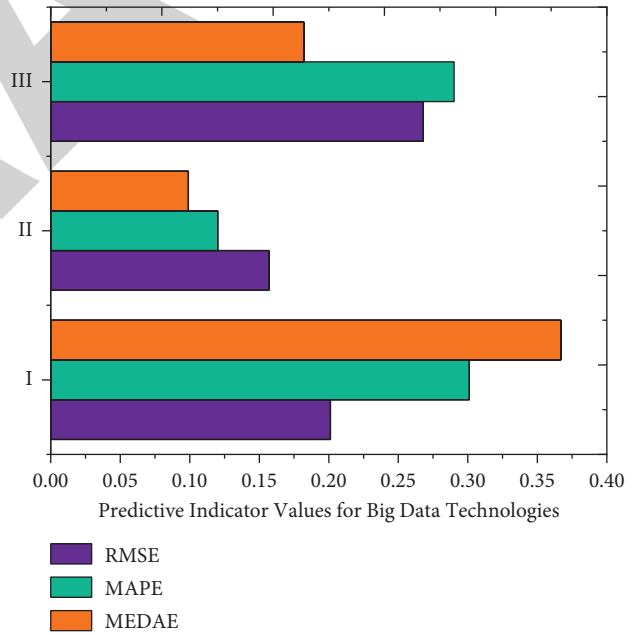


FIGURE 7: Quantitative predictor values of three big data technologies.

Figures 6 and 7 show the prediction performance of the three big data technologies introduced in this paper.

It should be specially pointed out that I represents the multidimensional support vector machine optimized, II represents fuzzy neural inference system, and III represents the Elman neural network.

As shown in Figures 6 and 7, the square of the correlation coefficient corresponding to fuzzy neural inference system is the largest, and the maximum value is 0.9851. In addition,

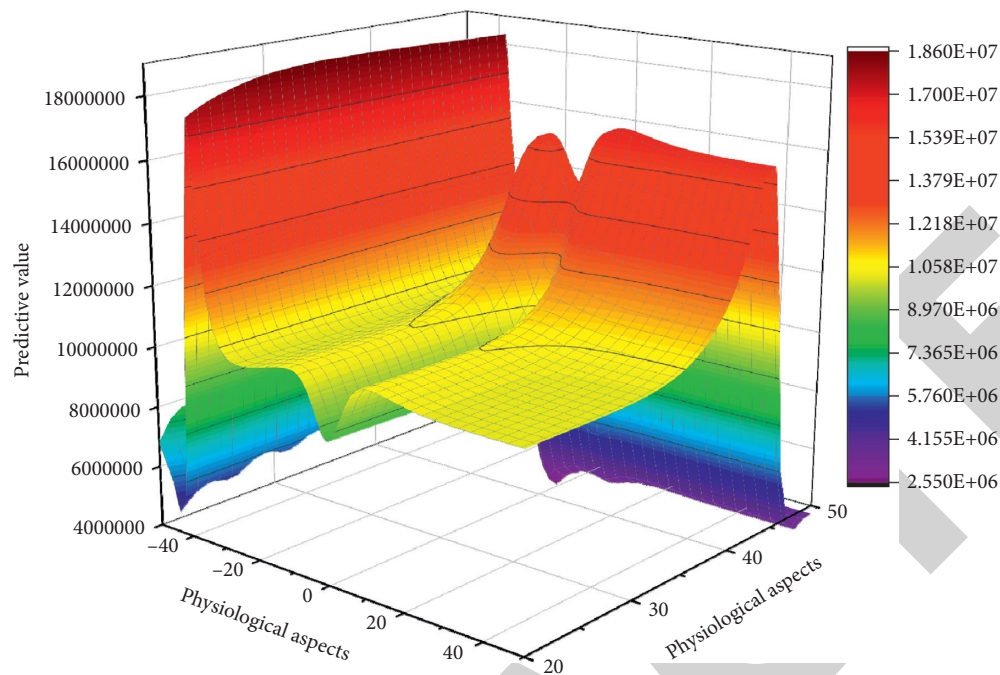


FIGURE 8: 3D prediction effect of the fuzzy neural network.

from the perspective of prediction indicators, the root mean square difference corresponding to fuzzy neural inference system is 0.3687. The three predictors are all the smallest. Among them, the minimum value of the root mean square difference is 0.1549. This comparison result shows that the prediction effect corresponding to the fuzzy neural inference system is the best.

It can be found that the fuzzy neural network reasoning system can be used as a representative big data technology in the innovative research of psychological adjustment and emotional health care in music teaching in universities.

In addition, in order to systematically evaluate the prediction effect of the fuzzy neural inference system, the 3D cloud map of the prediction data corresponding to the two aspects obtained by the inference system based on the fuzzy neural network is drawn in Figure 8. As shown in Figure 8, the predicted data of the physiology and psychology during the piano performance obtained by the fuzzy neural inference system show good continuity and consistency.

5. Conclusion

College music teachers and musicians are groups with their own special psychological state of the industry. In the teaching process, how to adjust to the psychological particularity of music teaching and the psychological status of music teachers in universities in order to improve the quality of teaching is an urgent problem to be paid attention to. With the advent of the era of big data, new innovative applications such as big data technology have been applied to the reform and innovation process of music teaching in Chinese universities. In order to quantify the evaluation indicators of psychological adjustment and emotional health care in music teaching, this paper takes piano teaching in

universities as an example and uses big data analysis technology to analyze the physiological and psychological evaluation indicators involved in the piano teaching process. To this end, this paper introduces three different big data technologies and uses them to predict the physiological and psychological data involved in the piano teaching process. The prediction effect shows that the prediction effect obtained by the fuzzy neural network system is the best. Its RMS deviation is only 0.16. The square of the correlation coefficient is the largest, and the maximum value reaches 0.98. In addition, the three-dimensional data cloud map involved in the prediction data show that the prediction data obtained by the fuzzy neural network system exhibits good continuity.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Research on the Creation of Chinese National Cultural Identity Symbols Based on Visual Images

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Cultural symbol generation has always been a challenging task to achieve symbols that can represent national culture and promote people's identification with Chinese culture. In this paper, we combine generative adversarial network (GAN) to propose a symbolic generation model of Chinese national cultural identity based on visual images. First, combining pattern search regular terms with generator cross-loss functions based on GAN generative adversarial networks to improve the pattern collapse phenomenon of generative adversarial networks. Second, the normal convolutional layer of the generator in the network structure is replaced with a deep-space separable convolution to improve the real-time performance of the model by reducing the model parameters. Through extensive testing on real datasets, the results show that the model in this paper can generate higher performance ethnic culture symbols while maintaining better temporal performance, which has some practical application value.

1. Introduction

The identification of Chinese cultural symbols and the image of the Chinese nation is an important element in strengthening the theoretical connotation, narrative system, and discourse system of Chinese national community consciousness. Promote the heritage protection and innovative intermingling of the cultures of all ethnic groups, establish and highlight the Chinese cultural symbols shared by all ethnic groups and the image of the Chinese nation, and enhance the identification of all ethnic groups with Chinese culture [1]. Establishing and highlighting the Chinese cultural symbols shared by all ethnic groups and the image of the Chinese nation is of great significance in realizing the Chinese dream of the great rejuvenation of the Chinese nation, casting a firm sense of Chinese national community and enhancing the international image of China [2].

Chinese cultural symbols are those symbols that can reflect the characteristics of Chinese culture and the characteristics of different ethnic groups in different regions, which embody the cultural connotation and spirituality of

China's long and profound history. Chinese cultural symbols can generally be divided into two main categories, one being natural symbols, such as mountains and rivers, and stars and constellations; the other category is man-made symbols, such as architecture and clothing. And there are numerous classifications of theories of their origin, such as the totemic theory, in which the predecessors of symbols were images created by ancient people for the natural objects they worshiped; functional statement originated from practical utility; decoration originated from the role of beautification, etc. In addition, Chinese national cultural symbols contain cultural connotations such as Confucianism, political and ethical culture, and ethnic culture [3]. Chinese cultural symbols such as Confucius culture and chess culture are an inseparable part of Chinese national culture and have rich cultural symbol resources.

Nowadays, the study of cultural symbols and visual images is highly valued, but the understanding of the cultural symbols and visual images of the Chinese community should be based on theoretical sorting and discernment, and we should emphasize the dynamic and process nature, the

interconnection and transformation between figurative and conceptual, and the coherence between intuitive visual images and abstract visual ideas [4]. Visual image research should use the human body as a medium, focus on the practitioner's active choice, and examine the relationship between the symbolic image and the intentional mental image. It emphasizes the multi-layered nature of cultural symbols and visual images in a holistic view of the Chinese national community and seeks to construct a mutually inclusive identity. Visual images should be recognized and understood within the multimodality of multisensory interventions, avoiding falling into the trap of visual centrism. In design practice, attention should be paid to discovering and grasping cultural symbols and visual image resources, respecting cultural knowledge and concepts in applied design, expanding participation and sharing, and implementing the theoretical understanding of casting a firm sense of Chinese national community as the main line [5].

Both in terms of national development evolution and national cultural psychology, the Chinese nation as a self-conscious national entity emerged from the confrontation between China and the Western powers in the last hundred years, but being a self-contained national entity is the result of thousands of years of the historical process. The pluralistic pattern of the Chinese nation is a product of history, but also a tangible existence. Chinese national community consciousness is expressed concretely as a state of unanimity, conceptual fit, and unity of will among members of the nation around important issues such as the historical lineage, survival intention, and direction of development of the Chinese nation. In the long process of development of Chinese civilization, Chinese people of all ethnic groups have contributed to the formation and development of Chinese culture, forming national images and cultural symbols with unique Chinese characteristics, these images and symbols are the concentrated embodiment of the living habits, spirituality, and values of the Chinese people of all ethnic groups, which have a universal cultural and political identity [6, 7].

Casting a firm sense of Chinese national community first comes from identifying with Chinese cultural symbols and the image of the Chinese nation in daily life. The image of the Chinese nation refers to the overall image of the Chinese community to the outside world, which is a relatively stable and generally recognized cultural symbol system formed through historical accumulation. Chinese cultural symbols and the image of the Chinese nation are pluralistic and integrated historical existences, both as objective realities and as spiritual and cultural existences. National identity is not an empty and abstract spiritual idea, but a concrete and sensual image rooted in real life [8]. These constructive imaginary realities are derived from everyday reality. The Chinese mountains, rivers, lakes, plants and flowers, festivals, cultural customs and activities, and "mascots" with national characteristics are typical representatives of the most Chinese image and cultural symbolism in daily life. From daily life reality, we analyze the national and cultural psychological structure behind these familiar national images and cultural symbols, from perceptual experience to

rational thinking, and systematically explore Chinese images and cultural symbols with cultural geography, cultural psychology, cultural politics [9, 10], etc. It is of great theoretical and practical significance to cast a firm sense of Chinese national community.

Usually, cultural symbols are mainly composed of "shape," "meaning," "color," and "movement" in their visual expression and application to grasp the four aspects. They do not exist as isolated symbols but are integrated to function together. The graphics will "speak," the mood will "feel," the colors will "tell," and the dynamics will "tell." In addition to giving the audience a sense of beauty, an excellent image film should be able to communicate directly with the audience. To this end, this paper proposes a symbol creation technique for visual images with the help of deep learning techniques. Firstly, the mode collapse of generative adversarial network (GAN) is improved by combining the pattern search regularization term with generator cross-loss function. Secondly, the common convolution layer of the generator in the network structure is replaced by deep-space separable convolution to improve the real-time performance of the model by reducing model parameters.

2. Current Status of Research

Chinese national culture has undergone thousands of years of development and evolution and has accumulated a wealth of symbolic material resources, and although our visual image design has made a lot of achievements in using these materials, some of them always have problems such as blindness and imitativeness in using local culture, favoring the form, and failing to accurately convey the main idea. Art designers [11] must have an overall clear knowledge of these national symbols in bridging modern visual communication design and national cultural symbols, and they should deeply understand the cultural background and spiritual connotation behind the symbols, be good at exploring, extending, and reconstructing them, reflecting the regional characteristics and national temperament they contain, and creating design work with strong vitality that meet the aesthetics of contemporary visual images [12].

2.1. Image Generation Model. In recent years, deep neural networks have made great progress in the field of image generation. Generally speaking, there are two types of commonly used generative models for image generation. One type of variational auto-encoder (VAE) [13] based generative model is a probabilistic statistical model. It mainly consists of an encoding network for inferring the statistical information of the input image and a decoding network for reconstructing the input image. This type of generative model has a series of advantages such as stable training and fast convergence. However, since the objective function of the VAE model optimization is the lower bound of the log-likelihood function, the generated image looks blurred overall. Another class of image generation models based on GANs [14] implicitly captures the probability distribution of real images through adversarial learning

between generators and discriminators. Through adversarial training, GANs-like models can generate clearer and more realistic images. However, the original GANs models still have many significant drawbacks, such as pattern collapse and training instability. Researchers have proposed some effective methods to stabilize the training process and improve the quality of the generated images. Besides, to make the generated images have certain desired properties, the researchers propose to use conditional GANs to constrain the generated images. For example, the introduction of auxiliary information such as class labels to guide the generation of handwritten digital images. So far, CGANs-based models have been widely used in super-resolution image generation, image style conversion, image restoration, and other fields. Because of the excellent performance of the adversarial network in generating images, we also use the adversarial network to complete the generation of target symbols.

2.2. Symbol Generation Model. Research work on symbol generation using deep neural networks can be broadly classified into two categories: one category is that the researchers use discrete symbol properties for symbol generation. For example, literature [15] proposed to encode information such as gender, expression category, and hair color into the bottleneck layer of the conditional VAE model to generate a facial expression generation model with diverse appearances. Literature [16] classified different expression states such as angry and happy into different domains and proposed StarGAN to realize the interconversion between several typical expressions. The discriminator of StarGAN needs to determine not only the authenticity of the generated image but also the domain from which it comes. Although these methods can generate high-quality symbolic expression images, however, the encoded discrete symbolic attributes are not sufficient to describe the rich culture. To solve this problem, the researchers explored how to integrate continuous auxiliary information into the generative model. Literature [17] proposed the CDAAE model that can separate symbolic information from each other. In CDAAE, given a reference symbol image, multiple cultural representations of the same culture can be generated by changing the FAU (Facial Action Unit) labels that represent different cultural strengths. GAGAN combines symbol shapes and GANs to make the generated symbols realistic, natural, and with specified symbol shapes. However, due to the semi-supervised nature of GAGAN itself, it does not provide any control over the generated symbolic information. Concerning the generation of continuous symbols, literature [18] have proposed a direct linear interpolation of two different symbol shapes using symbol feature points, and then these shapes are compressed into a one-dimensional coding vector using a fully connected network, and finally, the coding vector is fed into the adversarial network to generate the continuous symbols. Literature [19] also proposed the G2GAN model for cultural symbol synthesis with symbolic feature points as the controllable condition. G2GAN achieves the removal and generation of cultural symbols

through two generative networks, respectively, and then achieves the conversion of arbitrary symbols.

In this paper, we propose a simple and effective model for the generation of Chinese cultural identity symbols based on existing methods of facial expressions generation. To model different symbol shapes, we combine pattern search regular terms with generator crossover loss functions based on GAN generative adversarial networks and replace the normal convolutional layer of the generator in the network structure with a deep-space separable convolution improving the real-time performance of the model by reducing the model parameters.

3. Methodology

3.1. GAN. GAN consists of two parts: a generative network and a discriminative network. The discriminative network is to distinguish between the fake samples generated by the generator and the real samples. In contrast, generative networks are used to confuse the discriminator by generating fake samples. The generative and discriminative networks are trained simultaneously throughout the training process, constituting a dynamic two-player min-max game [20]. The GAN training process is shown in.

$$\begin{aligned} \min \max V(D, G) = & E_{x \sim P_{\text{data}}(x)} [\log D(x)] \\ & + E_{\tilde{x} \sim P_G} [\log (1 - D(\tilde{x}))], \end{aligned} \quad (1)$$

where x is the true sample, \tilde{x} is the generated sample, P_{data} is the true sample distribution, P_G is the generated sample distribution, D is the discriminator, and G is the generator. In the “game” process, when the $D(\tilde{x})$ value increases, the generated sample is largely close to the real sample; when the $D(x)$ value is larger and the $D(\tilde{x})$ value is smaller, the generated samples are more easily distinguished from the real samples. During the continuous game between the generator and the discriminator, the discriminator and the generator seek to minimize the JS (Jensen-Shannon) scatter. When and only when $P_{\text{data}} = P_G$, the global reach is optimal.

3.2. StarGAN. Compared to other GAN models, StarGAN solves the problem of interconversion between multiple cultural symbol categories. The model structure of StarGAN [21] is relatively simple and efficient, and its generator receives the input target domain c and the input sample x . The false samples output by G are transmitted to D , on the one hand, to determine the true and false samples and to perform domain classification. On the other hand, this fake sample is transmitted again to the generator with the target domain label c' of the input sample as input, to confuse the output sample with the original input sample and improve the similarity between them. The network structure of StarGAN is shown in Figure 1.

3.3. MS-StartGAN. In cultural symbol image generation, the quality of the samples obtained after text description transformation has an important impact on cultural symbol recognition. MSGAN [22] proposes to quantify the mode of

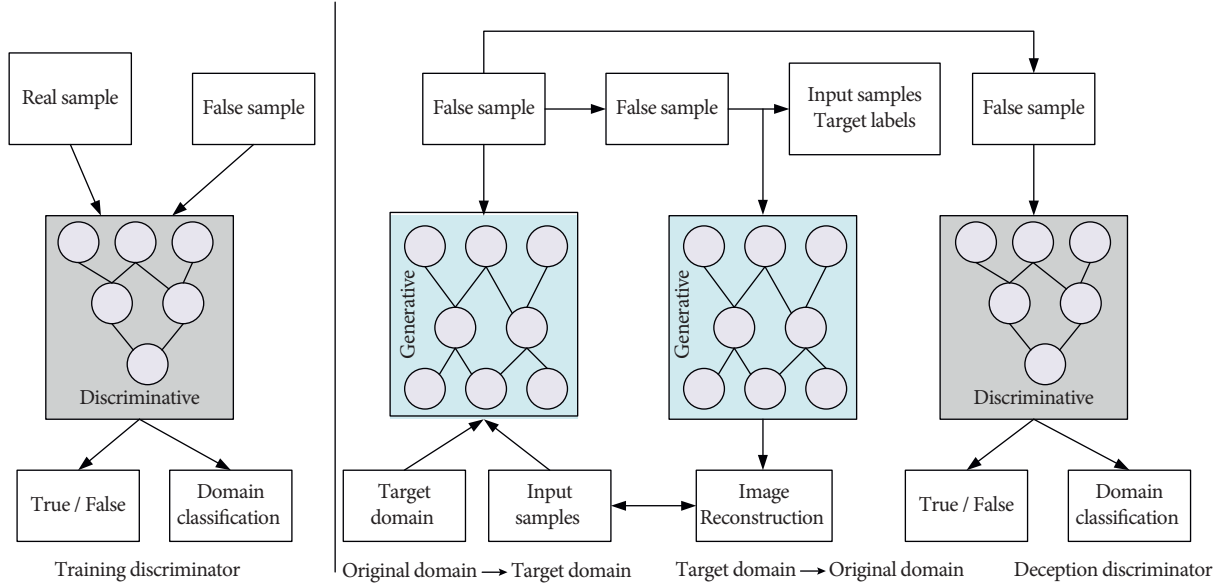


FIGURE 1: StarGAN network structure.

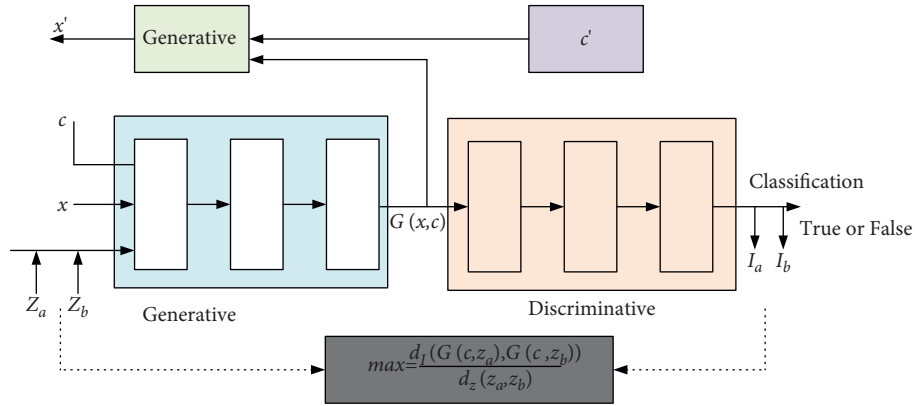


FIGURE 2: Principle of MS-starGAN network.

model collapse, i.e., distance ratio, to improve the mode collapse phenomenon by increasing the distance ratio, which in turn improves the sample quality. StarGAN can solve the problem of interconversion between multiple symbol classes, and the model structure is relatively simple and efficient. Thus, this paper proposes a pattern search StarGAN (MS-StarGAN) by combining the features of StarGAN and MSGAN models. MS-StarGAN adds a pattern search regular term to the generator objective function, which further solves the pattern collapse phenomenon by increasing the distance ratio to avoid input vectors with similar features appearing at the same mapping position all the time, resulting in improved quality and richness of symbolic images. The generator structure uses spatially separable convolution instead of convolutional layers, thus reducing the training parameters of the model and effectively improving the stability of the model training. The principle of MS-StarGAN is shown in Figure 2.

The dummy sample $G(x, c)$ is first generated by feeding the target domain c and the input sample x to the generator.

The dummy sample $G(x, c)$ is transmitted to the discriminator, which determines whether the generator generated the dummy sample $G(x, c)$ or the input sample x , and the domain classification result. And the fake sample $G(x, c)$ generated by the generator will be passed back to the generator again. At this time, this dummy sample $G(x, c)$ with the target domain label c' of the input sample is used as input, to confuse the output sample with the original input sample and improve the feature similarity between them. Adding a pattern search regular term between the input sample and the generated sample further improves the pattern collapse phenomenon and makes the generated cultural representation symbol sample more natural and smoother.

3.3.1. Generating Networks. The structure of the MS-StarGAN generator is shown in Figure 3. The entire network depth of the MS-StarGAN generator is 18, which includes 3 different convolutional layers, 6 residual blocks (each of

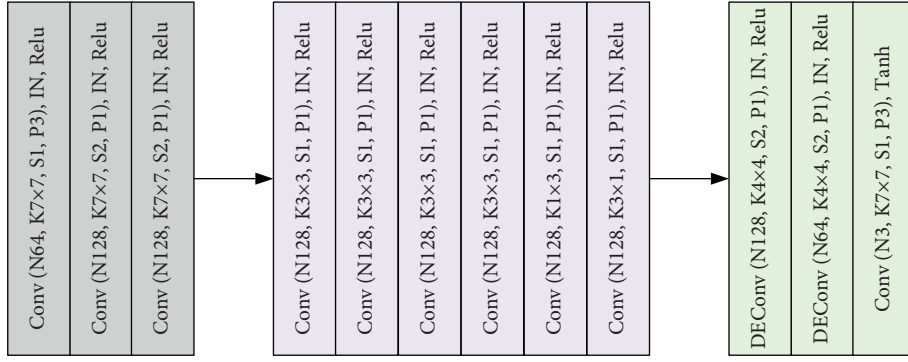


FIGURE 3: Structure of MS-starGAN generator.

which contains 2 layers of ordinary spatial convolutional layers), and 2 transposed convolutions. First, the first part receives samples and labels as input, with a convolution kernel size of 7×7 , a step size of 1, and a fill size of 3, and adds the instance normalization layer and ReLU as the excitation function. The incentive function accelerates training and improves stability. The second and third layers are down sampled with a convolution kernel size of 4×4 , a step size of 1, and a fill size of 2 to obtain a $4 \times 4 \times 256$ feature map. Secondly, a spatially separated convolution is used in the middle part to separate 3×3 into 3×1 and 1×3 , to reduce the number of parameters for network training. The final up sampling is performed using transposed convolution and the output uses the inverse function Tanh.

3.3.2. Discriminant Network. For the discriminator network, the entire network depth is 7. It inputs either true or false samples and determines their truth or falsity and the target domain they belong to, with a convolution kernel size of 4×4 , a step size of 2, and a fill size of 1. The middle part is the implicit layer so that the symbolic features can be obtained stably, and the number of convolution kernels is 128, 256, 512, 1024, and 2048 in order. And its output has two parts: the confrontation label and the classification label. The structure of the MS-StarGAN model is shown in Figure 4.

Here, to reduce the time overhead, depth-separable convolution is used instead of traditional convolutional layers to improve the real-time performance of the model by reducing the number of model parameters. Depth-separable convolution consists of depth-wise convolution (DW) and point-wise convolution (PC) [23, 24]. By decomposing the standard convolution process into multiple equivalent depth-wise convolutions and point-wise convolutions, the model computation is reduced while maintaining the accuracy of target recognition or detection. The structure of the deeply separable convolutional neural network is shown in Figure 5.

Traditional standard convolution uses a convolution kernel of size $L \times L$ and an output channel of size M for each convolution calculation; the deep convolution DW given in Figure 5 uses M convolution kernels of size $L \times L$ for each

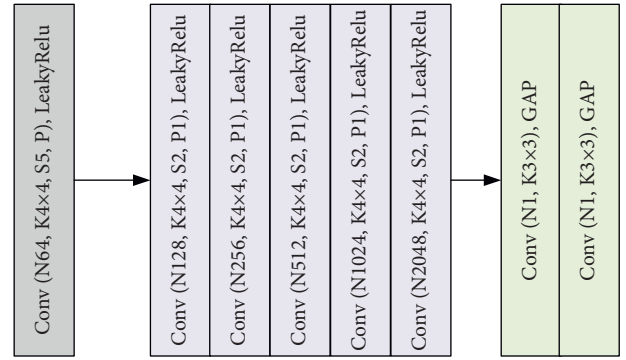


FIGURE 4: Structure of MS-starGAN discriminator.

convolution calculation during the operation, and the output is usually 1. The point-by-point convolutional PC uses M convolutional kernels of size 1×1 for convolutional filtering in each operation. The depth convolution DW and point-by-point convolution PC can be spliced into a standard convolution with a convolution kernel of size $L \times L$ and channel M . Among them, the number of parameters involved in the standard convolutional CNN calculation process is shown in .

$$\Delta_{\text{CNN}} = L \times L \times M \times N. \quad (2)$$

The number of parameters involved in the computation of depth-separable convolution with the combination of depth convolution DW and point-by-point convolution PC is shown in.

$$\Delta_{\text{DW,PC}} = L \times L \times 1 \times M + 1 \times 1 \times M \times N, \quad (3)$$

$$R = \frac{\Delta_{\text{DW,PC}}}{\Delta_{\text{CNN}}} = \frac{L \times L \times 1 \times M + 1 \times 1 \times M \times N}{L \times L \times M \times N} \quad (4)$$

$$= \frac{1}{L^2} + \frac{1}{N}.$$

From equation (4), it can be seen that when the convolution kernel $L \geq 2$, the number of parameters involved in the depth-separable convolution calculation process is significantly less than the number of parameters involved in the

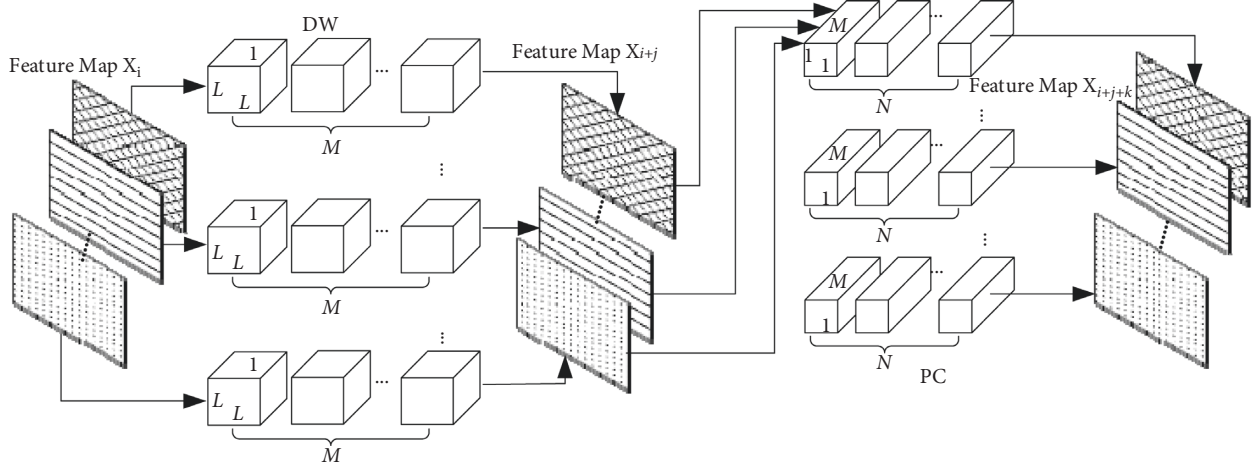


FIGURE 5: Model structure of deep separable convolution.

standard convolution calculation process. Thus, using depth-separable convolution instead of standard convolution can reduce the time overhead during the convolution calculation.

In the deep convolution process, a channel of the feature map is convolved by only one convolution kernel, and the number of convolution kernels is equal to the number of channels. The depth convolution is calculated as shown in.

$$F_{l,w,m} = \sum_{l,w,m}^{L,W,M} L_{l,w,m} \times X_{l+i,w+\omega,m+\kappa}, \quad (5)$$

where F denotes the input feature map; L is a filter of length l and width w , X denotes the input matrix, and m denotes the m th channel of M .

3.3.3. Crossover Loss Function. To achieve end-to-end optimization of the model in this paper, the cross-entropy loss function is used to calculate the deviation of the target value from the actual output value. The optimal value intervals used for positive and negative samples were obtained through extensive experiments. This function causes the neural network to output in the form of a probability distribution. Thus, cross-entropy can calculate the distance between the predicted probability distribution and the actual output probability distribution. Meanwhile, adding the equilibrium parameter $\theta=1.1$ can improve the prediction accuracy. The calculations are shown in equations (6)–(8).

$$X_t = wh_t + b, \quad (6)$$

where h_t is the decoder output hidden vector. X_t is the fully connected result.

$$P(y|x) = \frac{e^{h(x,y_i)}}{\sum_{j=1}^n e^{h(x,y_j)}}, \quad (7)$$

where x is the fully connected result, y is the true description, and P is the softmax function.

$$L(\theta) = - \sum_{t=1}^T \log p(y^t | y_{1:t-1}^*), \quad (8)$$

where θ denotes the model cross-entropy loss balance parameter.

4. Experimental Results and Analysis

4.1. Experimental Environment and Evaluation Index. The data set of this paper is mainly divided into two parts. The first part is self-built test data set, and the training data set mainly includes self-built data set and the existing open-source network data set. It mainly includes 13 kinds of symbols of national culture, including Chinese national heroes, festival representatives, and mascot copywriting.

The experimental environment in this paper is Windows 10 operating system. The experimental platform is an Intel(R) Core i7-7800X processor with six cores and six threads at 3.5 GHz. The experiments use the Pytorch deep learning framework to build the model, the development language is Python, and the V100 32G GPU with SGD optimizer to optimize the model parameters. The model has an initial learning rate of 0.0001, a Batch Size of 32, a weight decay rate of 0.0005, and a momentum of 0.9. Besides, to prevent overfitting of the model, Dropout is set to 0.5. The Loss and accuracy curves of the training and testing phases are shown in Figure 6. It can be seen that after the number of iterations reaches 240, the accuracy and Loss curve regions of the training and testing phases are smooth and the model reaches stable convergence.

To verify the effectiveness of the algorithm in this paper, a number of mainstream evaluation metrics are used to evaluate the model performance, specifically Accuracy, Precision, Recall, F1-score, and Time Overhead (TO) of action recognition for a single image, and the calculated expressions are shown in equations (9)–(12). The confusion matrix is shown in Table 1. In particular, the calculations between the Precision and Recall metrics are contradictory, and for this reason, the Precision-

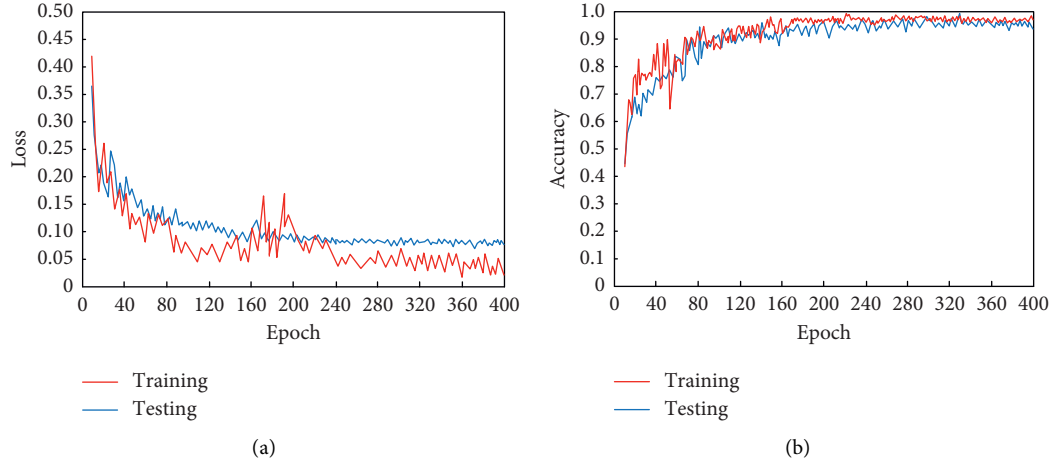


FIGURE 6: Curves of the training and testing phases. (a) Loss curve. (b) Accuracy curve.

TABLE 1: Confusion matrix calculation.

Actual		Predicted																					
		Positive						Negative															
Positive		T_P						F_P															
Negative		F_N						T_N															
0	36	3	0	0	0	0	40	0	36	5	0	0	0	0	40								
1	0	32	2	0	0	0	35	1	0	34	1	0	0	0	35								
2	0	0	32	0	0	0	30	2	0	0	33	0	0	0	30								
3	0	0	3	38	5	0	25	3	0	0	2	35	3	0	25								
4	0	0	0	0	35	1	20	4	0	0	0	2	35	1	20								
5	0	0	0	0	0	32	15	5	0	0	0	0	0	32	15								
	0	1	2	3	4	5	0		0	1	2	3	4	5	0								
		No.1							No.2							No.3							
		(a)							(b)							(c)							
0	37	1	0	0	0	0	40	0	36	0	0	0	0	0	40	0	33	1	0	0	0	0	40
1	0	33	3	0	0	0	35	1	1	35	3	0	0	0	35	1	2	36	0	0	0	0	35
2	0	0	35	2	0	0	30	2	0	0	32	2	0	0	30	2	0	1	35	0	0	0	30
3	0	0	2	33	0	0	25	3	0	0	4	32	3	0	25	3	0	0	0	38	2	0	25
4	0	0	0	5	35	3	20	4	0	0	0	0	33	3	20	4	0	0	0	0	32	4	20
5	0	0	0	0	0	33	15	5	0	0	0	0	0	35	15	5	0	0	0	1	34	15	
	0	1	2	3	4	5	0		0	1	2	3	4	5	0		0	1	2	3	4	5	0
		No.4							No.5							No.6							
		(d)							(e)							(f)							

FIGURE 7: Confusion matrix. (a) No. 1. (b) No. 2. (c) No. 3. (d) No. 4. (e) No. 5. (f) No. 6.

Recall curve is used for comparison in this paper. The larger the area enclosed under the curve, the better the classification performance of the model.

$$\text{Accuracy} = \frac{Tp + Tn}{Tp + Fp + Tn + Fn}, \quad (9)$$

$$\text{Precision} = \frac{Tp}{Tp + Fp}, \quad (10)$$

$$\text{Recall} = \frac{Tp}{Tp + Fn}, \quad (11)$$

$$F1 = \frac{2\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}. \quad (12)$$

4.2. Analysis of Results. The confusion matrix generated by the method in this paper in six sets of experiments is given in Figure 7, where the rows of the matrix represent the real symbol labels and the columns represent the symbol labels generated by the algorithm. From the confusion matrix, it can be concluded that the number of successive generations for the six symbols in the six sets of experiments is 205, 205, 211, 206, 203, and 208, and the accuracy of their generation is 93.61%, 93.61%, 93.36%, 92.79%, 92.69%, and 94.98%, respectively. In addition, the model in this paper can achieve a generation rate of 8 ms/images. From the above data, it can be seen that the model in this paper tends to perform stably on the results of multiple experiments, and also has good real-time performance, which verifies that the model in this paper has good robustness.

4.3. Comparison of Related Work. In order to verify the validity of the model in this paper, comparison experiments are conducted with the current mainstream models A [17], B [25], C [18], and D [26], respectively, and analyzed under the same data and environment. The detailed data are shown in Table 2. Figure 8 gives a comparison of the time overhead of the different models.

From Table 2, it can be seen that the model in this paper can achieve 93.68% Accuracy, 93.02% Precision, 92.96% Recall, and 92.88% F1. In terms of Accuracy, compared with the two best performing models C and D among all the compared models, the model in this paper improves (92.36% \rightarrow 93.68%) and (93.02% \rightarrow 93.68%), respectively. In terms of Precision, the models in this paper improved (91.98% \rightarrow 93.02%) and (92.56% \rightarrow 93.68%). In Recall, the models in this paper improved (92.05% \rightarrow 92.96%) and (92.37% \rightarrow 93.68%). In terms of F1, the model in this paper improves (91.81% \rightarrow 92.88%) and (91.94% \rightarrow 92.88%). The above data further verify that the model in this paper has better performance for symbol generation of Chinese national culture. This greatly promotes the spread of Chinese culture and increases the sense of national cultural identity and belonging.

From Figure 8, we can see that the model in this paper can achieve a generation rate of 8 ms/images, model A can

TABLE 2: Performance comparison of different models (%).

Methods	Accuracy	Precision	Recall	F1
A	90.08	90.13	89.52	90.01
B	91.30	91.11	90.28	91.06
C	92.36	91.98	92.05	91.81
D	93.02	92.56	92.37	91.94
Ours	93.68	93.02	92.96	92.88

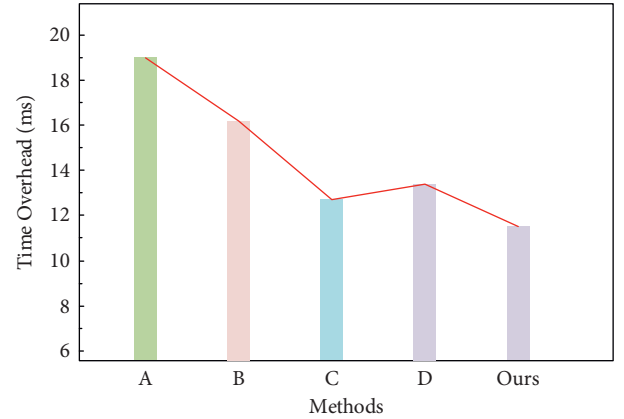


FIGURE 8: Comparison of time overhead between different models.

achieve a generation rate of 18.9 ms/images, model B can achieve a generation rate of 16.2 ms/images, model C can achieve a generation rate of 12.86 ms/images, and model D can achieve a generation rate of 13.91 ms/images generation rate. The above data further show that the model in this paper can achieve a better generation rate, mainly because this paper uses depth-separable convolution instead of traditional convolution in the discriminator stage to achieve a lower model time overhead by reducing the model parameters.

5. Conclusion

In this paper, we propose a new national culture symbol generation model based on the GAN network, which can greatly promote human's sense of identity and belonging to national culture and rapidly spread national culture. Specifically, this paper first proposes a pattern search network, MS-StartGAN, based on the GAN generative network by modeling based on the described data, and the pattern collapse phenomenon is further addressed by adding pattern search regular terms to the generator objective function to increase the distance ratio and alleviate input vectors with similar features from appearing at the same mapping positions all the time, which improves the quality and richness of the generated symbols. By testing on a large number of experiments, the results show that the model in this paper has good real-time performance while maintaining high generation accuracy.

Data Availability

The data used to support the findings of this study can be obtained from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Study on Hopf Branch of Stability of Time-Delay Unified System and Performance Evaluation Based on Deep Learning

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Deep learning is a breakthrough in machine learning research. It aims to establish a deep network structure that can simulate the human brain for analysis and learning, interpret data through the mechanism of layer-by-layer abstract feature representation, and has excellent feature learning capabilities. According to the input-output performance evaluation data of colleges and universities, three experiments are done. First, the feature expression ability of RBM, the basic building block of deep learning, is studied, and compared with PCA, the results show that RBM-fine-tuning has better performance than PCA-expressed classifier; the reconstruction error can be used to judge the hidden layer. As the number of RBM layers increases, the classification accuracy gradually increases, indicating the feasibility of the RBMs feature extractor. Second, the model in this study has a higher prediction accuracy than other classification models and clarifies the effectiveness of the modular deep learning model based on RBMs from the perspectives of network convergence analysis and network output analysis. The ability is stronger than DBN, and the obtained abstract feature representation is more conducive to classification. Although the classification accuracy rate of the model in this study has been improved, the model has certain limitations. The network initialization is still set based on experiments and experience, and the prediction accuracy rate is only 88.3%, which needs to be improved. The parameter training algorithm of RBMs can be further studied. To improve the more accurate reference basis for the performance evaluation of colleges and universities. Third, in the research of dynamical systems, the stability of the time-delay unified system at zero equilibrium and positive equilibrium is studied, and the conditions for generating the Hopf branch are given. At the same time, some conclusions are obtained through theoretical analysis. Numerical simulations further verify the validity of the theoretical results.

1. Introduction

Since the twentieth century, a large number of time-delay dynamics problems have appeared in many disciplines of natural science and social science, such as optical soliton communication, neural network, ecosystem, transportation schedules, and so on [1]. The evolution trend of the system depends not only on the current state of the system but also on the state of the system at a certain time or several moments in the past. We call this type of dynamical system a time-delay dynamical system. Strictly speaking, the time delay is usually unavoidable in dynamic systems, even in information systems that travel at the speed of light. In addition, unlike the dynamical system described by ordinary differential equations, the solution space of the time-delay dynamical system is infinite, and its theoretical analysis is

often difficult. Therefore, the study of delay differential equations is a very challenging direction [2].

Time delay often causes the motion of the system to become unstable, resulting in various forms of bifurcations [3]. Among these bifurcations, the most discussed is bifurcation, and this is mainly caused by the change of parameters. The time-delay system also shows more complex dynamics behavior. Therefore, studying bifurcation is an important aspect of studying dynamics. Mathematical models of time-delay systems belong to the category of functional differential equations (4). The essential difference from ordinary differential equations is that functional differential equations describing time-delay systems are infinite-dimensional “with memory”, while ordinary differential equations are finite-dimensional “memoryless” [5]. This makes it impossible to simply apply various mature

analysis and synthesis methods in the classical control theory mainly for finite-dimensional systems in the analysis and synthesis of time-delay systems.

Time-delay systems and time-delay phenomena widely exist in system models such as mechanical, physical, chemical, and biological systems, economic systems, and population dynamic systems [6]. Especially in engineering application disciplines and various industrial practices, the time-delay phenomenon is a common phenomenon, such as signal delay in network control systems, congestion delay in high-speed communication networks, artificial neural network time delay, slow thermal reaction process, and long pipeline material transmission. [7] The existence of a large number of time-delay phenomena often leads to the instability of the whole system and the deterioration of the dynamic performance of the system. The complexity of the analysis of time-delay systems relative to nontime-delay systems and the difficulty of designing corresponding control systems make time-delay systems a research hotspot in the field of control theory and control engineering [8]. The stability analysis of various time-delay systems is the starting point and foundation of time-delay system research and has important theoretical research significance and engineering application value.

Stability analysis of time-delay systems is the starting point of time-delay system research and the foundation of time-delay system synthesis problems. The predecessors have obtained a large number of time-delay system stability criteria from various ideas and approaches [9]. These criteria can be divided into the time-delay-independent stability criterion and the time-delay-dependent stability criterion according to the dependence on delay time information. In general, the time-delay independence criterion is relatively simple, but the conclusions are conservative, especially for systems with only small delays, the time-delay-dependent stability criterion is less conservative, but the verification process is more complicated [10]. It is worth noting that “for some systems whose stability is not affected by time delay, no matter how much time-delay there is, the system can remain stable, but the time-delay dependence criterion is conservative [11]. Stability analysis of time-delay systems, like nontime-delay systems, can also be mainly divided into time-domain methods and frequency-domain methods. In the following, starting from these two methods, we will briefly review the development of stability analysis of time-delay systems, with emphasis on the results of the following years.

The development of neural networks (NNs) has a long history, which can be roughly divided into the following three stages: the first stage is the enlightenment period. Since 1940, scholars have devoted themselves to the study of neural networks. The second stage is the low tide period [12]. Due to the linear characteristics of the structure of the perceptron model and the limited functions, the perceptron model can only identify linear samples and cannot identify nonlinear samples; the third stage is the renaissance period. In 1982, American physicist Hopfield proposed the discrete Hopfield network, introduced the energy function into the neural network for the first time,

and proved the stability of the network, which greatly promoted the development and research of neural networks [13]. Theoretically, the complexity of the model increases with the increase of parameters. The larger the capacity, the more complex the learning task can be accomplished by the model. On the contrary, the time and computational complexity of the complex model are high, and the training efficiency is relatively high.

At present, deep learning has been successfully applied in the fields of image recognition, speech recognition, natural language processing, and information retrieval [14]. Because of its wide potential market, a large number of scholars and enterprises are concerned about how to use deep learning to solve practical problems. For image classification and recognition, convolutional neural network (CNN) is an effective deep neural network method developed on the basis of neural networks. Since DBN ignores the two-dimensional structure of the image, some scholars combine DBN and CNN to propose Convolutional Deep Belief Networks (CDBN) by sharing weights at all positions in an image and obtaining the results [15].

The technical challenges faced by degree learning are mainly the problems faced by neural networks. As the number of layers continues to increase, the main challenges are: (1) there are few labeled datasets available, and the fine-tuning process of deep learning still uses supervised learning methods, so the quality of the classification model has a lot to do with the quantity and quality of the training dataset; (2) the interpretability of the network is low. Although deep learning can achieve good results and is widely used, it is still a “black box model” that is difficult to explain, because its internal knowledge expression is not intuitive, and the network learned is implied in the connection weights and biases, which is hard to understand. Some works have tried to improve the inexplicability of neural networks, mainly by extracting easy-to-understand symbolic rules from the knowledge representation of neural networks; and (3) overfitting. When the model learns the training samples are “too good” during the training process, it is likely to regard some characteristics of the training samples themselves as general properties of the potential samples, which leads to a reduction in the test error. It can also be said that the generalization ability is not strong, and this phenomenon is called overfitting [16, 17]. The strong learning ability and high complexity of neural networks may lead to overfitting. Data augmentation and regularization are two commonly used methods to solve overfitting.

Performance evaluation is an era requirement for higher education to develop from quantitative change to qualitative change [18]. For the Ministry of Education, it should consider how to effectively allocate resources among colleges and universities across the country to make the most of limited resources. Effective performance evaluation can promote the enthusiasm and autonomy of colleges and universities to improve work efficiency and innovate management methods [19]. At the same time, it can truthfully reflect the utilization of various resources in colleges and universities, the needs of colleges and universities, and the problems existing in the use of college

resources, so as to guide colleges and universities to allocate corresponding resources. Therefore, as the first step in the optimal allocation of resources, college performance evaluation is increasingly urgent and important to enrich the evaluation system of colleges and universities.

This study is based on the research background of the project “Research on the Optimal Allocation of Assets and Resources in Colleges and Universities”. With the rapid development of higher education, how to allocate and manage scientific research resources in research-oriented colleges and universities is the most concerning issue for the Ministry of Education and colleges and universities. In the higher education circles at home and abroad, the input and output performance evaluation of human resources, financial resources, and material resources are regarded as relatively weak links with great challenges and risks. For the multi-input performance evaluation system, its goal is to find the mapping relationship between input, output characteristics, and performance evaluation, that is to say, the essence of performance evaluation in this study is to find a nonlinear relationship between multifeature modules and a single output variable. Linear function is to obtain a multiclass learning model. First, the stability of time-delay unified systems at zero and positive equilibrium is studied, and the conditions for generating Hopf branches are given. At the same time, some conclusions are obtained through theoretical analysis. Numerical simulations further verify the validity of the theoretical results, then apply the deep learning nonlinear model method to the input-output performance evaluation data of colleges and universities, and conduct comparative experiments with Softmax classifier, BP neural network, and deep belief network.

2. Methods and Experiment Design

2.1. Stability and Branching of Time-Delay Unified Systems. Since the discovery of the first chaotic system in 2000, many new chaotic systems have been discovered by various methods, such as the famous Rosse system. In 1999, Chen discovered a new system that is dual to the Lorenz system in the study of chaotic anti-control (or chaptalization) [20]. In 2002, Lu and Chen further discovered a new critical chaotic system, which was later called the Lu system. Soon after, they unified the Lorenz system, Lu system, and Chen system with a smooth convex transformation, called the unified system, which can be expressed as

$$\begin{cases} \dot{x} = (25\alpha + 10)(y - x) \\ \dot{y} = (28 - 35\alpha)x - xz + (29\alpha - 1)y \\ \dot{z} = xy - \frac{\alpha + 8}{3}z \end{cases} \quad (1)$$

We consider adding a time-delay term to the unified system to control its dynamical behavior, adding $kz(t) - z(t - \tau)$ to the third item of the system:

$$\begin{cases} \dot{x} = (25\alpha + 10)(y - x) \\ \dot{y} = (28 - 35\alpha)x - xz + (29\alpha - 1)y \\ \dot{z} = xy - \frac{\alpha + 8}{3}z + kz(t) - z(t - \tau). \end{cases} \quad (2)$$

When $-8 \leq \alpha \leq 9/2$, the system has 3 balance points $(0,0,0)$, (x_0, y_0, z_0) , $(-x_0, -y_0, -z_0)$, where, $x_0 = y_0 = \sqrt{(\alpha + 8)(9 - 2\alpha)}$, $z_0 = 27 - 6\alpha$, when $\alpha < -8$ or $\alpha > 4.5$, the system only has one balance point $(0,0,0)$.

Linearizing the unified system at the origin can obtain the characteristic equation as

$$\left(\lambda + \frac{\alpha + 8}{3}\right)(\lambda^2 + (11 - 4\alpha)\lambda + (25\alpha + 10)(6\alpha - 27)) = 0. \quad (3)$$

The discriminant of the second term quadratic polynomial of the characteristic equation is written as $\Delta = -584\alpha^2 + 2372\alpha + 1201$, then the root of equation (3) is

$$\lambda_1 = -\frac{\alpha + 8}{3}, \lambda_2 = \frac{-(11 - 4\alpha) + \sqrt{\Delta}}{2}, \lambda_3 = \frac{-(11 - 4\alpha) - \sqrt{\Delta}}{2}. \quad (4)$$

When $-8 \leq \alpha \leq -0.4$, all roots have negative real parts origin in origin $(0,0,0)$.

Similarly, we can obtain the root of the characteristic equation for (2)

$$\begin{aligned} & \frac{1}{3}(-270 + 11\lambda - 615\alpha + 150\alpha^2 + \lambda^2 - 4\lambda\alpha) \\ & \cdot (3\lambda + 8 - 3k\alpha + 3e^{-\lambda\tau}k) = 0. \end{aligned} \quad (5)$$

Further simplification can be obtained:

$$\begin{cases} \omega = \frac{1}{3}\sqrt{(8 + \alpha)(6k - 8 - \alpha)} \\ \tau_n = \frac{1}{\omega} \left(a \tan\left(\frac{3\omega}{3k - 8 - \alpha}\right) + n\pi \right), n = 1 = 0, 1, \dots \end{cases} \quad (6)$$

When $(8 + \alpha)(6k - 8 - \alpha) < 0$, for all τ_n , the system equation (2) is all asymptotically stable.

Based on the above analysis, we have the following lemma:

- (1) If $(8 + \alpha)(6k - 8 - \alpha) < 0$, for all $\tau_n \in (0, +\infty)$, the characteristic root of the system (2) has a negative real part, and the system equation (2) is asymptotically stable
- (2) If $(8 + \alpha)(6k - 8 - \alpha) > 0$, for all $\tau_n \in (0, \tau_0)$, the characteristic root of the system equation (2) has a negative real part, and the system equation (2) is asymptotically stable

Using this lemma, we can get the following theorem about branching:

If τ_i is defined by (6), for all $\tau_n \in (0, +\infty)$, the characteristic root of the system (2) has a negative real part, and the system equation (2) is asymptotically stable.

2.2. Stability and Branching of Positive Equilibrium. For the stability of the system in balance point:

$$\begin{cases} x_1 = (25\alpha + 10)(y_1 - x_1) \\ y_1 = (28 - 35\alpha)x_1 - x_0 z_1 - z_0 x_1 + (29\alpha - 1)y_1 \\ z_1 = x_0 y_1 + y_0 x_1 - \frac{\alpha + 8}{3} z_1. \end{cases} \quad (7)$$

Discussing the stability of the system (7) in balance point (x_0, y_0, z_0) is equivalent to that in origin $(0,0,0)$.

After linearization, we can get

$$A = \begin{bmatrix} -(25\alpha + 10) & 25\alpha + 10 & 0 \\ 28 - 35\alpha - z_0 & 29\alpha - 1 & -x_0 \\ y_0 & x_0 & \frac{\alpha + 8}{3} \end{bmatrix}. \quad (8)$$

Thus,

$$\|\lambda I - A\| = \begin{vmatrix} \lambda + 25\alpha + 10 & -(25\alpha + 10) & 0 \\ -28 + 35\alpha + z_0 & \lambda - (29\alpha - 1) & -x_0 \\ -y_0 & -x_0 & \frac{\alpha + 8}{3} + \lambda \end{vmatrix} \quad (9)$$

$$= \lambda^3 + \left(\frac{41}{3} - \frac{11}{3\alpha}\right)\lambda^2 + \left(-\frac{10}{3\alpha^2} + \frac{304}{3} - 14\alpha\right)\lambda - 100\alpha^3 - 390\alpha^2 + 3460\alpha + 1440.$$

If $B = (41/3 - 11/3\alpha)$, $C = -10/3\alpha^2 + 304/3 - 14\alpha$, $D = -1000\alpha^3 - 390\alpha^2 + 3460\alpha + 1440$, we can obtain that

$$\lambda^3 + B\lambda^2 + C\lambda + D = 0. \quad (10)$$

Using the Hurwitz theorem, we can get the necessary and sufficient conditions for all roots of the equation (10) to have negative real parts are

$$\begin{cases} \alpha < \frac{41}{11} \\ -8 < \alpha < -0.0137, \text{ or } \alpha > 4.4896 \\ \alpha < -8, \text{ or } -\frac{2}{5} < \alpha < \frac{9}{2}. \end{cases} \quad (11)$$

Comprehensively available, when $0.4 < \alpha < -0.0137$, the system has a negative real part in (x_0, y_0, z_0) .

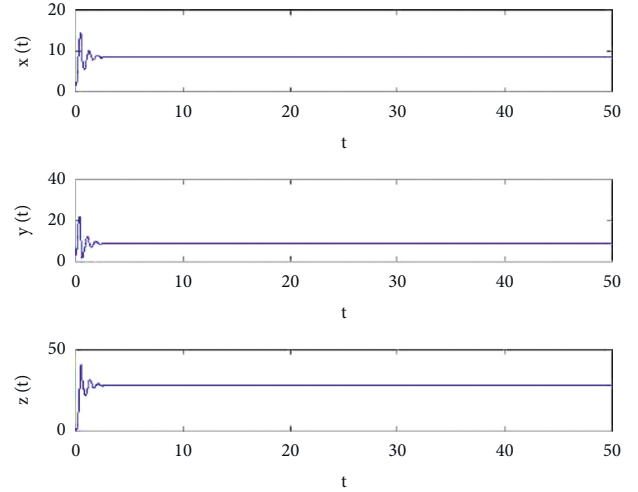


FIGURE 1: Latency graph of the system over time, when $\alpha = -0.2$.

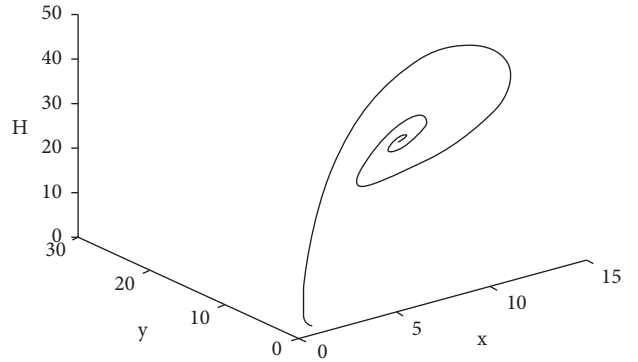


FIGURE 2: Phase diagram of the system, when $\alpha = -0.2$.

When $\alpha = -0.2$, we can obtain the phase diagrams as shown in Figures 1 and 2.

Lemma 1. *If*

$$\begin{aligned} F(\lambda, \tau_1, \tau_2, \dots, \tau_m) = & \lambda^n + p_1^{(0)}\lambda^{n-1} + \dots + p_{n-1}^{(0)}\lambda + p_n^{(0)} \\ & + [p_1^{(1)}\lambda^{n-1} + \dots + p_{n-1}^{(1)}\lambda + p_n^{(1)}]e^{-\lambda\tau_1} \\ & + \dots + [p_1^{(m)}\lambda^{n-1} + \dots + p_{n-1}^{(m)}\lambda + p_n^{(m)}] \\ & \cdot e^{-\lambda\tau_m}, \end{aligned} \quad (12)$$

where $\tau_i \geq 0 (i = 0, 1, \dots, m)$, $p_j^{(i)} (i = 0, 1, \dots, m; j = 1, 2, \dots, n)$ is constant, thus when (τ_1, \dots, τ_m) is changing, the sum of zero multiplicities of F on the half-plane changes if and only if a zero root appears on or crosses the imaginary axis.

Thus, we can obtain that: (1) if $\Delta = p^2 - 3q \leq 0$, for $\tau \in [0, +\infty)$, the system is asymptotically stable; (2) $\Delta = p^2 - 3q > 0$, for $\tau \in [0, +\infty)$, $z_1^* = (1/3)(-p + \sqrt{\Delta}) > 0$ and $h(z_1^*) \leq 0$, $h(z)$ has at least a positive real root z_k , and the original equation is asymptotically stable for $\tau \in [0, \tau_0)$; (3) if

the conditions in the (2) are all established, and $h'(z_k) \neq 0$, only when $\tau = \tau_k^{(j)}$, the system produced Hopf branches in balance points.

2.3. Data Set and Its Preprocessing. The project of optimizing the allocation of assets and resources in colleges and universities aims to further promote the reform of asset resource allocation plans of colleges and universities and the construction of disciplines in colleges and universities, so as to reasonably allocate various resources of colleges and universities, and realize the sustainable development of social services, discipline construction, and personnel training in colleges and universities. It is convenient to lead schools to formulate strategies that are in line with the development of the discipline and the facts. The strategy and operation method of the optimal allocation of university resources proposed by the project not only meet the requirements of building an economical and economical society but also improve the utilization rate and fairness of educational investment resources. The resource optimization allocation strategy takes 72 research universities of the Ministry of Education as the main objects [21]. By analyzing the basic contradictions within the universities and the status quo of input and output, the optimization allocation is divided into four processes: performance evaluation, resource optimization allocation, risk assessment, and benefit prediction. That is to say, the initial performance evaluation is based on the input and output resources of colleges and universities, and the initial performance and expected performance are optimally allocated, and the risk of performance deviation is estimated, and the economic, academic and social benefits brought by the optimal allocation, and then Further improvements to the optimization configuration process.

The data set in this study is based on the input-output data of 72 colleges and universities collected from 2007 to 2011, and then the performance evaluation data of colleges and universities is obtained by comprehensively evaluating the performance of colleges and universities. The first-level indicators of input are composed of financial resources, human resources, material resources, and intangible resources, with 14 second-level index variables and 42 third-level index variables; the first-level indicators of output include personnel training, scientific research, social services, It consists of disciplinary level and social influence, with 16 secondary indicator variables and 55 tertiary indicator variables, with a total of 360 sample data.

The three-level indicator variables in the input-output performance evaluation data of colleges and universities are used as candidate features. Since some feature data are missing, or most of the data values are 0, or have little correlation with the performance evaluation indicators, this part of the indicator data is deleted [22]. Therefore, there are two-part feature modules consisting of 29 input features and 27 output features. The 29 input characteristics are: the total number of faculty members, the number of full-time teachers, the number of administrative staff, the number of teaching assistants, the number of experimental

staff, the number of research and development staff, the proportion of full-time teachers with doctoral degrees, the proportion of full-time teachers above associate high school, 35 and/or 45-year-old teachers to full-time teachers, number of doctoral tutors, expert team, total value of fixed assets at the end of the year, school area, total school building area, teacher area, laboratory and self-study space area, total value of equipment, teaching and research, the total value of equipment, the number of paper books, the total expenditure, the total expenditure on education, the total expenditure on scientific research, the average expenditure on education per student, the number of national key disciplines, the number of national specialties, and the average value of comprehensive strength rankings (the first year), country orientation.

The 27 output features are the total number of students, the total number of graduates, the ratio of doctoral students, the ratio of master students, the number of 100 outstanding doctoral dissertations, the number of outstanding alumni, the number of academic or scientific (social science) works, the number of SSCI\SCIE \A&HCI combined papers, CSSCI\EI combined papers, CPCI-S papers, core journal papers, papers published in top 1/10 SCI journals with impact factor, citations of papers, the number of citations of SCI papers, the number of national natural science, scientific and technological progress and technological invention awards, the number of scientific research achievement awards (natural science and humanities and social sciences) of the Ministry of Education, the acceptance number of scientific and technological achievements, and the provincial natural science, technological progress, technological invention awards, the numbers, important international academic conferences, important domestic academic conferences, number of patents granted, income from scientific research, income from education, number of doctoral tutors (increment in the current year), expert teams (increment in the current year), number of national characteristic majors (increment in the current year), and comprehensive strength ranking Mean (increment for the year). Table 1 shows some sample data and characteristics in 2020.

The performance in the sample data is used as the output variable, and the original performance data are between 56 and 100. According to K-means clustering, the performance value is discretized into 4 category labels, which are expressed as 1, 2, 3, 4, and category labels. The larger the value, the better the performance, and the single output of the performance is discretized into a multioutput form. K-means clustering is still used to select training samples. The specific method is to perform cluster analysis on samples with performance category labels, $K=4$, and select 300 samples near the center of the class as training samples, and the rest as test samples, as shown in Table 2.

Because the input features have different dimensions and dimensional units, the training samples and test samples need to be normalized separately. Two common methods of data normalization are min-max normalization and Z-score normalization. Let feature x_i , x'_i is normalized features, the equation if normalization is

TABLE 1: Some sample data and characteristics in 2020.

Number	Input characteristics					Outpour characteristic				
	Faculty	Full-time teachers	Administrative staff	Counselors	Experimenters	Students	Graduate	Ph.D.(%)	Master (%)	Extinguished alumni
1	10910	3120	1397	1994	433	68219	14699	22.4	29.5	384
2	3665	1850	670	415	40	56121	10943	11.7	21.1	167
3	11585	3109	1701	1156	587	111245	10188	12.0	10.9	262
4	3852	1704	585	381	89	42228	9111	10.7	22.8	4
5	2902	1787	332	250	298	33069	8072	15.6	28.5	31
6	1791	1065	159	155	48	25029	6111	5.2	27.6	5
7	2171	1394	341	194	86	30318	6713	8.4	39.0	5
8	2832	1529	484	384	112	27315	8043	19.3	22.6	21
9	1697	1113	247	159	69	22415	5388	8.3	21.6	13
10	1665	969	251	218	72	14446	3991	8.2	24.6	3

TABLE 2: K-mean cluster result.

Cluster center of performance	Classification symbol	Multiple output form	Total sample	Training sample	Testing sample
62.8	1	[1,0,0,0]	124	105	19
68.4	2	[0,1,0,0]	113	101	12
75.6	3	[0,0,1,0]	95	74	21
89.5	4	[0,0,0,1]	28	20	8

$$x'_i = \frac{x_i - \min(x_i)}{\max(x_i) - \min(x_i)}, \quad (13)$$

$$x'_i = \frac{x_i - \text{mean}(x_i)}{st \ d(x_i)}, \quad (14)$$

where $\min()$ is the minimum value of x_i , $\max()$ is the maximum value of x_i , and $std()$ is the standard deviation of x_i .

3. Results and Discussion

3.1. Numerical Experiment. We assumed that $\alpha = 0$; thus, our system becomes the Lorenz system. We achieve the purpose of chaos control by adjusting the value of τ and ω , and the system is expressed as follows:

$$\begin{cases} \dot{x} = 10(y - x) \\ \dot{y} = 28x - xz - y \\ \dot{z} = xy - \frac{8}{3}z + kz(t) - z(t - \tau). \end{cases} \quad (15)$$

Obviously, the system has three balance points $O(0,0,0)$, $S_+(6\sqrt{2}, 6\sqrt{2}, 27)$, $S_-(-6\sqrt{2}, -6\sqrt{2}, 27)$. Here, we only consider $S_+(6\sqrt{2}, 6\sqrt{2}, 27)$.

Therefore, we can obtain the characteristic equation of the system (15) in S_+ point:

$$\lambda^3 + \left(\frac{41}{3} - k\right)\lambda^2 + \left(\frac{304}{3} - 11k\right)\lambda + 1440 + (k\lambda^2 + 11k\lambda)e^{-\lambda\tau} = 0. \quad (16)$$

When $\tau = 0$, the characteristic equation becomes

$$\lambda^3 + \frac{41}{3}\lambda^2 + \frac{304}{3}\lambda + 1440 = 0. \quad (17)$$

The three roots of the characteristic equation are $13.8546, 0.0940 + 10.1945i, 0.09 - 10.1945i$. Thus, when $\tau = 0$, the system (15) is in chaos.

When $\tau \neq 0$, $p = -(143/9) - (16/3)k$, $q = -(261842/9) + (1952/3)k$, $r = 2073600 - (256/9)k^2 - (48128/27)k + (7089697/81)$. Assuming $k = -1$, have: $p = -10.556$, $q = -29742$, $r = 89338$, $z_1^* = 103.1502$, $h(z_1^* = -9094.3)$. $h(z) = z^3 - 10.556z^2 - 29742z + 2073600$ has two positive roots, and one negative root. $z_1 = 108.6162$, $\omega_1 = 10.4219$, $\tau_1^{(j)} = 0.0542 + (2j\pi/\omega_1)$, $h(z_1) = 3357.3089$. $z_2 = 97.5818$, $\omega_2 = 9.8783$, $\tau_2^{(j)} = 0.0802 + (2j\pi/\omega_2)$, $h(z_2) = -3235.5507$.

Its numerical simulation diagram is shown in Figures 3–5.

It can be seen from the above simulation diagram that when $\tau > \tau_2^{(0)}$, the system is partially stable, otherwise is not stable.

3.2. Analysis of Effectiveness of Deep Learning Models. The method in this study firstly uses a Boltzmann machine (RBMs) feature extractor to train input features and output feature data to obtain two parts of new feature data, then reconstruct the new features as the input features of Softmax classifier, and then combine the two-layer RBMs and the Softmax classifiers are connected to form a modular deep learning network for multiclassification. Finally, the BP algorithm is used to reverse fine-tune the entire network to find the optimal parameters and output the predicted performance evaluation results.

The prediction accuracy rate can reflect whether the algorithm effectively predicts the performance evaluation of colleges and universities. The prediction accuracy rate (Acc) is based on the comparison of the reconstruction errors of

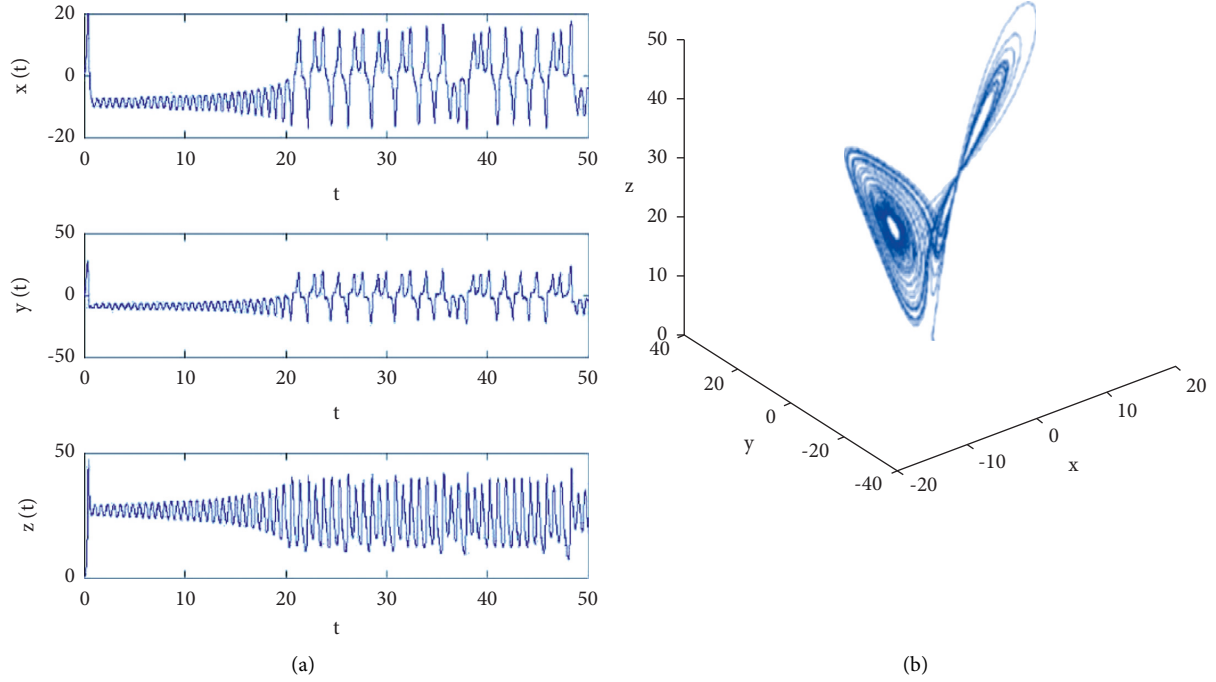


FIGURE 3: The time-delay graph of the system when $\tau = 0.04 < \tau_1^{(0)}$ (a); system phase diagram when $k = -1$, $\tau = 0.04 < \tau_1^{(0)}$ (b).

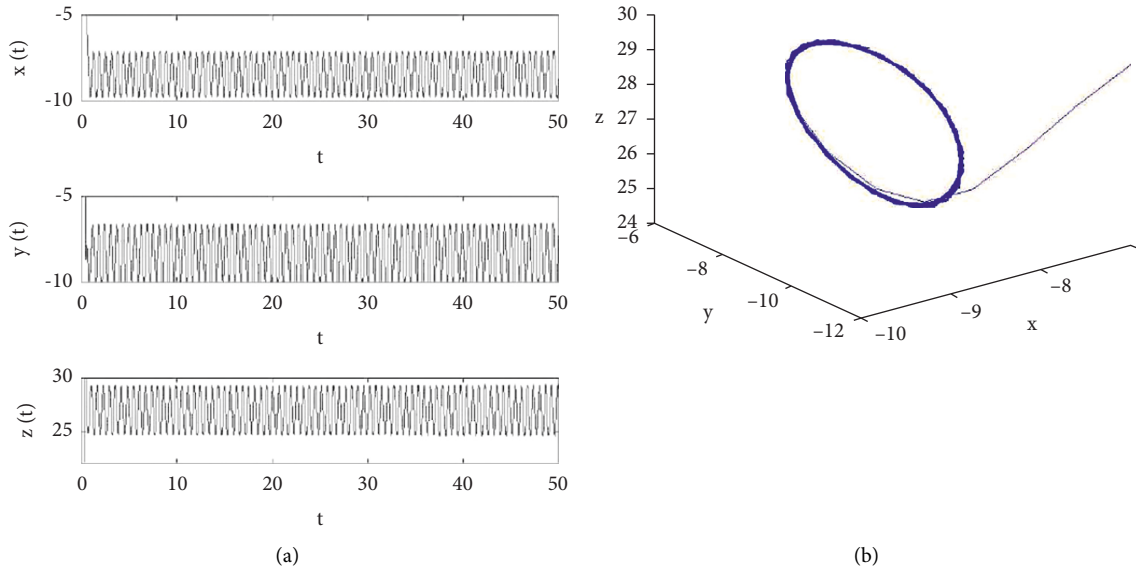


FIGURE 4: The time-delay graph of the system when $\tau = 0.0586 < \tau_1^{(0)} < \tau_2^{(0)}$ (a); system phase diagram when $\tau_1^{(0)} < \tau = 0.0586 < \tau_2^{(0)}$ (b).

each layer of RBMs based on input and output feature data. The layers of the RBMs feature extractor for given input and output and the number is 3 (including the input layer), and after many experiments and comparisons, the number of nodes in each layer of input and output RBMs is finally determined to be (29, 14, 10) and (27, 17, 11) respectively. The final model structure is shown in Figure 6. Table 3 shows the simulation results of the algorithm in this study on the performance evaluation data of colleges and universities. The Softmax classifier in the algorithm is a model used alone for classification; the BP neural network is a multihidden layer

neural network, the activation function is a sigmoid function, and the number of nodes in each layer is [56, 31, 21, 4]. DBN-Softmax is a deep belief network whose top-level classifier is a Softmax classifier, and the number of hidden layer nodes of two-layer RBM is (31, 21); on the basis of the method in this study, RBMs-Softmax is a classification model without fine-tuning, which is used to emphasize that reverse fine-tuning has a significant effect on improving the performance of the classifier.

According to Table 3, The following can be obtained: (1) when only the Softmax classifier is used for classification,

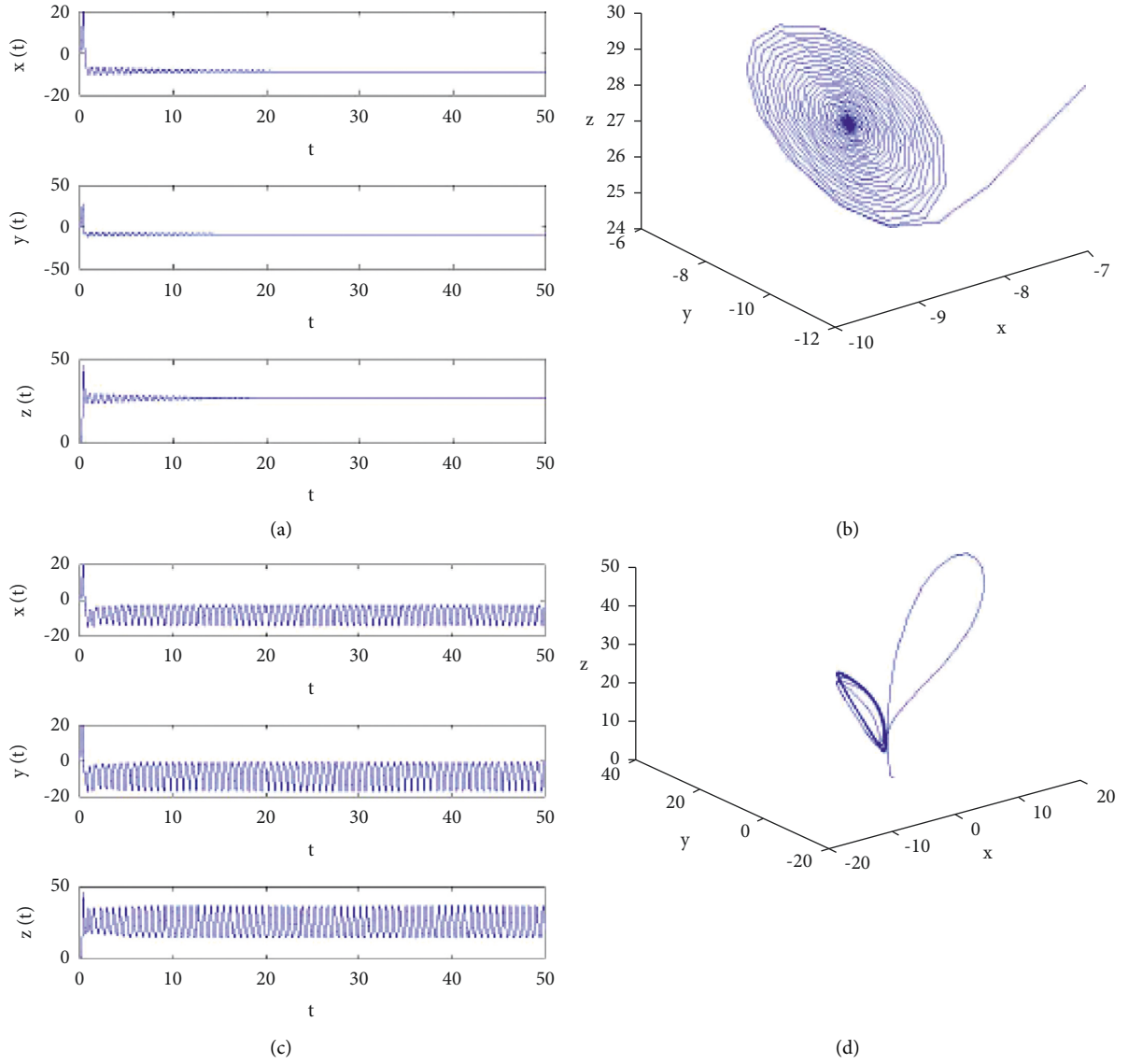


FIGURE 5: The time-delay graph of the system when $\tau = 0.10 > \tau_2^{(0)}$ (a) and $\tau = 1.30 > \tau_1^{(0)}$ (c); system phase diagram when, $\tau = 0.10 > \tau_2^{(0)}$ (b) and $\tau = 1.30 > \tau_1^{(0)}$ (d).

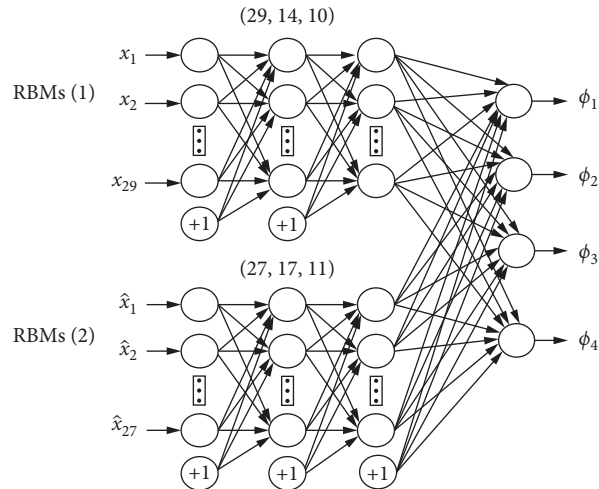


FIGURE 6: Structure diagram of the university performance evaluation model.

TABLE 3: Comparison table of prediction accuracy rate of each algorithm.

Algorithm	Number of iterations	Number of hidden layer nodes	Number of fine-tuning	Acc (%)
Softmax	100	None	None	73.1
BP neural network	None	(31,21)	200	83.3
DBN-softmax	300	(31,21)	200	85.20
RBM-softmax	300	(14,10), (17,11)	None	78.22
Our method	300	(14,10), (17,11)	200	88.5

with the increase in the number of iterations, the prediction accuracy rate is improved to a certain extent. When the number of iterations is set to 300, the accuracy rate is 78.3%. The accuracy rates of DBN-Softmax and the method in this study are both higher than Softmax, indicating that it is effective to extract features from the input data first and classify using new feature data; (2) the accuracy rate of the method in this study is higher than that of the BP neural network, which may be due to the BP neural network. The neural network is limited by the number of hidden layer nodes, a random selection of initial parameters, and no abstract feature extraction ability; (3) the prediction accuracy rate before fine-tuning the method in this study is 76.7%, and the accuracy rate after fine-tuning is increased by 11.6%. The importance of reverse fine-tuning to network parameter learning is shown, indicating that fine-tuning is effective in improving the performance of the classifier; (4) combined with the characteristics of the data in this study, the prediction accuracy rate of using two RBMs is higher than that of one RBM, namely DBN-Softmax. The feasibility and effectiveness of the model proposed in this study are verified.

3.3. Deep Learning Model Convergence Analysis. The network convergence is reflected in the fine-tuning process after combining multiple RBMs and Softmax classifiers. The algorithm efficiency is evaluated according to the convergence. The change curve of the loss function of equations (13) and (14) with the number of fine-tuning iterations is shown in Figure 7. Although the loss function value will fluctuate slightly, but in general, with the increase in the number of iterations, the loss function gradually decreases and tends to be stable, which means that the model in this study has a good convergence speed.

3.4. Analysis of the Output Results of the Deep Learning Model. We input 60 test samples into the trained network, obtain the new feature data of each sample data in two layers of RBMs, and classify through the final Softmax classifier to obtain the corresponding classification result of each sample. The input data of 5 samples (sample 1, sample 2, sample 3, sample 4, and sample 5) and the output values of RBMs in each layer of RBM are randomly selected as the data for the performance analysis of the RBMs feature extractor. The

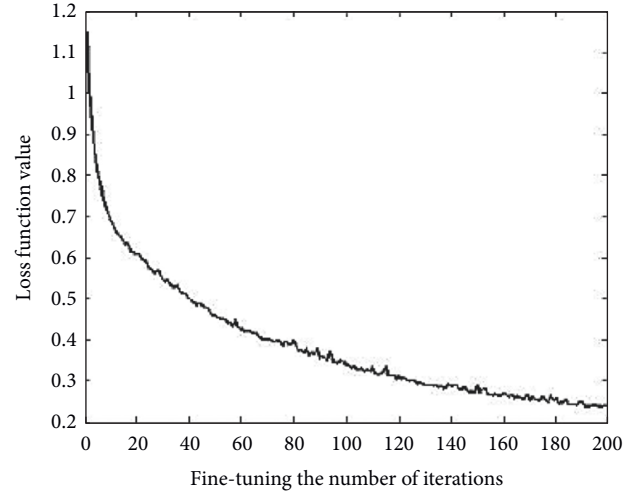


FIGURE 7: The graph of the change of the loss function value with the number of iterations.

input data of input and output samples are complex, and the difference between samples and the separability between sample characteristics are not large. After a layer of RBM, the data distribution of each sample is clearer and the separability becomes stronger. After the two-layer RBM function, each sample presents a very clear data distribution, and the features have high separability. RBMs feature extractors can mine distributed feature representations of data, presenting them in a more clearly separable form. In short, the above shows that the model in this study obtains a more abstract feature representation for the input data through multilayer RBM, that is, the feature representation of RBM from the bottom to the high level becomes more and more abstract, the separability of the sample features becomes stronger, and there are fewer possible guesses. The more conducive to classification. The separability of the new features of the model in this study after passing through multiple RBMs is stronger than that of the DBN passing through a single RBM, which shows that the feature expression ability of the model in this study is higher than that of the DBN on the dataset of multifeature modules.

Table 4 shows the network output results of some test sample data in the Softmax classifier. The output results are divided into 4 categories. Each data in the table represents the probability value corresponding to each category, and the sum of the probability that each sample belongs to all 4 categories. If it is 1, in which category the sample has the largest probability value, the prediction performance evaluation of the sample is classified into which category. For example, in sample 1, the probability of belonging to category 1 is 0.94, which is greater than the probability of belonging to categories 2, 3, and 4, the predicted performance evaluation corresponding to sample 1 is recorded as 1.

The network output result of the test sample is changed to the predicted performance evaluation. Table 5 shows the confusion matrix M of the category labels of the method in this study. The category label of the row vector is the actual

TABLE 4: Partial test sample data output table.

Sample	Class 1	Class 2	Class 3	Class 4
1	0.9400	0.0425	0.0087	0.0087
2	0.0018	0.0713	0.8949	0.0319
3	0.9402	0.0424	0.0087	0.0087
4	0.0303	0.9513	0.0151	0.0033
5	0.002	0.0031	0.0468	0.9500
6	0.0950	0.8818	0.0169	0.0063
7	0.9381	0.0438	0.0091	0.0090
8	0.2405	0.7314	0.0189	0.0093
9	0.0002	0.0030	0.0437	0.9531
10	0.0005	0.0183	0.09601	0.0212

TABLE 5: Confusion matrix for performance category labels.

Classification labels	1	2	3	4
1	18	1	0	0
2	1	9	2	0
3	0	0	18	3
4	0	0	0	8

TABLE 6: Comparison of evaluation indicators of various algorithms.

Algorithm	AP (%)	AR (%)	Acc (%)
Softmax classification machine	78.7	74.12	78.33
BP neural network	86.5	78.99	83.33
DBN-softmax	85.3	84.12	85.00
Our methods	87.66	89.64	89.12

performance evaluation, and the category label of the column vector is the predicted performance evaluation of the network output. Precision and recall come from information retrieval and are used to measure the performance of search engines. This study uses precision and recall in the field of information retrieval to define the precision and recall of each category label as follows:

$$\begin{cases} P(i) = M_{ii}/\text{sum}(M_{\cdot i}) \times 100\% \\ R(i) = \frac{M_{ii}}{\text{sum}(M_i)} \times 100\% \end{cases}, \quad (18)$$

where $P(i)$ and $R(i)$ are the precision and recall of the i th class, respectively. M_{ii} is the number of correct samples identified by the i th class label. $M_{\cdot i}$, M_i are the i th column vector and the i th row vector of the confusion matrix M , respectively, and sum is the sum of the vectors.

The model in this study is evaluated from the average precision, average recall, and prediction accuracy. The average recall (AP) and average precision (AR) are shown in (19), where K represents the number of categories. The final experimental results are shown in Table 6. It can be seen from the table that the three evaluation indicators of the method in this study are all larger than BP neural network and DBN-Softmax, indicating that the method in this study is superior to other algorithms in the evaluation of input-

output performance in colleges and universities, and is feasible and effective.

$$\begin{cases} AP = \sum_{i=1}^K P(i)/K \\ AR = \sum_{i=1}^K R(i)/K. \end{cases} \quad (19)$$

4. Conclusions

Deep learning is a major breakthrough in machine learning research. It aims to establish a deep network structure that can simulate the human brain for analysis and learning, interpret data through the mechanism of layer-by-layer abstract feature representation, and has excellent feature learning capabilities. Deep learning is a framework for building multilayer neural networks on unsupervised data proposed by Hinton et al. It uses a greedy layer-by-layer unsupervised method to solve the parameter optimization problem of deep neural networks.

In our study, a modular deep learning model based on RBMs is improved for the input and output feature module data of university performance evaluation. The model of this study is applied to the performance evaluation data of colleges and universities for experimental analysis. The results show that the prediction accuracy rate, average precision rate, and average recall rate of this method are 86.87%, 88.86%, and 88.33% respectively, which are higher than Softmax classifier, BP neural network, and DBN. In addition, after network fine-tuning, the accuracy of this method is increased by 11.6%, which reflects the importance of reverse fine-tuning for network parameter learning. From the convergence analysis of the network, it can be seen that the value of the loss function gradually decreases and tends to be stable with the increase of the number of iterations, indicating that the model in this study has a good convergence speed. The method in this study is compared with DBN. The results show that the new data features are more separable after the feature extraction of multiple RBMs, which shows that the method in this study has the ability to abstract feature expression layer by layer for the input data, and can extract features that are beneficial to classification or prediction. The above fully illustrates the effectiveness and superiority of the method in this study, and the use of the model to comprehensively evaluate the performance of colleges and universities under the influence of high-dimensional factors and obtain relatively satisfactory evaluation results.

In the research of a dynamical system, the stability of a time-delay unified system at zero equilibrium and positive equilibrium is studied, and the conditions for generating the Hopf branch are given. At the same time, some conclusions are obtained through theoretical analysis. Numerical simulations further verify the validity of the theoretical results.

In the future research study, we will first explore the relationship between the solutions of nonlinear differential equations, and use the solution method to find the

transformation of nonlinear variable coefficient differential equations. Second, we will further study dynamical systems, study system stability, and the Hopf branch, and use the computer to carry out a numerical simulation to verify the correctness of the conclusion.

The model in this study has a higher prediction accuracy than other classification models and clarifies the effectiveness of the modular deep learning model based on RBMs from the perspectives of network convergence analysis and network output analysis. The feature expression ability of this model is stronger than DBN, the resulting abstract feature representation is more conducive to classification. Although the classification accuracy rate of the model in this study has been improved, the model has certain limitations. The network initialization is still set based on experiments and experience, and the prediction accuracy rate is only 88.3%, which needs to be improved. The parameter training algorithm of RBMs can be further studied to improve the more accurate reference basis for the performance evaluation of colleges and universities.

Data Availability

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

Conflicts of Interest

The author declares no conflicts of interest regarding the present study.

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Research Article

Aviation and Airspace Management under Rough Set Theory

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With the development of aviation industry, a series of problems have appeared in aviation and airspace, among which the most prominent problem is the congestion of aviation and airspace. Airspace congestion has become a major problem in the development of civil aviation in China. Especially in the central and eastern regions of China, airspace congestion is becoming more and more serious. To better solve the problem of airspace congestion, rough set theory and the Fuzzy C-means (FCM) model are first analyzed. By analyzing the temporal and spatial characteristics of traffic congestion in the control sector, a multisector traffic congestion identification model is established based on radar track data. Four multisector congestion characteristics including equivalent traffic volume, proximity, saturation, and traffic density are established. FCM and rough set theory are used to classify and identify sector congestion. Finally, the model based on FCM-rough set theory is compared with other methods based on the data of the regional control sector in northwest China. The experimental results show that the congestion recognition rate of the model is 92.6%, 93.5%, and 94.2%, and the congestion misjudgment rate is 1.5%, 1.2%, and 1.3%, respectively. Hence, the multisector congestion recognition model has a high recognition rate and a low misjudgment rate, and the overall discrimination result is relatively stable. By comparing the proposed method with other methods, it is concluded that the recognition accuracy of the model based on FCM theory is superior to other methods. In summary, the congestion situation of the sector is affected by a variety of macro- and micro-characteristics of the sector, and the congestion identification model is feasible and efficient. Multisector traffic congestion identification has certain application value for airspace planning, air traffic control-assisted decision making, and air traffic flow management. This work can optimize the aviation and airspace management system and provide relevant suggestions for the study of aviation and airspace congestion.

1. Introduction

In recent years, relevant departments of China have gradually realized the great value of the general aviation industry in promoting national economic development and industrial structure transformation and have issued a series of policies to support its development. With the booming development of China's general aviation industry, the demand for airspace resources has been increasing, and the effectiveness of airspace utilization and the safety of general aviation flight have been affected, bringing enormous pressure to airspace management. Promoting the reform of airspace management has become a hot topic of concern [1]. Affected by historical factors, the reform process of airspace

management in China is slow, but relevant national departments have been trying to promote the reform process [2]. In October 2018, the Civil Aviation Administration of China (CAAC) issued the overall plan for the construction of low-altitude flight service guarantee system. The plan provides solutions to problems in the implementation of such guidelines issued in 2010. According to several aviation experts, this move is an important measure of CAAC to accelerate the reform of decentralization, regulation, and service, which will help accelerate the reform of low-altitude air traffic control and drive the development of the general aviation industry [3]. At present, there is some research foundation about airspace congestion nationally and internationally. Fanice compared the traffic demand of sectors,

anchor points, and crossing routes with capacity thresholds to monitor and warn the air traffic congestion situation [4]. Bo and Jesper studied measures to alleviate congestion in European airspace from the perspective of flight plans and operational networks of airlines [5]. Daniel analyzed airspace congestion from the perspective of air traffic complexity and extracted the traffic complexity characteristics of airspace congestion [6]. The above studies focus on the congestion theory of a single traffic unit, but they have not carried out the study of multisector traffic congestion, and have not analyzed the congestion situation of multisector and large-area airspace from the macro-level. It is difficult to recognize traffic congestion in real time because the research index is too heavy on the consequence index.

The key to an intelligent information system is knowledge expression. From a large amount of existing data information, the analysis of valuable rule information is called knowledge acquisition, which helps to transform knowledge from original representations (raw data representations) into new ideal expressions. Knowledge acquisition of rough set theory usually obtains system knowledge through data table knowledge such as an information table [7]. First, the concept of knowledge utilization classification is briefly introduced. Then, a knowledge representation system is introduced to describe the function of the information table. A formal description is given, and the decision table is discussed in detail. Finally, the decision weights and decision rules corresponding to the decision table are discussed [8]. The logical model, framework, semantic network, state space, and generation rule are commonly used knowledge representation methods at present. These are the research directions and contents of knowledge expression [9]. Information table knowledge representation based on rough set theory is a scientific tool for knowledge representation and processing. To deal with practical problems in daily life, the research object is usually limited to a specific area or corresponding numerical value. The set of all individuals in this region is the problem domain [10]. In 1982, Polish mathematician Professor Palak announced the birth of rough set theory. The first international symposium on rough set theory was held in Poland in 1992, and an international symposium on rough set theory has been held every year since then. The International Rough Set Society was formally established in 2005 and published the latest research progress papers on rough set theory and its applications in some journals and magazines. Since the first China Rough Set and Soft Computing Symposium was successfully held in Chongqing University of Posts and Telecommunications in 2001, the research and communication of rough set theory started. Since then, the conference has been held annually, involving mathematics, management science, information science, computer science, control science, and systems science. In 2003, China Artificial Intelligence Society Rough Set and Soft Computing Special Committee was established in Guangzhou.

Literature showed that many scholars have conducted research studies on air and airspace management at present. At present, air and airspace traffic is complex, and most research studies focus on the analysis of the complexity of

single air traffic, but there is a lack of research studies on multisector traffic congestion [11]. To this end, research on multisector congestion identification method is carried out to analyze the spatio-temporal characteristics of aviation and airspace sector congestion and traffic congestion law of multisector in detail. The congestion indexes of equivalent traffic volume, proximity, saturation, and traffic density are established. Fuzzy C-means (FCM)-rough set theory is used to establish the multisector traffic congestion identification model, which can identify the multisector congestion problem from the level of regional control center. It has certain application value for airspace planning, control operation, and air traffic flow management. The innovation of the study is different from the traditional aviation and airspace management research. By focusing on the problem of airspace congestion and combining FCM theory with rough set theory, the problem of airspace congestion is analyzed more comprehensively and the experimental results are more reliable [12].

The research framework of this work is as follows: First, rough set theory is analyzed so as to lay a foundation for further analysis of FCM-rough set theory. Second, according to the radar track data, the congestion characteristics of the airspace are analyzed, and the congestion index of the airspace sector is selected. Then, based on the FCM-rough set theory and the selected crowding index, the FCM-rough set aviation sector congestion identification model is established, and the identification model is tested. Furthermore, the FCM-rough set model designed in this work is compared with other models to judge the effect of the model.

2. Methods

2.1. Rough Set Theory Analysis

2.1.1. Basic Theoretical Analysis. Rough set theory is another mathematical tool to deal with uncertainty after probability theory, fuzzy set, and evidence theory. In 1982, a set of theories was proposed to study incomplete data and inaccurate knowledge expression, learning, and induction [13]. The main idea is deriving the decision or classification rules of the problem through knowledge reduction on the premise of keeping the classification ability unchanged. From a mathematical point of view, rough sets are the study of sets. From a programming point of view, rough sets are studied by matrices, just some special matrices. From the perspective of artificial intelligence, rough sets study decision tables [14]. The main feature of a rough set is that it does not need to provide subjective evaluation of knowledge or data but can achieve the purpose of deleting redundant information, comparing the degree and roughness of incomplete knowledge, and defining the dependence and importance of attributes based on only observation data [15].

Both rough sets and fuzzy sets can deal with incomplete data, but their processing methods are different. The fuzzy set pays attention to the vagueness of describing information, while the rough set emphasizes the indiscernability, imprecision, and vagueness of data [16]. Using the language of image processing as an analogy, when discussing the

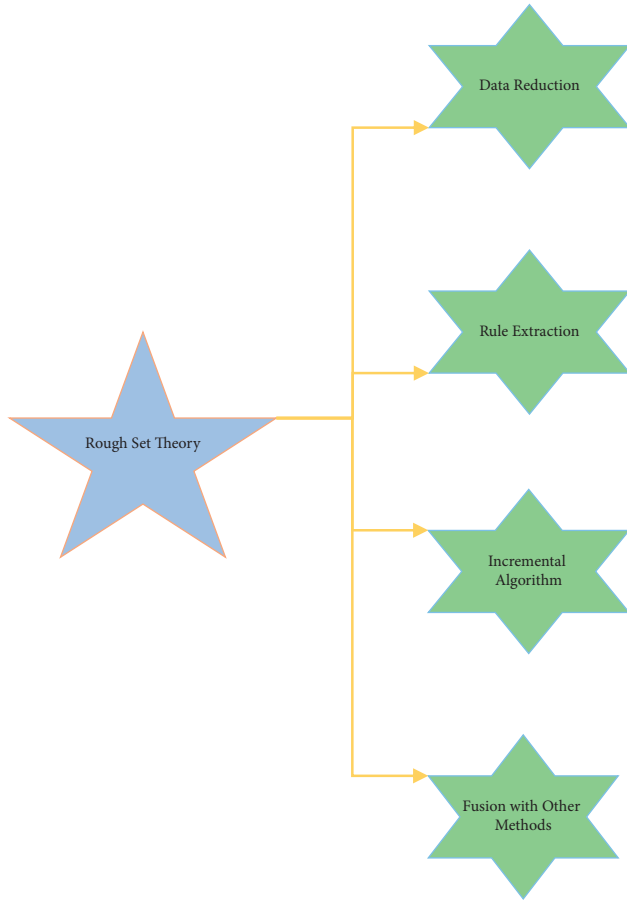


FIGURE 1: Rough set theory in action.

clarity of an image, a rough set emphasizes the size of the image pixels, while a fuzzy set emphasizes the existence of different gray levels of pixels. Rough set studies the relationship between sets of objects in different classes, focusing on classification. Fuzzy set studies the membership of different objects belonging to the same class, especially the degree of membership. Therefore, rough set and fuzzy set are two different theories, but they are not opposite to each other. They can complement each other in dealing with imperfect data [17]. Rough set theory is widely applied in data mining, involving fields such as medical research, market analysis, business risk prediction, meteorology, speech recognition, and engineering design [18]. In numerous data mining systems, the role of rough set theory is shown in Figure 1.

In Figure 1, the role of rough set theory mainly focuses on the following aspects: I. Data reduction. Rough set theory can provide effective methods for data reduction in information systems. In the preprocessing stage of the data mining system, the redundant information (attribute, object, attribute value, etc.) can be deleted by rough set theory, which can greatly improve the operation speed of system. II. Rule extraction. Compared with other methods (such as neural networks), using rough set theory to generate rules is relatively simple and direct. Each object in the information system corresponds to a rule. The general steps of generating

rules in rough set theory are as follows. Step 1: A reduction of conditional attributes is harvested, and redundant attributes are deleted. Step 2: The redundant attribute values of each rule are deleted. Step 3: The remaining rules are merged [19]. III. Incremental algorithm. In the face of large-scale and high-dimensional data in data mining, finding an effective incremental algorithm is a research hotspot. IV. Integration with other methods. The combination of rough set theory and other methods, such as neural networks, genetic algorithms, fuzzy mathematics, and decision trees, can give play to their respective advantages and greatly enhance the efficiency of data mining [20].

2.1.2. Fuzzy C-Means Rough Set Theory Analysis. Fuzzy control is a classical method in the field of automatic control. Its principle is fuzzy mathematics and fuzzy logic. Fuzzy clustering is a kind of clustering algorithm in which each object can partly belong to a certain class, that is, the value of membership degree is not limited to 0 and 1 but in the interval of $[0,1]$ [21]. Objects no longer have either/or characteristics for classes but can belong to multiple classes at the same time, and the specific degree of belonging to classes can be expressed by a membership function [22]. Among various fuzzy clustering algorithms, the fuzzy C-means algorithm is the most important and widely used. This algorithm first extended the clustering criterion function of hard clustering to fuzzy clustering, proposed the error square sum function with membership weighting, and then performed further expansion work [23]. The standard FCM algorithm is an iterative method in clustering methods, clustering a group of objects into the best C class by minimizing the weighted sum of error squares [24]. This algorithm allows overlapping parts between classes, allowing objects to be included in multiple classes [25]. The algorithm needs to minimize the following objective function:

$$J_m = \sum_{k=1}^c \sum_{i=1}^n u_{ki}^m \|x_i - u_{k2}\|, \quad (1)$$

$$s.t. \sum_{k=1}^c u_{ki} \in [0, 1], 0 \leq \sum_{i=1}^n u_{ki} \leq n,$$

where n is the number of data objects, $c(2 \leq c \leq n)$ is the number of clusters, the operator $\|$ is the Euclidean norm, and x_i is the i th data object in d -dimensional vector space. Parameter m ($m \geq 1$) is the weight factor of the membership function of FCM, which can control the fuzzy degree of partition data. The larger the value of m , the greater the fuzziness of the function. u_k ($1 \leq k \leq c$) represents the center of the class, and u_{ki} ($1 \leq k \leq c, 1 \leq i \leq n$) represents the degree to which x_i belongs to the k th class [26–37]. The algorithm framework of FCM is shown in Figure 2.

In Figure 2, the fuzzy C-means algorithm consists of six steps:

- (1) Step 1: initialization. The iteration termination threshold ϵ , cluster number C , and fuzzy factor M are set.
- (2) Step 2: the iteration counter $q=0$ is set.

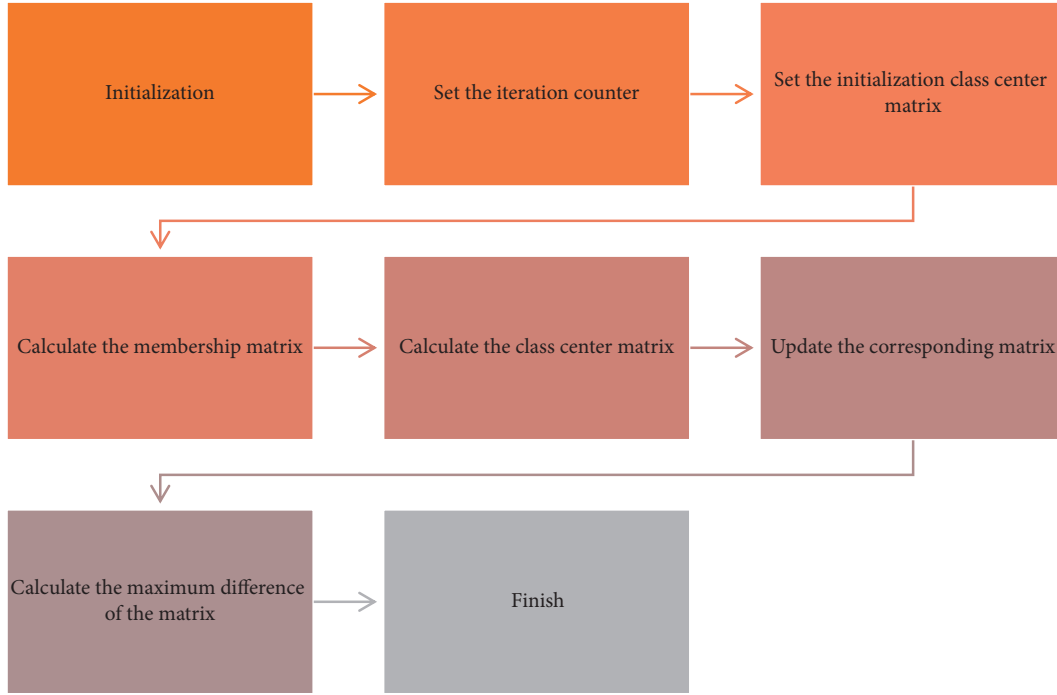


FIGURE 2: FCM algorithm block diagram.

- (3) Step 3: the class center matrix is randomly initialized [27], and the calculation method is shown in

$$C^{(q)} = C_k \quad (k = 1, 2, \dots, c). \quad (2)$$

- (4) Step 4: the membership matrix $U^{(q)}$ is calculated according to $C^{(q)}$, as shown in

$$U_q = \frac{1}{\sum_{k=1}^c (d_{ji}/d_{ki})^{2/m-1}}. \quad (3)$$

- (5) Step 5: the class center matrix $C^{(q+1)}$ is calculated according to $U^{(q)}$, as shown in

$$C^{(q+1)} = \frac{\sum_{i=1}^N u_{ji}^m X_i}{\sum_{i=1}^N u_{ji}^m}. \quad (4)$$

- (6) Step 6: the membership matrix $U^{(q+1)}$ is updated according to $C^{(q+1)}$ and (3); Step 7: if $\max\{U^{(q+1)} - U^{(q)}\} \leq \varepsilon$, the algorithm stops. Otherwise, $q = q + 1$, it will return to Step 4 [28].

FCM is an extension of the traditional K-means algorithm, which continuously updates the membership degree by minimizing the intra-class spacing. When the membership degree of all objects to all classes is determined, the class with the largest membership degree is selected as the class to which the object belongs [26–37].

2.2. Analysis of Airspace Congestion Characteristics Based on Radar Track Data. Congestion identification in the airspace sector based on radar track data is studied. At present, studies on airspace congestion mainly use simulation data, statistical

prediction data, controller workload data, etc., but few studies are based on radar track data. Radar track data have been used for traffic flow and inbound and outbound program identification, airspace operation status monitoring, and airspace complexity analysis. Based on radar track data research, it has the advantages of real time, accuracy, and practicability. Using the radar track data of a certain area control sector and based on the geographic information tool, the radar track data are processed to construct the airspace congestion evaluation indicator. To meet the modeling requirements, it is necessary to discretize the radar track data. The original radar track data are discretized at an interval of 5 min, and the isolated and abnormal data as well as the repeated track point data within the time slice are eliminated to generate track sample data. Based on the characteristics of radar track data, the traffic congestion situation is analyzed from macro- and micro-dimensions. The built metrics are detailed in Figure 3.

In Figure 3, traffic congestion characteristic indicators of equivalent traffic volume, proximity rate, saturation, and traffic density in four sectors are constructed. I. Equivalent traffic volume indicator. It is defined as the total equivalent sorties of aircraft in the sector within a unit time interval. When the traffic volume is greater, the sector is more prone to congestion. Different types of aircraft vary in size, flight performance, flight speed, and control workload. For this reason, equivalent traffic volume is selected to describe the quantitative characteristics of aircraft in the sector. The equivalent traffic volume is obtained by summing the number of different types of aircraft by weighting, and the weighting calculation is shown as follows:

$$q = k_1 a_1 + k_2 a_2 + k_3 a_3, \quad (5)$$

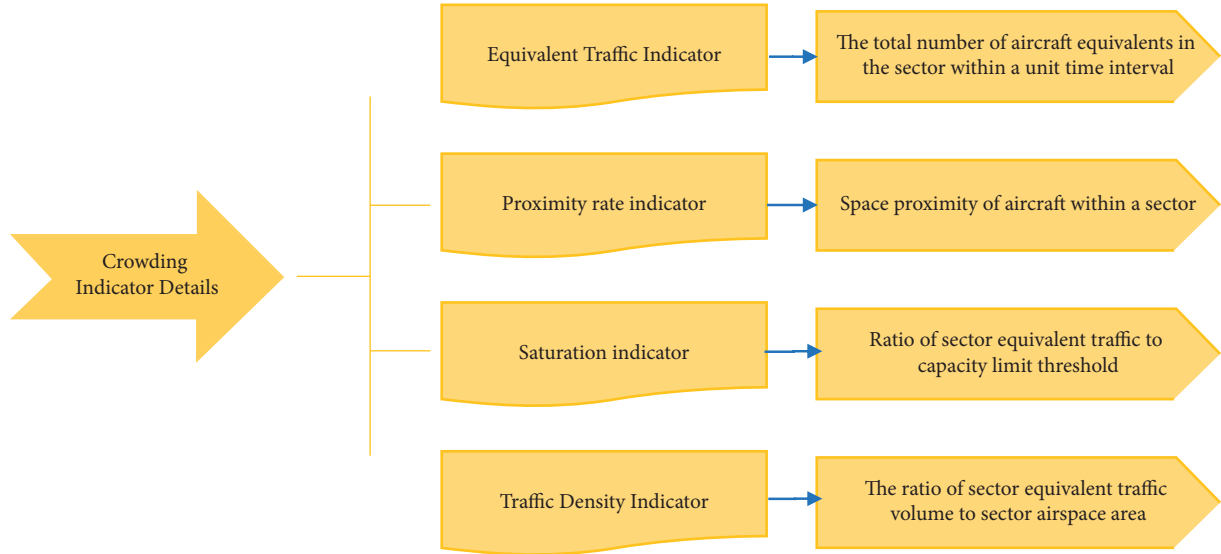


FIGURE 3: Build metrics detail diagram.

where q is the equivalent traffic volume of the sector; a_1 , a_2 , and a_3 are the times of the heavy machine, medium machine, and light machine, respectively; and k_1 , k_2 , and k_3 are the corresponding weights of heavy, medium, and light machines, respectively. Taking the light machine as the equivalent standard, the coefficients of the heavy machine, medium machine, and light machine are $k_1 = 1.3$, $k_2 = 1.1$, and $k_3 = 1.0$, respectively.

Proximity Indicator. The proximity rate describes the spatial proximity of aircraft in a sector and reflects the characteristics of traffic distribution. The space distribution of aircraft affects the degree of sector congestion. The traffic proximity rate of the sector reflects the congestion degree of the sector from the micro-level. In the radar control environment, aircraft in the sector must meet the horizontal minimum interval of more than 10 km or the vertical minimum interval of 300 m; either of the two must meet; otherwise, it will constitute a dangerous approach and violate the control operation rules. Therefore, the Euclidean distance is not simply used to determine the approach degree of the aircraft. The ellipsoid is used to define the relative distance of the aircraft and calculate the approach rate of the sector. The calculation is as follows:

$$d_{ji} = \left\| \begin{matrix} \overrightarrow{po_i} \\ \overrightarrow{po_j} \end{matrix} \right\|_{a,h} = \sqrt{\frac{(x_i - x_j)^2 + (y_i - y_j)^2}{a^2} + \frac{(z_i - z_j)^2}{h^2}},$$

$$p = \sum_{i=1}^N \sum_{j=1, i \neq j}^N e^{-d_{ij}},$$

$$p_{\text{sector}} = \frac{p}{N}, \quad (6)$$

where d_{ij} is the relative distance between aircraft i and j in the sector; $\overrightarrow{po_i}$, $\overrightarrow{po_j}$ is the position vector of aircraft i and j ; a

and h are the horizontal minimum safety interval and vertical minimum safety interval, respectively; (x_i, y_i) and (x_j, y_j) are the coordinate positions of aircraft i and j , respectively; (z_i, z_j) is the flight altitude of aircraft i and j ; p is the proximity of aircraft in the sector; N is the number of aircraft in the sector; and p_{sector} is the sector proximity rate.

According to the above equations, the sector proximity rate is the ratio of the sector proximity to the sector traffic volume, reflecting the proximity of aircraft in the sector. When the aircraft is denser, the relative distance is smaller, the sector proximity rate is larger, and the sector is more crowded. Taking the measured radar track data of a certain day in northwest China as an example, the airspace proximity and proximity rate are calculated, and the results are shown in Figure 4.

In Figure 4, after comparison of the traffic volume, the proximity curve and the proximity rate curve are relatively close to the traffic volume curve. Therefore, both the proximity and proximity rate can reflect the intensity of aircraft distribution in the sector.

III. Saturation indicator. It is defined as the ratio of sector equivalent traffic volume to the capacity limit threshold in a certain period of time. Saturation can well measure the degree of traffic load in sectors and facilitate the comparison of congestion degree among different sectors. The calculation method is as follows:

$$s_i = \frac{q_i}{c}, \quad (7)$$

where s_i is the traffic saturation of the i th interval sector, q_i is the equivalent traffic volume of the space unit in time interval i , and c is the capacity limit threshold of the sector. The sector capacity limit threshold c adopts the data obtained from the capacity assessment results of the controlled sectors of Air Traffic Management Bureau of Civil Aviation Administration of China. To realize the fine management of air traffic control operations, the civil aviation air traffic control authority has basically

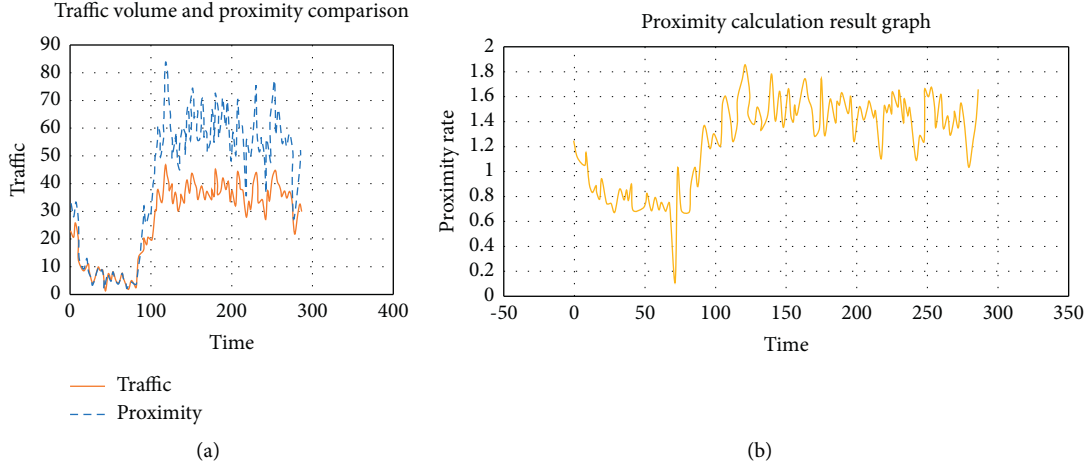


FIGURE 4: Spatial proximity and proximity result diagram. (a) Traffic volume and proximity comparison diagram of a certain sector and (b) calculation results of the proximity rate.

completed the capacity evaluation of the control sector, and the corresponding capacity limits of the control sector have accurate data.

IV. Traffic density indicator. It is defined as the ratio of sector equivalent traffic volume to sector airspace area, represented by k . Under the same traffic volume, the smaller the sector space is, the smaller the maneuvering space of the aircraft will be, and the more crowded the airspace will be. The traffic density of a sector can reflect the congestion degree of the sector and facilitate the comparison of congestion degree among different sectors.

2.3. FCM-Rough Set Sector Congestion Identification Model in Aviation Airspace

2.3.1. Crowding Degree Division of Multiple Sectors Based on FCM. The radar track data are collected for pre-processing, and the equivalent traffic volume, proximity rate, saturation, and traffic density of the sector are calculated at a statistical interval of 5 min so that the sector traffic congestion characteristic matrix X is constructed. The FCM clustering method is used for X clustering analysis, and the congestion degree of the airspace sector is divided. The FCM algorithm divides n groups of crowding feature vectors into m fuzzy groups, where $1 \leq i \leq n$, calculates the clustering center of each group, and calculates the membership value of each group of feature vectors belonging to each group of clustering centers to determine the crowding degree corresponding to each group of feature vectors. Due to the selection of continuous radar track data, the traffic volume in some intervals is zero. Therefore, the traffic congestion degree is classified into six levels, namely, zero traffic volume, little traffic volume, smooth, stable, crowded, and seriously crowded. The corresponding clustering centers are also six. FCM clustering can only

classify the degree of sector congestion, so rough set theory is used to identify the degree of airspace sector congestion.

2.3.2. Congestion Identification of Airspace Multisector Based on Rough Set. Rough set theory is used to identify sector congestion. Rough set theory is an effective way to deal with imprecise, uncertain, and incomplete data and extract the required knowledge. The knowledge representation system for discriminating sector traffic congestion is a quad $S = (U, A, V, f)$, where U is the domain of sector congestion characteristics. A is the set of sector congestion attributes, which is composed of conditional attribute C and decision attribute D , $C = \{\text{equivalent traffic volume, proximity rate, saturation, traffic density}\}$ and $D = \{\text{category description: unblocked state, crowded state}\}$. V is the corresponding range of the attribute. f is a traffic congestion information function that assigns an information value to the traffic congestion object attribute of each sector. The value of the sector congestion attribute is discretized to facilitate attribute reduction. The purpose of attribute reduction is to remove unnecessary attributes from the attribute set. By reducing the congestion attribute, the identification rules of sector traffic congestion can be generated.

Figure 5 shows the computational flow of the FCM-rough set aviation airspace sector congestion identification model.

In Figure 5, the calculation process of the FCM-rough set aviation airspace sector congestion identification model is shown as follows: (I) Data preparation: multisector radar track data are collected, sector congestion characteristic indicator values are calculated, and multisector traffic congestion characteristic matrix X is constructed in chronological order. (II) Classification of traffic congestion degree: the FCM algorithm is adopted to cluster the sector traffic congestion feature matrix X . The number of cluster centers is $m = 6$, and the iteration

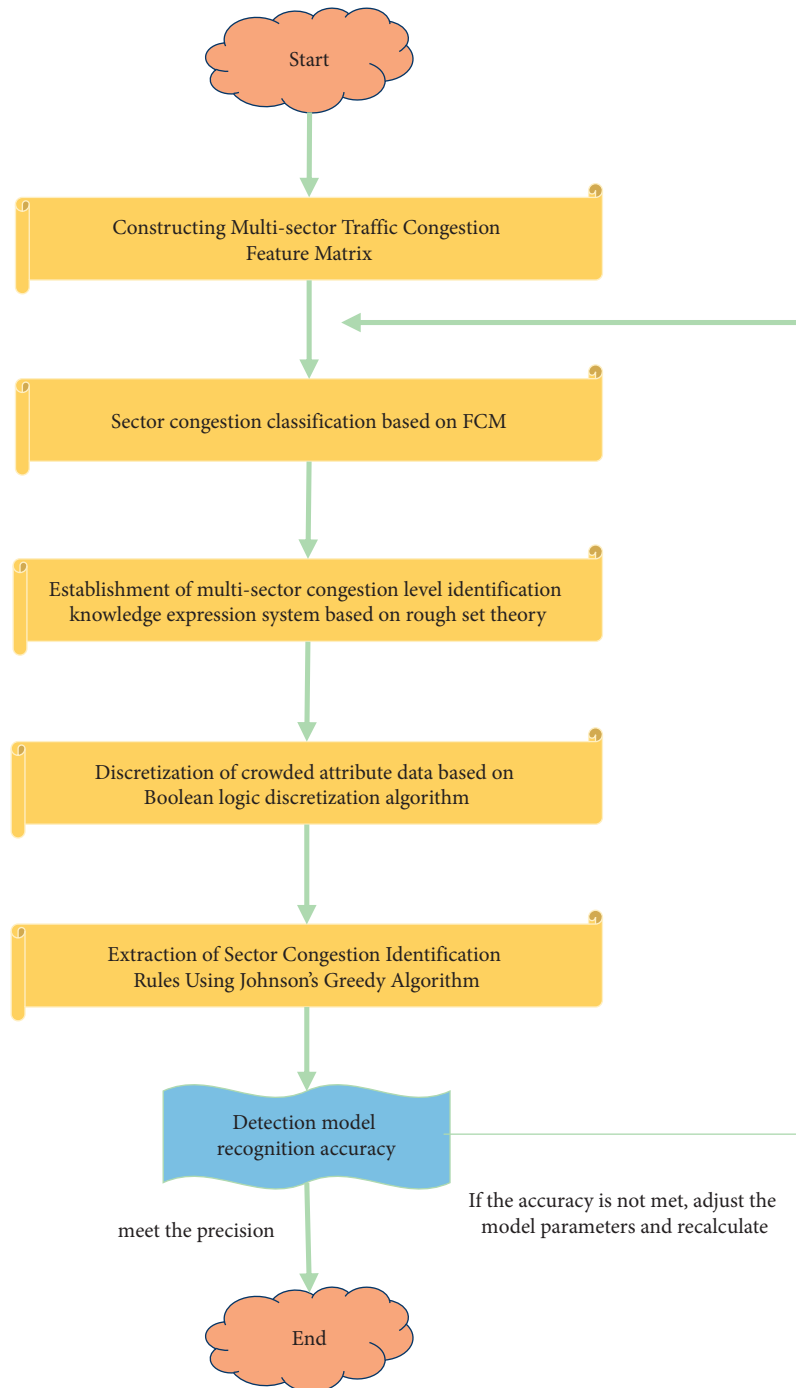


FIGURE 5: Flow chart of model calculation.

stop threshold is $E = 1 \times 10^{-6}$. The clustering center of each crowded category is obtained to minimize the sum of squares of weighted errors within the class. The fuzzy division method, namely, membership matrix, is adopted to determine the crowding degree of each time slice of multiple sectors. Sector congestion can be classified into zero traffic volume, little traffic volume, smooth, stable, crowded, and seriously crowded. (III) A sector congestion recognition knowledge representation system is established. A sector congestion recognition knowledge

representation system is constructed by selecting the sector congestion characteristics and corresponding congestion levels. The conditional attributes are equivalent traffic volume, proximity, saturation, and traffic density, and the decision attributes are unblocked state and congestion state, in which congestion degree zero traffic volume, little traffic volume, smooth, and stable are the unblocked state, and congestion degree crowded and severe crowded are the congestion state. (IV) Discretization of crowding attribute data: a Boolean logic

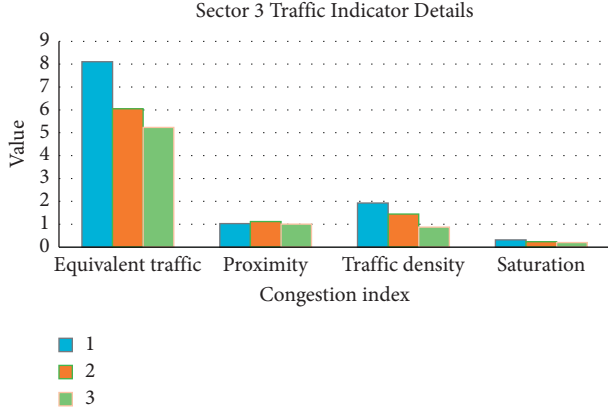


FIGURE 6: Detail diagram of the traffic congestion indicator in sector.

discretization algorithm is used to find the minimum possible set of segmentation points according to the initial segmentation points while maintaining the indiscernible relation of the information system. (V) The crowding attribute is reduced, and the decision rules are extracted. The Johnson greedy algorithm is used to reduce the discrete traffic congestion attributes, delete the unimportant, redundant, and interfering attributes, and screen out the key attributes that can reflect the essential relationship between data under the condition that the classification ability of the knowledge base remains unchanged. (VI) The identification accuracy of the detection model. If the accuracy requirements are not met, return to Step II, adjust the model parameters, recalculate, and meet the accuracy requirements until the end of the model calculation.

2.4. FCM-Rough Set Identification Model Verification of Airspace Sector Congestion. In the experiment, the radar traffic data of three sectors in a controlled airspace in northwest China are selected as the research object to study the traffic congestion problem in the airspace multisector and verify the effectiveness of the research model. The traffic congestion indicator of the sector is shown in Figure 6.

In Figure 6, the current traffic volume of sector 1 is 8.11, the proximity is 1.029, the traffic density is 1.925×10^{-4} , and the saturation is 0.32. The current traffic volume of sector 2 is 6.05, the proximity is 1.118, the traffic density is 1.444×10^{-4} , and the saturation is 0.24. The current traffic volume of sector 3 is 5.23, the proximity is 1.055, the traffic density is 0.875×10^{-4} , and the saturation is 0.2. The model output is compared with the actual situation, and the congestion discriminant rate I and congestion misjudgment rate R are used to measure the validity of the model. The calculations of the indicators are as follows:

$$I = \frac{\text{NIR}}{\text{IT}}, \quad (8)$$

$$R = \frac{\text{FNIR}}{\text{NIR}}.$$

TABLE 1: Multisector congestion identification rule table.

No.	Saturation	Proximity	Equivalent traffic	Crowding decision value
1	$[0.71 + \infty)$	$[1.25 + \infty)$	$[15 + \infty)$	Crowded
2	$[0.71 + \infty)$	$[0, 0.125)$	$[15 + \infty)$	Crowded
3	$[0.71 + \infty)$	$[0, 0.125)$	$[10, 15)$	Crowded
4	$[0, 0.71)$	$[1.25 + \infty)$	$[15 + \infty)$	Crowded
5	$[0.71 + \infty)$	$[1.25 + \infty)$	$[10, 15)$	Crowded
6	$[0, 0.71)$	$[0, 0.125)$	$[10, 15)$	Unblocked
7	$[0, 0.71)$	$[0, 0.125)$	$[15 + \infty)$	Unblocked
8	$[0, 0.71)$	$[0, 0.125)$	$[0, 10)$	Unblocked
9	$[0.71 + \infty)$	$[0, 0.125)$	$[0, 10)$	Unblocked

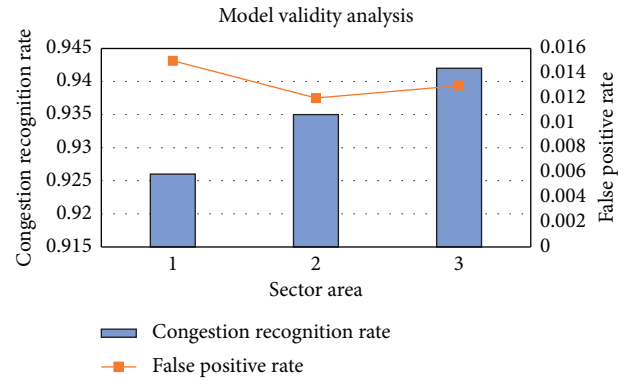


FIGURE 7: Analysis results of model validity.

NIR is the congestion number detected at time t . IT is the actual number of crowding events at time t . FNIR is the crowded number of false positives at time t .

3. Results

3.1. Model Recognition Rate Analysis. The congestion recognition rate of the aviation and airspace multisector based on FCM-rough set theory is analyzed, and the recognition rules are shown in Table 1.

In Table 1, according to saturation, proximity, and the actual value range of the current traffic volume, the current aviation and airspace sector congestion degree can be obtained corresponding to different categories in Table 1. Two indicators, congestion discriminant rate I and congestion misjudgment rate R , are calculated to evaluate the validity of the model. The result is shown in Figure 7.

In Figure 7, after sampling detection of recognition results, the congestion recognition rate and misjudgment rate of the model for sector 1 are 92.6% and 1.5%, respectively. The congestion recognition rate of sector 2 is 93.5%, and the congestion misjudgment rate is 1.2%. The congestion recognition rate of sector 3 is 94.2%, and the congestion misjudgment rate is 1.3%. Notably, the multisector congestion recognition model has a high recognition rate and a low misjudgment rate, and the overall discrimination result is relatively stable, which can accurately identify the congestion degree of the multisector.

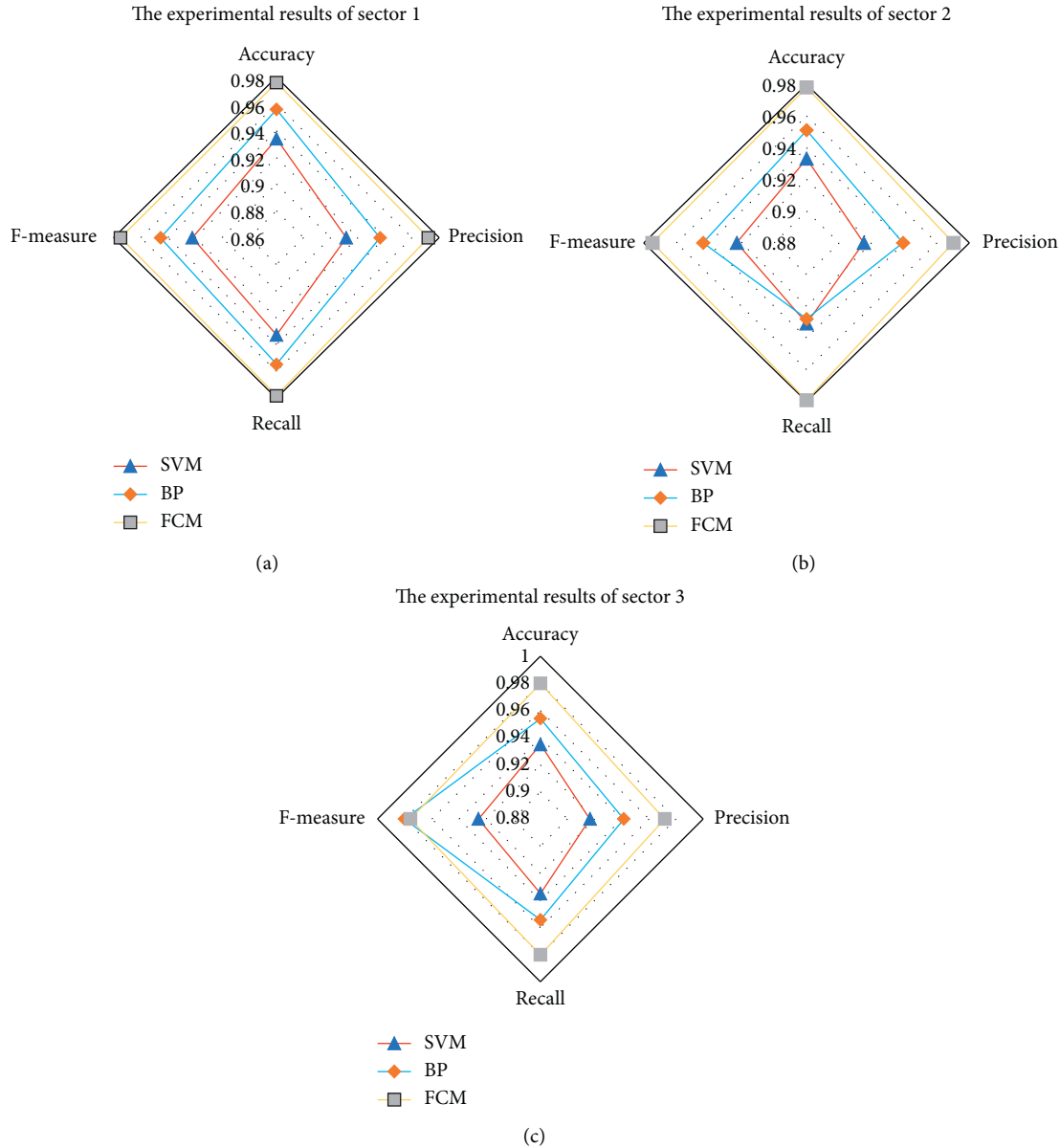


FIGURE 8: Comparison of the experimental results of different methods. (a) Comparison diagram of sector 1, (b) comparison diagram of sector 2, and (c) comparison diagram of sector 3.

3.2. Crowding Judgment Model Analysis Based on FCM-Rough Set Theory. To verify the superiority of the proposed method, the proposed method is compared with the Back Propagation (BP) neural network structure and Support Vector Machine (SVM) method. The basic idea of the BP neural network algorithm is that the input signal is input through the input layer, and output from the output layer through the hidden layer calculation. The output value is compared with the marked value. If there is error, the error is propagated reversely from the output layer to the input layer. In this process, the gradient descent algorithm is used to adjust the weight of neurons. The SVM algorithm is a supervised learning model to analyze data in classification and regression. Given a set of training instances, each training instance is marked as belonging to one or the other of two

categories. The SVM training algorithm creates a model that assigns new instances to one of two categories, making it an improbability binary linear classifier. The SVM model represents instances as points in space so that instances of separate categories are separated as clearly as possible. The new instances are then mapped to the same space, and the category is predicted based on which side of the interval they fall on. The comparative experimental results of the three models are shown in Figure 8.

In Figure 8, in the experimental results of sector 1, the accuracy of the SVM-based method is 93%, the precision is 91.2%, the recall rate is 93.5%, and the F measure is 92.4%. The accuracy of the method based on the BP neural network is 95.8%, the precision is 93.9%, the recall rate is 95.6%, and the F measure is 94.6%. The method based on FCM-rough

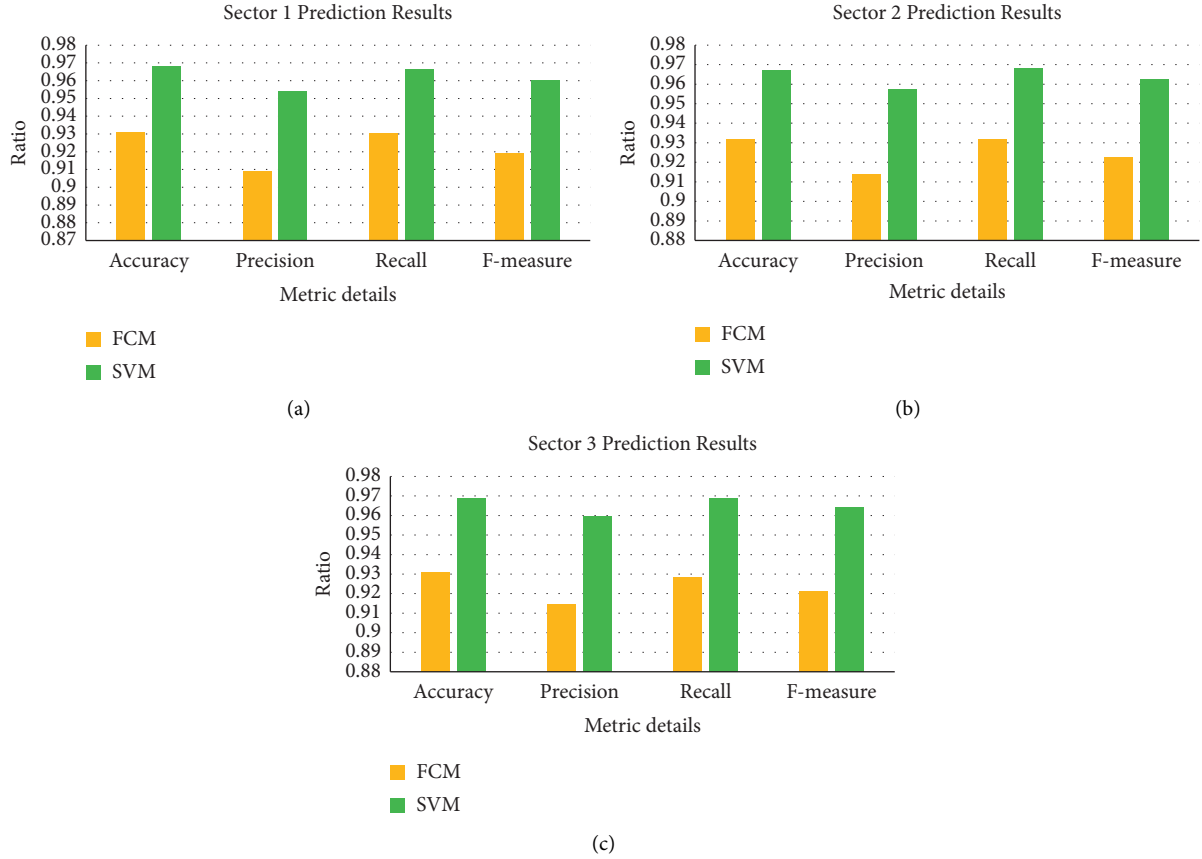


FIGURE 9: Prediction accuracy results. (a) Sector 1 (b) sector 2 and (c) sector 3.

set theory designed in this work has 97.7% accuracy, 97.2% precision, 97.7% recall rate, and 97.6% F measure.

In the experimental results of sector 2, the accuracy of the SVM-based method is 93.4%, the precision is 91.5%, the recall rate is 93%, and the F measure is 92.3%. The accuracy of the method based on the BP neural network is 95.1%, the precision is 93.9%, the recall rate is 93%, and the F measure is 94.4%. The method based on FCM-rough set theory designed in this work has 97.8% accuracy, 97% precision, 97.9% recall rate, and 97.5% F measure.

In the experimental results of sector 3, the accuracy of the SVM-based method is 93.5%, the precision is 91.7%, the recall rate is 93.5%, and the F measure is 92.6%. The accuracy of the method based on the BP neural network is 95.4%, the precision is 93.1%, the recall rate is 95.4%, and the F measure is 98%. The method based on FCM-rough set theory designed in this work has 98% accuracy, 97.1% precision, 98% recall rate, and 97.6% F measure.

Comprehensive analysis shows that the method based on FCM-rough set theory designed in this work has higher accuracy and a better model effect.

The prediction accuracy of the model for the congestion degree of the aviation and airspace sector is analyzed, and the design model is compared with the SVM method. The results are shown in Figure 9.

In Figure 9, after comprehensive analysis of the prediction indicator results of the three sectors, it is found that the prediction accuracy of the model based on FCM-rough

set theory designed in this study is higher than that of the SVM-based algorithm, so the model designed in this study has a high accuracy in predicting the traffic congestion degree of aviation and airspace.

4. Conclusion

First, rough set theory and the FCM model are analyzed. Second, the two research theories are combined for analysis. Then, FCM-rough set theory is applied to the identification of traffic congestion in aviation and airspace in multiple sectors, and appropriate indicators of aviation and airspace sector congestion are selected. Then, the actual radar track data of the regional control sector in northwest China are used to verify the case. The results show that FCM can quickly classify the congestion degree of sectors and analyze the spatial and temporal evolution of traffic congestion degree from the macro-perspective and the dimensions of multiple sectors. The recognition model can discretize attributes quickly and remove redundant information, and the congestion recognition rate can reach 92.6%. The congestion attribute of multisectors can be predicted in real time by identifying the congestion degree of sectors based on the radar track data, which can be used to assist the decision-making of aviation and airspace management and air traffic flow management. The deficiency of this work lies in the small number of selected variables and survey samples. The next research focus is collecting more experimental data for

in-depth analysis. The innovation of this work lies in focusing on the problem of airspace congestion and combining FCM theory with rough set theory, which analyzes the problem of airspace congestion in a more comprehensive way, and the experimental results are more reliable. This work can optimize the aviation and airspace management system and provide relevant suggestions for the study of aviation and airspace congestion.

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

Scenario-Based Teaching Design of International Trade Practice Based on Deep Learning

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In the context of the fourth global industrial revolution, the trading environment of international trade is undergoing profound changes. In today's deep integration of globalization, the teaching mode of economic application courses—international trade practice situational teaching mode—is bound to change. This article sorts out the problems existing in the curriculum from the perspectives of the integration of the practical curriculum, the cohesion of the trade process, and the teaching concepts and methods. On the basis of deep learning, a situational teaching design process of international trade practice is constructed.

1. Introduction

The development trend of society, economy, science and technology, and culture in the 21st century and the process of China's economic integration into economic globalization have made China's demand for various types of talents continue to change, and the requirements for talent specifications continue to increase, which objectively requires continuous reform of higher education [1]. In order to meet the needs of China's higher education reform and development, we should further strengthen curriculum construction and improve teaching quality. Continuously improve, refine, enrich, and develop the connotation of the curriculum, increase the reform of teaching content and methods, make curriculum construction and teaching reform a process of mutual matching, dynamic development, and continuous deepening, and give play to teaching reform and curriculum construction. It emphasizes on both theory and practice teaching in order to comprehensively improve the comprehensive quality of students. The simulation teaching system of international trade [2, 3] is designed and developed based on the simulation of international trade practice [4–6]. Simulate the whole process of generating, transmitting, receiving, reviewing, and feedback on a full set of documents involved in international trade practice from

the perspective of time and business sequence. The main object of its simulation is the business, documents, and document delivery of all relevant enterprises, functional departments, and institutions in international trade practice. Among them, business simulation is carried out according to the actual situation of various enterprises, institutions, and relevant rules, which is the simulation of the actual business. Document simulation in international trade is realized by electronic paper documents [7, 8], which is the reproduction of various paper documents currently used in international trade practice [9]. Document delivery simulates the traditional transmission methods of various documents, such as fax, mail, direct delivery, and so on.

The training goal of the international economics and trade major is to cultivate foreign economic and trade talents with theoretical analysis and practical operation ability [10, 11]. Therefore, it is very important to cultivate the practical business ability of foreign trade in this major [12]. In the teaching operation, due to the extremely limited ability of enterprises to accept students' professional internships, general enterprises are reluctant to let students go to the enterprise due to business secrets and other reasons. In order to enable students of this major to combine theoretical knowledge with practice and internalize book knowledge into students' practical ability, it is

necessary to set up a centralized and independent practice link that simulates actual business in the school. The importance of practical teaching lies in the students' ability to use the knowledge learned in the classroom, through hands-on operation, simulation experiments, and personal experience. International trade practice [13, 14] is a core main course of international economics and trade, and it is also a highly practical course. Much knowledge is only described by teachers in language, and students will feel very abstract and difficult to understand, but after the practical operation, abstract problems become tangible things that can be seen and touched, and students can easily understand them. On the other hand, practical teaching also strengthens students' ability to analyze and solve practical problems.

"International Trade Practice Course Design" is an important practical teaching link arranged after the "International Trade Practice" course, which is required by professional education. Its teaching purpose is to make students familiar with and understand the specific operation procedures of actual foreign trade business through the simulation operation of this practical link on the basis of mastering the basic principles, basic knowledge, and basic skills and methods of engaging in international trade practice so as to enhance some perceptual knowledge and further understanding, consolidation, and deepening of the international trade practice theories and methods that have been learned, improve students' ability to identify, analyze, and solve problems. This largely solves the problem of difficult professional practice for students. In the specific operation of international goods trading practice, students can quickly become familiar with international market research of import and export, formulation of export marketing plans, inquiries, offers, counteroffers, drafting export contracts, reviewing letters of credit, and drafting various documents. Master various basic skills be familiar with such as export documents, familiar with the operation mode of international trade logistics, capital flow, and business flow, understanding the different positions of different parties in international trade, the specific work and interaction they face, and learn how foreign trade companies use various methods. The idea of achieving the best benefit, understand the macroeconomic phenomena such as supply and demand balance, reasonable competition, and learn to use it rationally. In the course design, students can give full play to their subjective initiative, truly master and absorb the knowledge learned in the classroom, and lay a good foundation for entering the workplace in the future.

In recent years, deep learning research has become a popular choice for some educators, but these researches mostly stay at the theoretical level; that is, conceptual research on deep learning, feature research, and empirical research are very scarce. As we all know, teaching is not only a science, but also an art. Teaching is a creative and unpredictable activity, because teaching activities are faced with living individuals, and teaching only at the theoretical level is untenably becoming a priority.

2. Related Technologies

2.1. Related Concepts

2.1.1. Deep Learning. Compared with shallow learning, deep learning avoids shallow, fragmented, and isolated classroom teaching. In the more than 40 years since the concept of deep learning was proposed, different scholars have developed their own views on the concept of deep learning, mainly including the following:

Chinese scholar Zhang Sujuan believes that deep learning should focus on cultivating student's creativity, criticality, and critical thinking. This requires teachers to study the curriculum standards, carry out knowledge learning and ability training at the same time when designing teaching content, and acquire the ability to acquire knowledge while acquiring knowledge. However, Zhang Sujuan's scholars over-emphasized the cultivation of geographical thinking ability, which weakened the development of students' geographical methods and emotional attitudes and values.

American Keith Sawyer's definition of deep learning focuses on learners' connection between new and old knowledge. He believes that deep learning is to summarize new knowledge into the original knowledge system by finding adaptive patterns and methods [15] and develop a new understanding of knowledge and a process of comprehensive reflection in the process.

Jiahou believes that the premise of deep learning is "understanding." Students should treat new knowledge and new ideas critically and summarize them into their own cognitive structure through their own understanding. Such knowledge can be flexibly transferred to various situations so as to solve the corresponding problem. It can be seen that Jiahou's definition of deep learning emphasizes the initiative of students, and the process of deep learning should reflect the subjectivity of students, but whether students can learn actively and reflect the status of subjectivity is affected by many factors, such as the role of teachers, whether the teaching environment provides favorable conditions.

Through the above analysis, the author believes that the concept of deep learning can be understood as follows: from the perspective of the learning roles, deep learning emphasizes the subjectivity of learners, and at the time emphasizes the leadership guidance of teachers; from the perspective of learning form, deep learners are necessary. Knowledge is deeply processed to promote long-term memory of knowledge; from the perspective of the learning process, deep learning requires learners to actively devote themselves to the learning process; from the perspective of the learning experience, deep learning focuses on stimulating the learners' intrinsic motivation to learn. Learners generate learning satisfaction and make learning an enjoyable experience.

In fact, deep learning and shallow learning are not two completely opposite concepts. Deep learning is sometimes based on shallow learning, while deep learning is the reprocessing of shallow learning and the development of shallow learning. The relationship is shown in Figure 1.

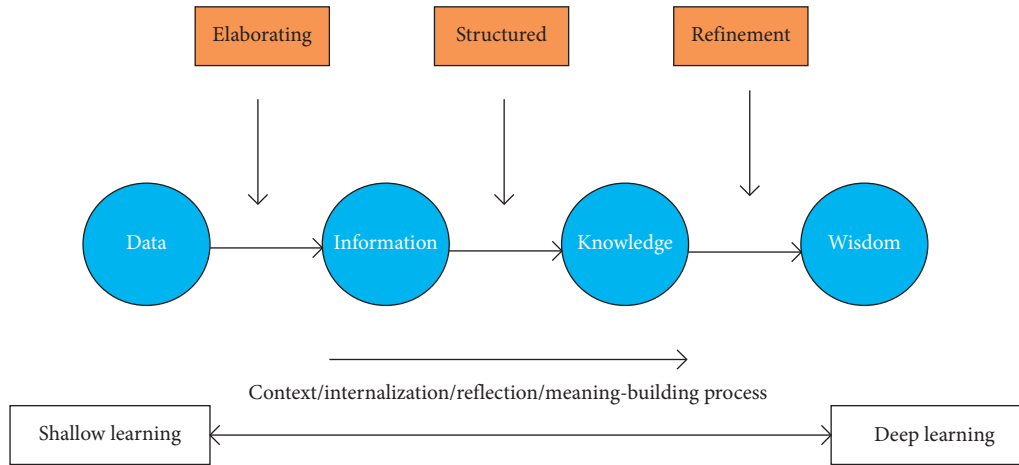


FIGURE 1: Progressive relationship between shallow learning and deep learning.

2.1.2. Instructional Design. Teaching design was first produced in the combat training of soldiers in the World War II and then gradually applied to school teaching.

Instructional design is a bridge between theory and practice. In instructional design, teachers are designers. Teachers design learning activities according to course requirements and the characteristics of students so as to meet the requirements of teaching and learning. Different scholars have different views on teaching design. For example, how to overcome scholars think that teaching design is a systematic process, a process of systematic transformation of theory into teaching objectives, teaching methods, teaching evaluation, and other teaching links. In their "Principles of Teaching System Design," Yang Jiumin and Fan Guanjin advocated that teaching design should be based on learning theory, teaching theory, and communication theory and evaluate and revise teaching design through systematic methods.

Through the above propositions, teaching design can be understood as the use of systematic methods, based on pedagogical theory, psychological theory, communication theory, and so on, through media tools, according to the requirements of the curriculum to reasonably design all aspects of the teaching process so as to achieve teaching the purpose and the process of discovering teaching problems and solving teaching problems. Figure 2 is the instructional design process diagram.

2.1.3. Higher-Order Thinking. Higher-order thinking refers to thinking, in which thinking activities occur at a higher cognitive level, also known as high-level thinking [16]. Higher-order thinking originated from Bloom's taxonomy of cognitive goals, and then Anderson divided educational goals into knowledge goals and cognitive goals on the basis of Bloom's classification of cognitive goals. Cognitive goals include creation, evaluation, analysis, application, comprehension, and memory (Figure 3).

From the cognitive level, analyzing, evaluating, and creating goals belong to higher-order thinking, while remembering, understanding, and applying goals belong to

lower-order thinking. To cultivate students' higher-order thinking, it is necessary to transform students' learning methods and increase the depth of knowledge learning and understanding. Therefore, the cultivation of higher-order thinking focuses on students' "learning" rather than teachers' "teaching." Therefore, only by changing the traditional teaching methods can teachers indirectly cause changes in students' learning methods so that students can learn to learn autonomously and construct themselves, thereby promoting the occurrence of deep learning and the cultivation of advanced thinking ability.

2.2. Theoretical Basis

2.2.1. General Systems Theory. System theory advocates the use of systematic methods, ideas, and viewpoints to study and solve problems because, in the view of system theory, everything in the world exists systematically, so the object of study should be regarded as a system as a whole and in the form of a system. Seek solutions to the problem. Therefore, the guidance of system theory to teaching design is to take education and teaching as a system as a whole, to integrate all elements of teaching design in teaching design, to use systematic methods to order the whole process, and to provide a mode of teaching design. The development of systems theory has broadened the vision of instructional design, making instructional design not only focus on internal structural objects, but also on social systems closely related to education, which also provides support for the richness and rationality of instructional design.

2.2.2. Information Dissemination Theory. Information dissemination theory mainly studies the laws of information dissemination in nature and summarizes the common points of information dissemination in nature. Because the educational process is also a special information dissemination process, the dissemination theory is suitable for the study of education. In the process of dissemination of educational information, the characteristics of the information recipients, the age, gender, and personality of the students

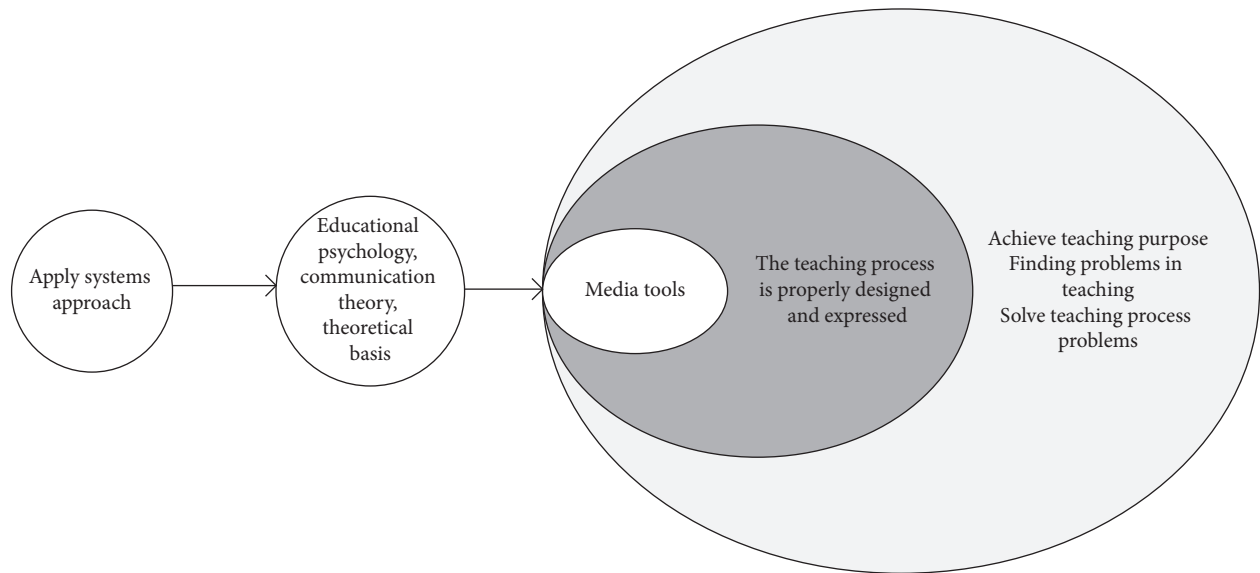


FIGURE 2: Instructional design process diagram.

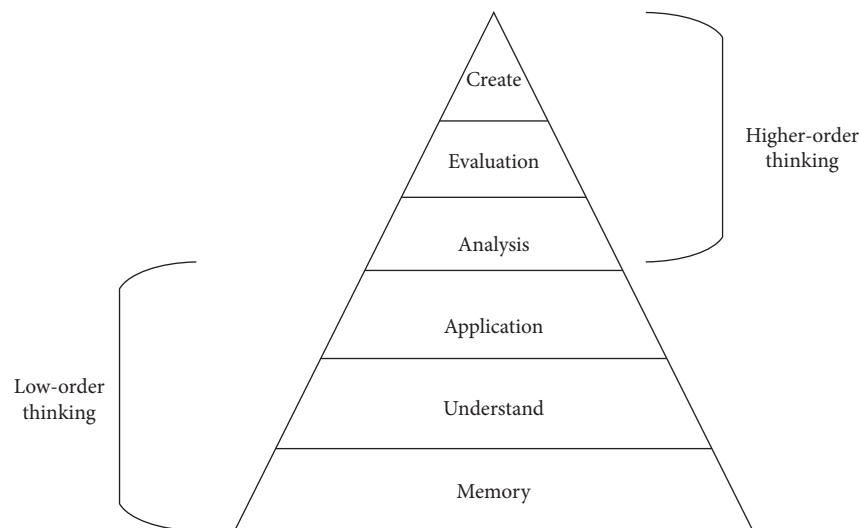


FIGURE 3: Anderson's educational goal classification diagram.

should be considered, and the structure and sequence of the information should be considered. After rational organization, it should be more in line with the psychology of the information recipients. The number of information should not be too much or too little. Too much will easily “overload,” and too little will make it difficult to concentrate students’ attention. Only by considering these comprehensively can the quality of information dissemination be guaranteed.

2.2.3. Learning Theory. Learning theory is a psychological theory that mainly studies the nature of human learning and explores the formation mechanism of learners’ learning process. Since instructional design mainly creates a learning environment according to the actual needs and

characteristics of learners, the research results of learning theory have practical significance for the research on the instructional design of educators.

(1) Constructivist Learning Theory. China’s basic education reform is influenced by the constructivist learning theory. The theory originated in the 1980s, and its main views are mainly reflected in three aspects. First, the dynamic nature of knowledge is emphasized in terms of knowledge. First, deep learning believes that knowledge is flexible, the elaboration of things is not objective, and learners need to conduct specific analysis according to actual problems; second, deep learning believes that knowledge requires a certain carrier, the learners need to use a certain “intermediary” to complete the deep understanding of knowledge. Second, pay attention to the learning situation in learning. Constructivism believes that students need a certain situation when they actively

construct and process knowledge. This situation must be related to social life, and knowledge that has not been lived is not easy to be internalized by students. Third, pay attention to the existing experience structure of students in terms of students, which emphasizes the need to pay attention to the connection between before and after knowledge when carrying out instructional design, take students' previous experience as a starting point, and on this basis guide students to build new knowledge, thereby doing deep learning.

(2) *Learning the Pyramid Theory.* The learning pyramid theory originated in the mid-1940s and was proposed by the American scholar Edgar Dyer based on the research results of the Maine National Training Laboratory. Influence of quantity [17], the structure of the learning pyramid theory is shown in Figure 4 below.

Starting from the top of the tower and descending in order, the learners' learning styles continued to change, and they were at higher and higher cognitive levels. The results showed that the students remembered more and more content after two weeks. The first way of learning is "listening to talk"; that is, the traditional teacher tells the students to listen, and there is little interaction between teachers and students. The effect of this learning method can be imagined. The experimental results also prove that the learners' memory content after two weeks is only 5%, the second allows learners to read, and the knowledge retention rate reaches 10%, the third learning method mobilizes a variety of senses, and the learning effect becomes better, but the retention rate is 20%, and the learning effect of demonstration is better; the knowledge retention rate is 30%. The learning effect of discussion, practice, and immediate application and transfer to others is better, and the knowledge retention rate after two weeks reaches 50%, 75%, and 90%.

Therefore, Dell classifies learning according to the different learning effects of learners in different ways. Learning methods with a learning effect of less than 30% are called passive learning, while those with a learning effect of more than 50% (discussion, practice, and teaching to others) are called active learning. For active learning, the research results of the learning pyramid theory have proved the importance of active learning, so the theory provides theoretical support for the idea that instructional design should change the way students learn.

3. Research Ideas and Methods

3.1. Research Ideas

3.1.1. *Determine the Topic and Consult the Literature.* First, determine the topic, and then collect literature on deep learning on the one hand, and review and organize related literature on deep learning strategies and deep learning cognitive process models based on allosteric models on the other hand.

3.1.2. *Investigation and Research to Find Problems.* Through the questionnaire analysis of students and teachers, the current situation of deep learning in international trade

in senior high schools is understood [16, 18], and the problems existing in deep learning of international trade are discovered [15, 17, 19].

3.1.3. *Implement and Verify the Effectiveness of the Integrated Instructional Design.* Aiming at the problems existing in the situational teaching of international trade practice, the deep learning strategy based on the allosteric model constructs the teaching process and combines with the cognitive process model of deep learning to supplement and improve to construct a more scientific and reasonable integrated teaching design. Carry out teaching practice in the practice school, and verify the effectiveness of the integrated teaching design according to the teaching effect [20].

3.1.4. *Summarize and Draw Conclusions.* Through the analysis and summary of the data and interview results, conclusions are drawn to provide teaching references for front-line teachers.

The specific research ideas are shown in Figure 5.

3.2. Research Methods

3.2.1. *Literature Research Method.* By collecting, arranging, and reviewing a large number of relevant literature materials, we can form a holistic understanding of the current research on the teaching design of international trade units based on deep learning and comprehensively grasp the deep learning strategies based on allosteric models and the cognitive process model of deep learning. It lays a theoretical foundation for the construction of integrated teaching design ideas.

3.2.2. *Investigation Method.* Drawing on other people's questionnaires and according to the concepts and characteristics of deep learning, we design questionnaires for teachers and students, respectively, and then conduct surveys. Through the statistical analysis of the questionnaire data, we can understand the current situation of deep learning in international trade and find out the problems existing in deep learning of teachers and students so as to promote the deep learning of students in a targeted manner.

3.2.3. *Case Study Method.* Select the content in the textbook of International Trade, adopt the integrated teaching design idea to promote students' in-depth learning to design and analyze relevant cases, and analyze and illustrate the effectiveness of the teaching design.

3.2.4. *Experimental Method.* Select multiple classes with similar levels, apply the designed teaching cases to actual classroom teaching activities, and compare with the conventional teaching mode of the control class to test the effectiveness of the deep learning teaching design [21].

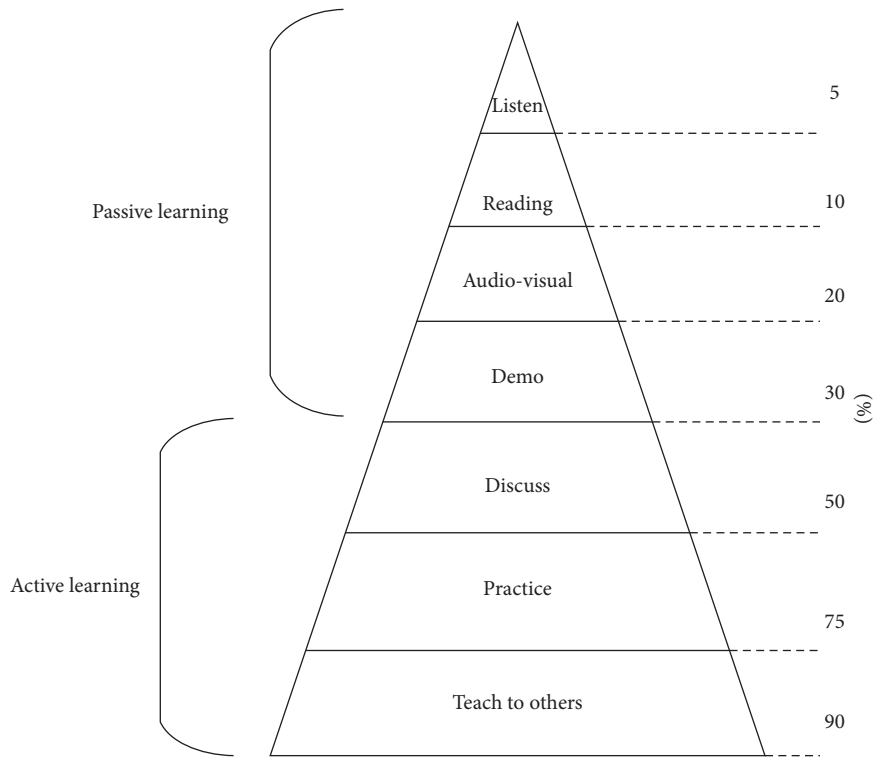


FIGURE 4: Structure diagram of learning pyramid theory.

3.3. Unit Instructional Design

3.3.1. The Meaning of Unit Instructional Design. To understand unit instructional design, we must first understand what unit instruction is. Xiao-Ping believes that unit teaching refers to a teaching method that focuses on a certain unit, allowing students to promote their cognitive transfer through various inquiry activities, improve students' problem-solving and other higher-order thinking skills, and develop a spirit of active inquiry. Li Yingkui believes that the scope of unit teaching should not be limited by the "teaching unit" in the textbook, but should cover the teaching theme composed of some related knowledge points or several lessons. The whole teaching theme is interconnected and interacting organisms [22]. The "unit" cannot be equated with the "teaching unit" of the textbook because the "unit" can also be a "teaching theme" composed of several "units of the textbook." The subject of International Trade is a relatively systematic subject, and most teachers of International Trade will recognize the "unit" from the perspective of content, that is, tend to the connotation of "teaching material unit." In the actual teaching process, it is possible to refer to the established structure of the textbook and use a chapter directly as a unit or appropriately reorganize the content and combine it into a new unit, which is more conducive to the formation of students' knowledge system [23].

Regarding the unit teaching design, Professor Zhong Qiquan believes that the unit teaching design should be grasped as a whole, taking the content with a certain theme as the core as

an organic whole, through the formulation of unit teaching objectives, the design of unit teaching plans, and the unit evaluation, to complete complex teaching activities. Different from the class design, the unit teaching design emphasizes the systematic and procedural content of the unit, starting from the cognitive law and the logical sequence of psychological development, and arranges the teaching content reasonably [24]. In the process of unit teaching implementation, not only should we focus on imparting knowledge points of the system, but also on promoting the smooth completion of the unit goals so as to achieve high-quality teaching.

3.3.2. The Model of Unit Instructional Design. The effective implementation of unit teaching design is inseparable from the unit teaching mode. Although the model of unit instructional design has not yet been developed, the "ADDIE model" has been recognized by most scholars. "ADDIE model" consists of five parts, namely, score, design, development, practice, and evaluation. Among them, "analysis" refers to the systematic analysis of students, teaching materials, learning conditions, and so on; "design" refers to the design of class hours and unit teaching objectives, selection of appropriate teaching methods and strategies, and reasonable planning of the teaching sequence; and "development" is to carry out the unit instructional design [25]. "Implementation" means implementing the unit teaching plan that has been designed. "Evaluation" refers to the evaluation of students' learning effects and teachers' reflection on their own teaching. The above five elements influence each other and connect with each other, and the specific relationship is shown in Figure 6.

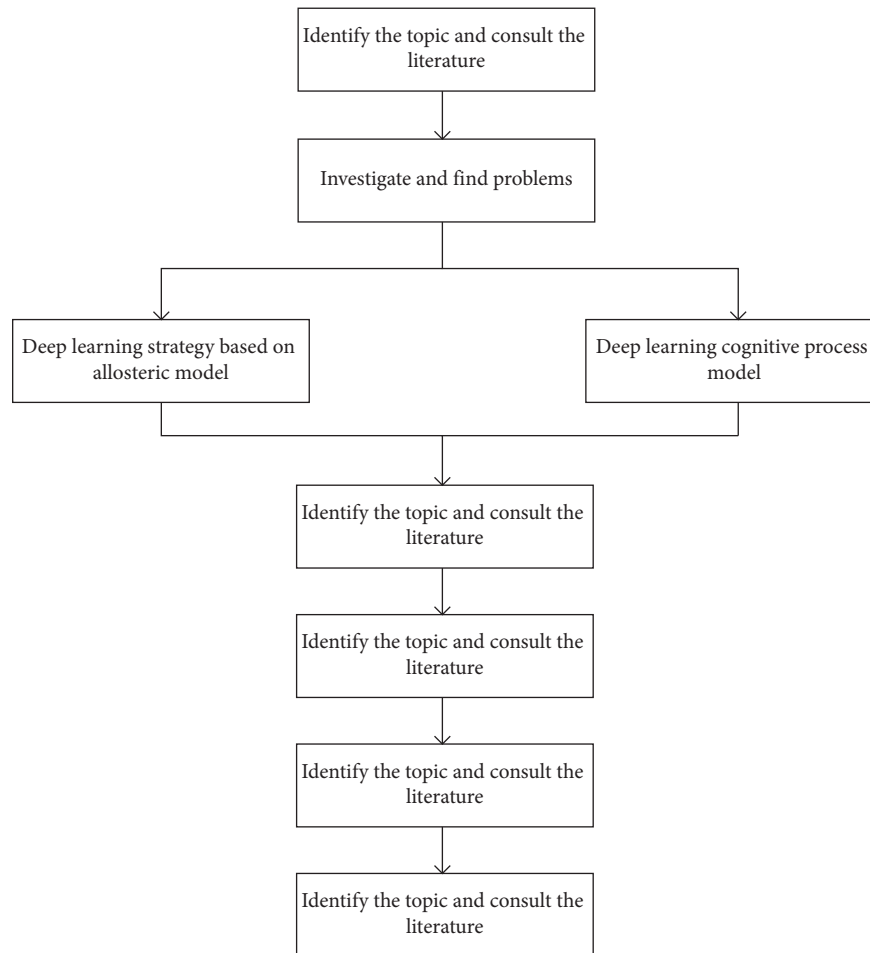


FIGURE 5: Flowchart of research ideas.

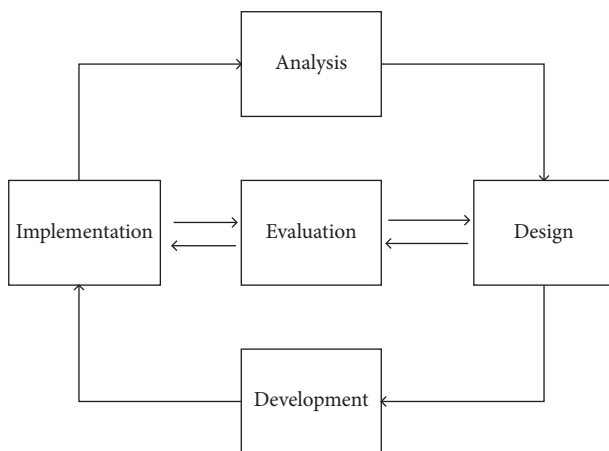


FIGURE 6: General schema of the ADDIE model.

3.3.3. Principles of Unit Instructional Design. In the teaching design of the international trade unit based on deep learning, teachers should pay attention to the following principles and apply them flexibly in order to better promote students' deep learning.

- (i) *Systematic Principle.* Each part of teaching design is not only relatively independent but also mutually restricting and interdependent. It is an organic system. Although their center is the optimization of the teaching effect, the roles of each part in the whole system are not the same. In addition, the classroom teaching design should be based on the whole, and each part should be coordinated and unified with the teaching system so as to realize the optimization of the whole teaching system.
- (ii) *Procedural Principle.* In teaching design, the former part constrains the latter part, and at the same time the latter part depends on and affects the former part, and the order cannot be reversed. For example, it is more scientific only after the analysis of learning situation and the analysis of teaching materials have been determined. For another example, after determining the major and difficult points, choosing appropriate teaching methods and guiding students to adopt appropriate learning methods will be more conducive to teachers' teaching and students' learning [26].
- (iii) *Diversity Principle.* When organizing unit teaching activities, teachers should select appropriate

teaching activities according to the teaching content, and all teaching activities should be conducive to deepening students' understanding of knowledge and experience. At the same time, we should pay attention to the diversity of activity forms and strive to use various forms of activities to achieve our goals.

- (iv) *Feasibility Principle*. In addition, the instructional design also needs to follow the feasibility principle. First of all, the purpose of teaching design is to better guide specific teaching practices, so teaching design must follow operability, and teachers need to carefully design feasible teaching activities. Secondly, the teaching design should comprehensively consider the subjective and objective conditions, in which the subjective conditions involve the level of teachers and the specific conditions of the students; the objective conditions should consider factors, such as regional differences and teaching equipment.

3.4. Construction of Instructional Design Process

3.4.1. Deep Learning Cognitive Process Model. Mu Yanjin and Duan Jinju proposed a deep learning cognitive process model based on Gagne's teaching theory [20] of nine sections and other related cognitive models, as shown in Figure 7.

This model is the basis of deep learning instructional design, and each process is explained below: the motivation stage is the process of stimulating students' learning motivation; the preparation stage is the stage of stimulating students' existing knowledge and establishing connections with new knowledge; the comprehension stage and the attention in cognitive psychology corresponds to selective perception. At this stage, learners are required to focus their attention on stimuli related to their own learning goals; the acquisition stage is the process of encoding information and storing it in short-term memory; maintaining the recall stage is the process of retrieving the information in the long-term memory. The learner usually solves well-structured problems in this stage; that is to say, the learner only needs to work on structural problems. Knowledge can be transferred and applied in a new context; the information stored in the creative phase is reconstructed for use in the process of solving ill-structured problems.

3.4.2. Integrated Instructional Design Process. By analyzing the deep learning teaching process based on the allosteric learning model and the cognitive process model of deep learning constructed above, it can be seen that the teaching processes of the two are mostly corresponding. The author believes that if the start-up strategy is used in the preparation stage to better link the old and new knowledge, a more complete and scientific deep learning integrated instructional design process will be constructed, and the "design" in the ADDIE model of unit instructional design will be improved. The specific teaching process design is shown in Figure 8.

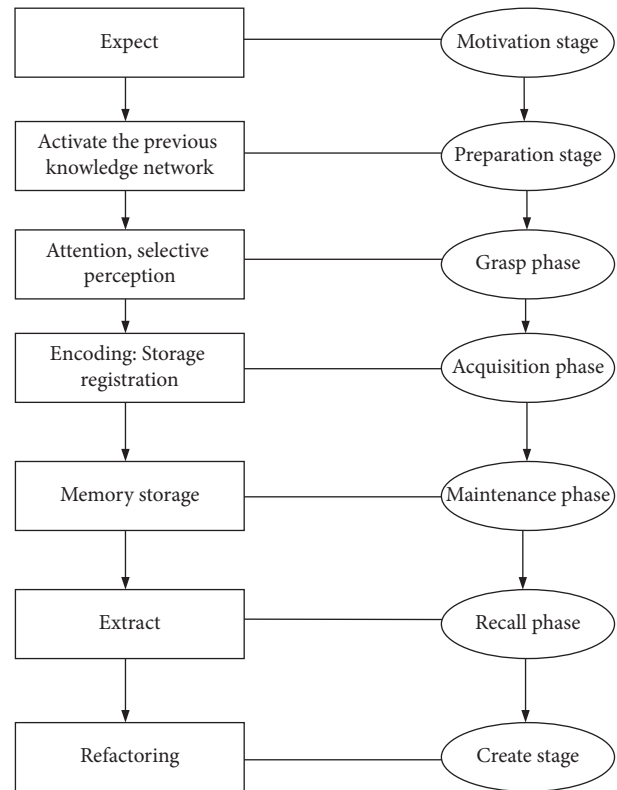


FIGURE 7: The cognitive process model of deep learning.

(1) *Stimulate the Engine and Improve the Learning Initiative*. Deep learning is a kind of active learning, which requires learners to actively participate, and learning motivation is the engine to stimulate and maintain students' learning activities. Therefore, stimulating students' learning motivation is the initial link. Only when students' motivation to learn is fully stimulated, students will be willing to participate in the learning process and learn actively.

(2) *Activate Old Knowledge and Establish Connections*. Deep learning is learning based on original knowledge. Therefore, with the help of the advance organizer prepared in advance, a certain connection can be established between the original old knowledge in students' minds and the new knowledge to be learned, which is conducive to students' understanding of new knowledge and construction.

(3) *Multiple Confrontations, Deconstructing the Original Concept*. Before students learn new knowledge, the knowledge that already exists in their minds may have a certain impact on the learning of new knowledge. This knowledge can be confronted between students and students, students and teachers, students and the original knowledge and experience, and students and new information so that students can discover the problem by themselves and then deconstruct the original concept, which is conducive to the follow-up knowledge learning.

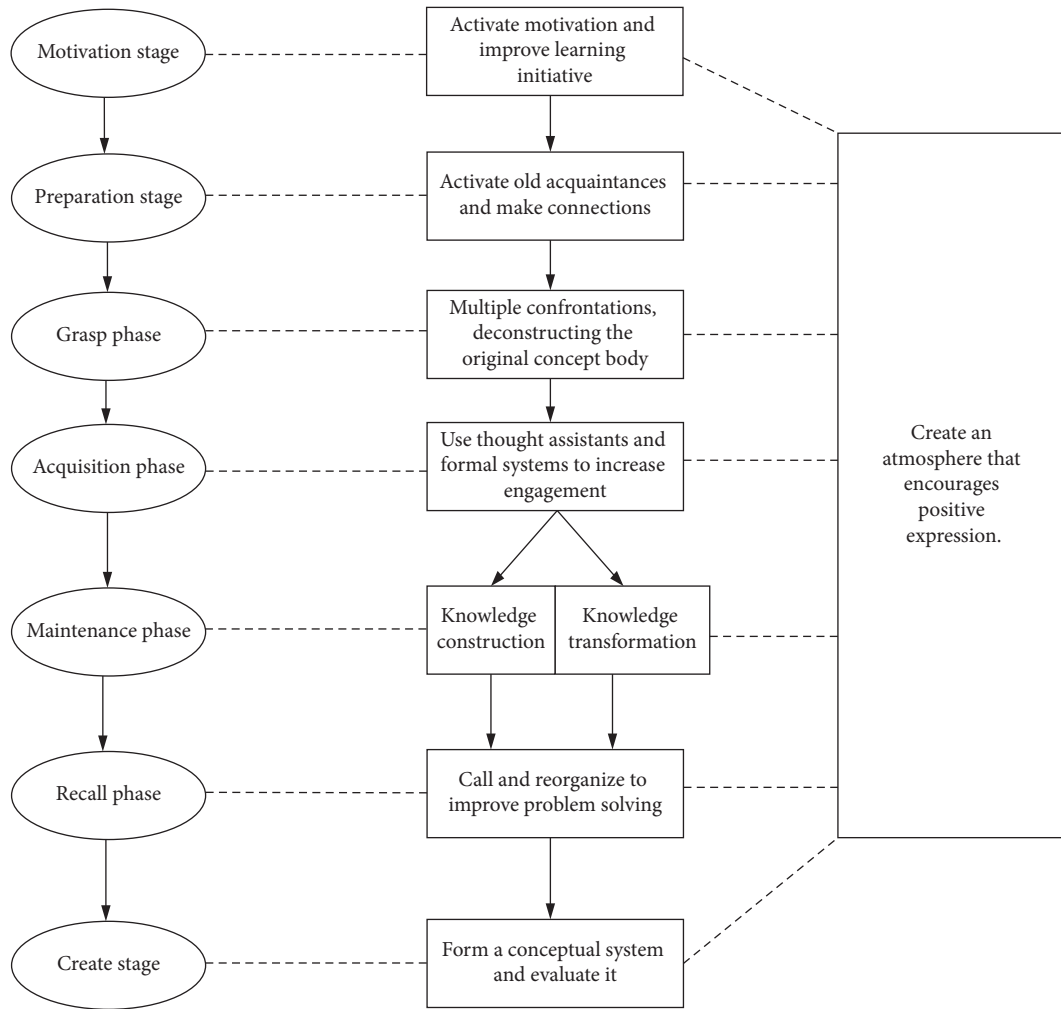


FIGURE 8: Deep learning teaching design process.

(4) *Use Mind Assistants and Formal Systems to Increase Engagement.* Different from the traditional teaching method, the integrated teaching process emphasizes the flexible use of various thinking assistants and formal systems, such as role-playing and model construction, which can improve the participation of students and better implement the students' dominant position. In the process of participating in various activities, students will also have a deeper understanding of knowledge, complete the construction and transformation of knowledge, and promote the occurrence of students' deep learning.

(5) *Call and Reorganize to Improve Problem-Solving Ability.* This process is mainly oriented to problem solving. For well-structured problems, students only need to call out the knowledge stored in their minds; while for some poorly structured problems, students need to create knowledge stored in their minds. Reorganization: whether it is a simple

transfer of knowledge or a higher level of creation, it is beneficial to improve students' ability to solve real situational problems.

(6) *Form a Conceptual System for Evaluation.* Fragmented and isolated knowledge is "inert knowledge," which is not integrated with the original knowledge but is simply accepted by the brain and therefore cannot be used. Students' learning should not be "fragmented" learning but should be systematic learning. In the teaching process, teachers should guide students to gradually form a conceptual system, and this process can also be used as a way to evaluate whether students' deep learning occurs.

In addition, teachers should ensure that the entire teaching process is carried out in an atmosphere full of trust. Only when students feel trust can they express their opinions boldly, which will help teachers understand students' thoughts and discover the students' learning process.

Existing problems: at the same time, in the process of expressing themselves boldly, the students also improved their various abilities, such as language expression.

4. Conclusion

The course design of the course project “International Trade Business Process” is very effective in the course implementation process. Through job-oriented course design based on job requirements, students have clear learning goals and effectively improve the effectiveness of teaching; through some case analysis and scenario simulation, students have a clearer career plan for this major and can better plan their own career; through intensive training such as practical training, students’ professional ability has been greatly improved, and has been well received by employers.

Data Availability

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

Conflicts of Interest

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

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Research Article

Talent Management Recommendation Technology Based on Deep Learning

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Nowadays, with the vigorous development of information management technology, talent management has become a hot field that scholars pay attention to. The flow of talent between companies has become increasingly frequent. A large number of cooperative behaviors have produced a large number of cooperative results and subsequently brought a large amount of data on what to do. A huge network of collaborators has also been quietly formed, and how to mine valuable information from it has become a research hotspot, among which talent recommendation is one of the most important topics. Talent recommendation, when an enterprise introduces high-quality talents, provides valuable reference suggestions and selects candidates. When introducing talents, enterprises should not only consider the ability level of talents but also consider the cooperative relationship between them and enterprise personnel. Therefore, it is necessary to analyze the network of partners to find out the rules. There are only author nodes in the isomorphic collaborator network, and the connection between nodes is the cooperative relationship. On this basis, this paper constructs a heterogeneous collaborator network; that is, there are multiple types of nodes and connections in the network. The main research problem of this paper is to find an indicator to measure the strength of association between scholars in the collaborator network and to recommend potential academic talents for enterprises. Based on the data of academic research cooperation network, we carried out sufficient experiments to demonstrate the effectiveness of the heterogeneous cooperation network model proposed in this paper.

1. Introduction

Talent management refers to the expectations of the human capital required by the organization and the plans to meet these anticipated needs [1–3]. Over the past decade or so, talent management has grown in importance for both the industry and academia [4–10]. Good talent management is about empowering employees with good skills, knowledge, cognitive abilities, and the potential to do a good job [11–18]. Talent management is also an important and necessary skill for employees themselves. Finding good and talented people is not difficult, but ensuring they are willing to continue serving the same organization is a challenge. Nowadays, with the deepening of cooperation and exchanges between enterprises, cross-enterprise cooperation and exchanges have also promoted the successful implementation of industry-university-research projects [19, 20]. A large number of

cooperative behaviors have produced a large number of cooperative results and subsequently brought a large amount of cooperation and exchange data [21–23]. A huge network of collaborators has also been quietly formed, and how to mine valuable information from it has become a research hotspot, among which talent recommendation is one of the most important topics. Talent recommendation, when an enterprise introduces high-quality talents, provides valuable reference suggestions and selects candidates. In addition to measuring the degree of conformity of the candidates' personal capabilities with the needs of the enterprise, the partnership between the candidates and the enterprise should also be considered. Therefore, it is necessary to analyze the network of partners to find out the rules [4–7]. There are only candidates' nodes in the homogeneous network, and the connection between the nodes is the cooperative relationship. On this basis, this paper constructs a

heterogeneous collaborator network; that is, there are multiple types of nodes and connections in the network. The main research problem of this paper is to find an indicator to measure the strength of association between scholars in the collaborator network and to recommend potential academic talents for enterprises. In summary, the main contributions of this paper are as follows:

- (1) Determine the edge weight of the homogeneous partner network by introducing the cooperation effect, propose a link-based talent recommendation model based on the homogeneous cooperation network, give the definition and calculation method of cooperation trust, and discuss cooperation under three constraints' relationship, and the recommended probability calculation methods are given, respectively.
- (2) Based on the heterogeneous collaborator network, the PathSim algorithm based on journal partition is proposed, and the experiment proves that the result of the algorithm is more in line with the actual situation. Considering the semantic information of meta-paths, this paper integrates two meta-paths to measure the similarity between candidates.
- (3) Adopt the authoritative ranking algorithm based on the dual-type network to calculate the authoritative value of candidates in the institution and propose a talent recommendation model based on the authoritative ranking of candidates. Experimental results show that our proposed model outperforms other baselines.

2. Related Work

The importance of scientific research cooperation has been mentioned above, and research on cooperation networks has also emerged. In foreign countries, Watts and Strogatz [8] proposed a small network-coupled dynamical system network for small social network analysis, which enhances the signal propagation speed, computing power, and synchronization in the network. Newman [9] proposed the social network structure of scientific research collaborators and constructed a cooperation network through the document archive to form a small world. Through the small world, scientists can show the path of short-term cooperation, analyze the cooperation between their research fields, and clear differences in patterns. Barabási et al. [10] proposed that, by synthesizing the evolution of scientists' cooperative complex network systems, the dynamics of topologies, and their evolutionary mechanisms through a synthesis of numerical and roles, recommendations or other services that are developed based on co-authors' networks are also beneficial for the study of other complex networks. Wagner and Leydesdorff [11] hypothesized that the collaboration of scientific researchers is a self-organizing network, applied network analysis tools to show that the growth of international collaborators is based on the organizing principle of limited attachment, and explored the impact of institutional constraints on the self-organizing mechanism. Yoshikane

et al. [12] analyzed the activities of scientific researchers from the perspective of the global network structure of scientists and collaborators and compared two kinds of importance of researchers in the network between computer science theory and application. Krichel and Bakkalbasi [13] used RePEc data to construct a high-quality author database and used these data to examine how different network structures affect economists' rankings through author centrality. Choil et al. [14] studied how co-authorship is initiated at the organizational and sectoral levels of international cooperation networks and showed that the university sector in rich English-speaking countries and the government sector in non-English-speaking nonrich countries are in the OECD that played a key role in international cooperation between countries. Whittington [15] studied the differences in scientific collaboration positioning and collaborator characteristics between men and women, as well as the impact of networks on scientists' future productivity, and found that some network benefits depend on gender. Rubin et al. [16] used a game-theoretic model to delve into the dynamics of discrimination and academic cooperation and found that, in cooperative networks, minority groups may end up being discriminated against when cooperating. Ribeiro et al. [17] investigated the extent of the development of international scientific research cooperation and the structure of cooperation, showing that international cooperation has been growing in a particular pattern, forming a disproportionate network. For heterogeneous information networks, Sun et al. [18] proposed the problem of co-authorship prediction in heterogeneous document networks, proposed a meta-path-based topological feature, and defined a metric method on the topological feature. After that, Sun et al. [19] proposed a similarity measurement algorithm based on meta-path and gave an optimization algorithm that uses pruning to reduce the time complexity. Krichel et al. [13] proposed a combination of classification and ranking algorithms to improve the performance of the classifier, which can make the ranking results more accurate.

3. The Proposed System

This section first introduces the definition of the collaborator network and uses the cooperation relationship matrix to describe the collaborator network; it analyzes and gives the definition of the importance of researchers in the collaborator network and proposes a method for screening high-level researchers based on this; secondly, based on the isomorphic collaborator network, the calculation method of the cooperation edge weight is given, and the similarity measurement method of the academic level of researchers and the cooperation intensity measurement method between universities are analyzed and given. Finally, the recommendation probability model is given for the three cooperation situations, respectively. The second half of this section is mainly based on the analysis of the heterogeneous collaborator network. First, the related concepts of the heterogeneous collaborator network are given, and the similarity algorithm based on the meta-path is introduced. On this basis, the similarity of the impact factors of journals

in different regions is proposed. Secondly, based on the semantics of different meta-paths, a more convincing and more realistic meta-path is given; then, a calculation method of authority value based on dual-type networks is proposed, and finally, talent recommendation is discussed and a talent recommendation model is given.

3.1. Analysis of the Importance of Partner Networks. In the collaborator network, the scholar node is the bridge of academic links. The higher the importance, the more it can promote the communication and development of the academic circle. There are many evaluation indicators for evaluating a scholar, such as the h -index, which is a method for evaluating the academic level of a scholar, which means that most h papers have been cited at least h times.

As shown in Figure 1, utilizing CiteSpace to display the original partner network, it can be seen that the nodes closer to the center are more active, and the nodes at the edge of the network are scattered and isolated. Before the experiment, it is necessary to remove the less important nodes in the network, which can not only reduce the time complexity of the subsequent experiments but also filter the nodes that do not meet the requirements in advance because, when making talent recommendation, it tends to recommend researchers with higher academic ability. The researchers at the edge and those close to the center have a big difference in academic ability and scientific research communication, and the possibility of being recommended is low. Only researchers with higher academic ability are recommended to be more versatile and more in line with the actual situation.

3.2. Betweenness Acceleration Algorithm. For the collaboration network, if the betweenness of the entire network is calculated according to the betweenness definition, the time complexity is high [24–31]. Brandes [20] proposed an accelerated algorithm for betweenness. The algorithm is based on breadth-first search. The principle of this algorithm is described below. For a given graph $G = (E, V)$, define pair-dependency; the formula is as follows:

$$\delta_{st}(v) = \frac{\delta_{st}(v)}{\delta_{st}}, \quad (1)$$

where δ_{st} is the number of shortest paths from node s to node t and $\delta_{st}(v)$ is the number of shortest paths from node s to node t passing through node v .

Then, the betweenness BC_v of node v is denoted as follows:

$$BC_v = \sum_{s \neq t \neq v} \delta_{st}(v). \quad (2)$$

For computing $\delta_{st}(v)$, we introduce predecessor node denoted as follows:

$$P_s(v) = \{u \in V: u, v \in E, d_G(s, v) = d_G(s, u) + w(u, v)\}. \quad (3)$$

Next, we utilize (4) to calculate $\delta_{st}(v)$ as follows:

$$\delta_{st}(v) = \begin{cases} \delta_{sv} \cdot \delta_{vt}, & d(s, v) + d(v, t) = d(s, t), \\ 0, & \text{other.} \end{cases} \quad (4)$$

3.3. Cooperation Strength Calculation Network Edge Weight.

In 2001, Newman proposed a side weight calculation algorithm based on cooperation frequency and cooperation intensity. This method distributes cooperation contributions equally based on the number of cooperators, and the cooperation intensity between authors is inversely proportional to the number of cooperators. The calculation method is that, in a paper with k number of collaborators, each researcher should evenly distribute the cooperation time to other $(k-1)$ collaborators. So, the cooperation between the collaborators in this paper is the intensity, which is $1/(k-1)$, and the cooperation strength between researchers i and j in paper m is as follows:

$$W_{ij}^m = \frac{1}{n_m - 1}, \quad (5)$$

where n_m is the number of collaboration scholars in the m th paper, so the cooperation strength is denoted as follows:

$$W_{ij} = \sum_k W_{ij}^k = \sum_k \frac{1}{n_k - 1}. \quad (6)$$

It is more reasonable to simulate the distribution of cooperation intensity based on the equal share of cooperation contribution. However, there also are shortcomings. In reality, the scientific research value of each paper is different. The scientific research level of the collaborators of the papers published in a journal is higher, the time cost of cooperating to complete the paper is greater, and the cooperation intensity between the collaborators should be greater. Therefore, this method only simulates the cooperation intensity under ideal conditions, and it still needs to be improved (Figure 2).

3.4. Authority Value Calculation. In a collaborator network, links between objects of different types affect their authoritative rankings under the same type. Drawing on the ideas of PageRank and HITS algorithms, this paper proposes an authoritative ranking algorithm based on dual-type networks. In the dual-type network of scholars and journals, there are two kinds of link relationships in the network: the connection between scholars and journals represents the journals that have included papers published by scholars (the weight of the link is the number of papers included in the journal) and the links between scholars and scholars represent the cooperative relationship (the number of academic collaborations). The authoritative value algorithm proposed in this paper is based on the scholar-journal dual-type network.



FIGURE 1: Original collaborator network.

Although the authoritative value of each scholar can be calculated through the journal-scholar network, because of the journal partition table of the Chinese Academy of Sciences, the first-region journals only account for the top 5% of all journals, which also leads to a relatively high number of papers included in the few first-region journals. In the above algorithm, if all journals are treated the same, the authoritative ranking of journals in lower divisions with more papers will become “inflated,” and it will also lead to scholars who publish more papers to obtain higher rankings, even if these papers were all published in lower-division journals. Therefore, this paper divides the journal-scholar network into the following four categories according to the journal division: the first-region journal-scholar network, the second-region journal-scholar network, the third-region journal-scholar network, and the fourth-region journal-scholar network. The normalized authority values in these four networks are $\text{Authority}_{Ak}^*(i)$, and weights are assigned to different authority values to obtain the final scholar authority value. Since the impact factors of journals in each division are almost the same, this can well avoid errors caused by the large difference in the number of papers included:

$$\text{Authority}_A^*(i) = \sum_{k=1}^4 \theta_k \text{Authority}_{Ak}^*(i). \quad (7)$$

3.5. Talent Recommendation Model. When introducing talents in a specific scientific research direction, the school first selects the researchers who meet the scientific research direction, obtains the recommendation list through the

heterogeneous recommendation algorithm, and finally uses the authoritative value as the weight to obtain the final talent recommendation list. This paper uses the normalized authority value to measure the influence of researcher i and takes it as the weight of each recommendation list. Next, we define the talent factor (TF) denoted as

$$TF_j = \sum_{i=1}^N \text{Authority}_A^*(i) p(i, j), \quad (8)$$

where N is the number of scientific research personnel in the school who meet the school’s introduction requirements. In a heterogeneous network, it is the similarity between the two. Finally, sort the TF values from high-to-low to generate a talent recommendation list. The higher the TF value is, the more the researcher meets the school’s introduction requirements.

This recommendation model is only suggestive. To take an extreme example, an off campus scholar A has cooperated with the scientific research “leaders” of our university for many times and published many important achievements, while another scholar B has also cooperated with several teachers of our university, but only published papers in four regional journals. Relatively speaking, scholar A has a higher academic level and has a close relationship with the scientific research personnel with high authority value in the school. According to the experience, scholar A should be more in line with the requirements of talent introduction. However, because scholar B cooperates with many researchers in the university and finally combines the weights of multiple researchers, the talent coefficient of scholar A is greater than

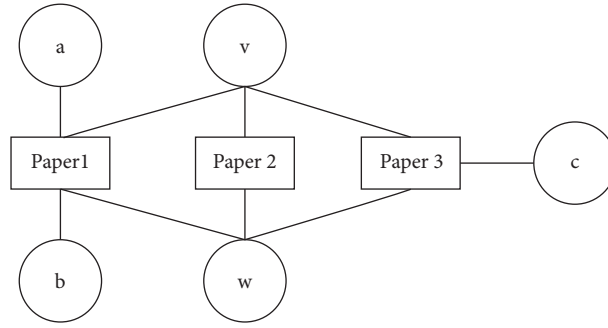


FIGURE 2: Example for collaboration network.

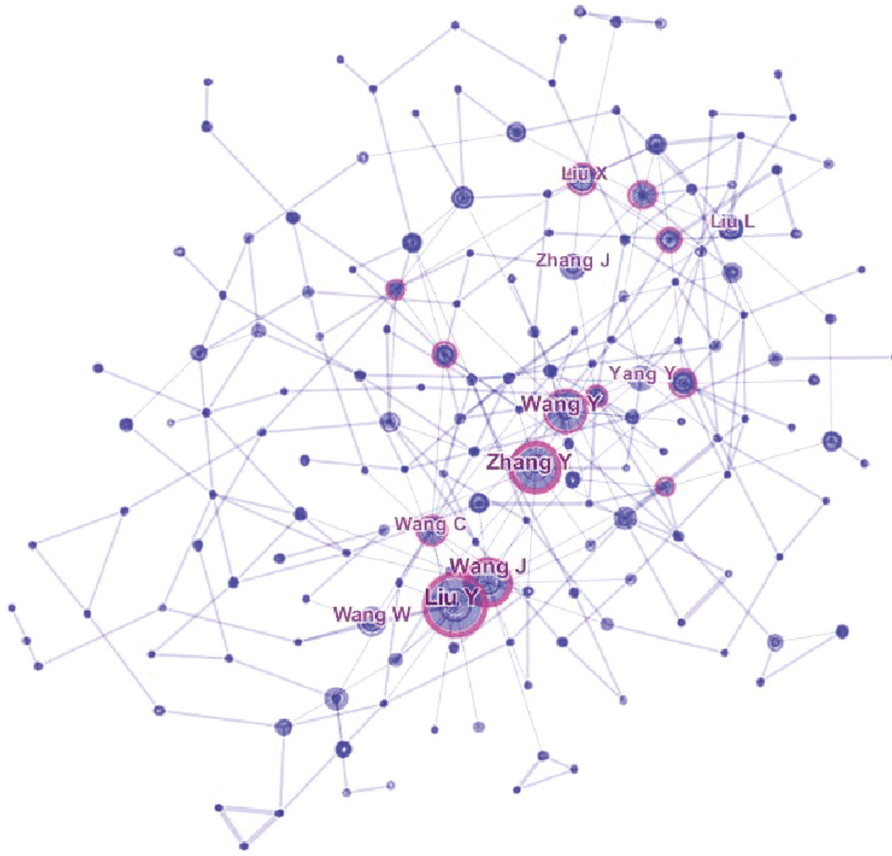


FIGURE 3: Example for the collaboration network without edge nodes.

that of scholar B. This is obviously unreasonable, so the talent recommendation model proposed in this paper is only for the talent recommendation mechanism. One way of thinking is that when introducing talents, schools can integrate a variety of selection methods or set certain thresholds to screen out unsuitable candidates in advance.

4. Empirical Study

4.1. Dataset Analysis. We have captured the SCI data of 985 colleges and universities from 2010 to present. The paper data cover 13 disciplines. In order to avoid the influence of the paper data of other disciplines on the results, we screened out the paper data of the computer discipline. The filter

conditions are computer science and artificial intelligence, computer hardware and structure, computer information system, computer application, software engineering, and a computer theory method; a total of 42723 SCI papers were screened.

Before the experiment, we removed the edge nodes by the betweenness of the nodes in the network. As shown in Figure 3, we used NetworkX to construct a simple visual construction of the collaborator network after the edge nodes were partially removed. It can be seen that the co-operation between college teachers tends to be within the school cooperate. We got 5012 researchers. We compared the author's name and abbreviation with the teacher information of the school and matched the teachers of the

TABLE 1: The comparison results of our proposed model and PathSim.

NDCG	PathSim	Our method
Top-10	0.4532	0.7175
Top-20	0.5154	0.6426
Top-30	0.4862	0.6544

school of computer science. It was found that except for the teachers of the school, the rest were doctoral students with a high volume of collaborative publications. The academic ability is strong. When the school introduces talents, the cooperative relationship between these doctoral students and off-campus researchers cannot be ignored. Strong links can also be used as the basis for talent recommendation and indicators and give the recommended results.

4.2. Experimental Results. This section adopts the NDCG [20] evaluation metric to evaluate the computational results of the two recommendation algorithms. NDCG is often used as a ranking evaluation index. The more coincident the sorting result is with the desired result, the higher the NDCG value. Its value is between 0 and 1. IDCG is the ideal DCG value, that is, the maximum DCG value obtained in descending order of correlation. NDCG normalizes the DCG value in this way.

In this experiment, the PathSim algorithm is selected as the benchmark, and the top-10, top-20, and top-30 lists of the experimental results under the network recommendation algorithm and the NDCG value of the marked ranking are calculated, respectively, so as to evaluate the recommendation quality of the two algorithms. The experimental results are shown in Table 1. It can be seen from the experimental results that, in three cases, the recommendation quality of the network recommendation algorithm is better than that of the PathSim algorithm. This is because the PathSim algorithm ignores the influence factors of nodes in the meta-path, and the results contain a lot of scientific research level. Lower researchers, so the results are quite different from the marked rankings. In the heterogeneous network recommendation algorithm, the PathSim algorithm based on impact factor is used, which considers the importance of nodes in the meta-path and is more in line with the reality, so the results of the algorithm are significantly better than the traditional PathSim algorithm. Under top-20 and top-30, the recommendation quality of the network algorithm decreases. The main reason is that the recommendation list of the algorithm recommends more indirect/link collaborators in these two ranges, these collaborators, and the university's researchers. The number of papers published in the same journal is small, so the recommendation results are not ideal.

5. Conclusion

In the face of the increasingly complex talent market, both enterprises and colleges and universities have continuously strengthened the needs of college management. Based on this background, this paper starts from the perspective of

academic talent recommendation and builds a recommendation model based on the paper cooperation network. Firstly, the importance of nodes in the collaborator network is discussed, the betweenness acceleration algorithm is selected to calculate the importance of nodes in the network, and the original collaborator network is filtered according to the node betweenness, and cooperation with a relatively high academic level is obtained. After that, the edge weight of the partner network is discussed, and the edge weight calculation method that introduces the cooperation effect is used. Then, the characteristics of the cooperation relationship under the homogeneous partner network are analyzed, and probability models are recommended, respectively. Then, a heterogeneous network of partners is proposed. A similarity measurement algorithm, based on journal impact factor, discusses and selects three more convincing meta-paths to comprehensively consider the similarity between researchers. Finally, an authoritative value calculation method based on a heterogeneous network is proposed. Based on the authoritative value of scholars, the final talent recommendation list is constructed. Future research can be extended from the academic talent market to the more general university employment talent market. At the same time, the effective mechanism in talent recommendation is found by exploring the internal mechanism of the cooperation network.

Data Availability

The dataset can be obtained from the author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Design and Application of Yoga Intelligent Teaching Platform Based on Internet of Things

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With the rapid development of economy, science, and technology, people's pursuit of quality of life continues to improve, leisure sports have gradually become a trend, and yoga, as a traditional and fashionable way of fitness, is favored by more and more people. However, the traditional training class yoga teaching time is fixed, which will have many inconveniences for professionals. However, learning according to the teaching video cannot guarantee the accuracy of the movement and may not achieve the training effect. Therefore, in this situation, intelligent e-yoga teaching is of great significance to improve the training level. This system is based on Internet of things technology, selects Kinect as the sensing carrier of human motion information, and designs an electronic yoga teaching system. The system integrates the functions of motion information acquisition and motion evaluation. First, standard yoga movements are collected through Kinect as a comparison template for yoga training. Second, the system collects the trainers' action data, uses Hausdorff distance algorithm to evaluate the similarity of action flow, and identifies the action name based on the threshold. Third, through the motion evaluation algorithm based on joint point angle measurement, it points out the joint points whose actions are not in place. Based on the completion time of the action, the action speed is evaluated. Finally, the system outputs the evaluation results in the form of text and voice through text conversion technology. The system can carry out efficient posture recognition and can achieve the purpose of evaluating the training quality and giving guiding suggestions. It can meet the basic training needs of users and has great application value.

1. Introduction

At present, the world is in a period of rapid economic development. When people enjoy the convenience brought by social development, they are also under increasing pressure. In the highly competitive labor market, people put a lot of time and energy into their work. The high-intensity work makes many professionals have no time to exercise, which also leads to the continuous decline of their physical quality. Professionals are in a subhealth state, with a surge of people suffering from headache, insomnia, endocrine disorders, depression, and other diseases. At the same time, the harm caused by subhealth problems cannot be ignored. As we all know, physical exercise can effectively relieve and release pressure and has a positive role in promoting

physical and mental health. Among many fitness methods, yoga, as a fashionable exercise method that is both healthy and healthy, is gradually favored by many professionals and school students. Yoga is a combination of body posture and psychological awareness to achieve the purpose of self-cultivation. Unlike physical exercise, yoga is mainly used to strengthen the body. The investigation of yoga practitioners for many years shows that yoga exercise can make the mental state of practitioners become peaceful, alleviate the anxiety caused by work competition, and reduce the frustration in life. It is of great significance to adjust the psychological state and physiological balance. At the same time, yoga has the power of curing diseases; long-term practice of yoga can prevent chronic diseases such as hypertension, varicose veins, and arteriosclerosis and can enhance human

immunity. The medical profession has confirmed that yoga can effectively regulate the endocrine system and nervous system of the human body, thus helping to promote the physical and mental health of the human body.

In contemporary society, people tend to participate in yoga training institutions as the main way of learning. Although this is an effective way, the learning environment and learning progress are generally controlled by teachers, and the time is fixed, so it brings a lot of inconvenience [1]. At the same time, there are few professional formal yoga education institutions. Many so-called professional yoga coaches can obtain the qualification certificate after short-term training in some training institutions. It is difficult to guarantee the professionalism of these yoga coaches. Many people also choose to download teaching videos from the resource-rich network to learn by themselves. Although this approach is convenient and easy to operate, it cannot guarantee the accuracy of action and achieve the expected effect without guidance. Second, improper yoga practice will cause great damage to people's body. According to the statistics of sports injury cases in the hospital, the proportion of lumbar disc protrusion and spinal joint dislocation caused by improper exercise has increased significantly, and in these cases, the injury caused by yoga practice accounts for a large proportion. Therefore, blind practice without professional guidance will not only fail to achieve the effect of fitness but will bring damage and disease to the body in all aspects.

The significance of this research is to apply Kinect to yoga teaching in combination with Internet of things technology. As a new computer software development carrier, Kinect not only has a high-resolution camera but also can collect user action information in real time and support voice input. This system uses this device to capture the action data flow of students and professionals. After matching and comparison, the system can give the matching degree of user actions and standard actions in real time and remind users to make targeted improvements. This computer-aided instruction system can make yoga lovers who have a strong demand for self-study adjustment in time according to the system prompts to ensure the accuracy of their movements. At the same time, this teaching platform is cheap and universally applicable, which solves the problems of time and space in yoga learning.

This study uses the mainstream Internet of things technology to design a yoga teaching system based on Kinect, which mainly includes the following research contents: building an electronic yoga teaching system based on Kinect. The system can automatically capture the yoga movements of trainers and can use Hausdorff algorithm to give the similarity of movements by comparing them with the standard movements in the template database. Motion evaluation is based on joint point angle. By measuring the angle between skeletons in real time and comparing it with the angle between skeletons of template action, we can more intuitively see the unqualified joint points.

2. Related Work

2.1. Human-Computer Interaction. Human-computer interaction (HCI) is a science used to study the interaction between computer systems and users. It has a close relationship with artificial intelligence, virtual reality, ergonomics, and other technical fields [2–7]. The design of human-computer interaction system is required to be simple and easy to operate with intuitive visualization function. Now, human-computer interaction technology has been one of the key research contents in the computer field, and it is also the focus of competition in the field of science and technology.

As an important part of the computer field, human-computer interaction technology has developed from the initial human to adapt to the computer to the current computer to adapt to people. This process has gone through more than half a century and has also reaped great progress and achievements. Natural, efficient, and ubiquitous human-computer interaction technology is the intersection of research directions in many fields, such as intelligent science and technology, computer, mathematics, psychology, and even physiology [8–13]. It is one of the focuses of computer research at present and in the future, and it is also the development trend of information field in the future.

The human-computer interaction mainly goes through the following five stages: (1) *Manual Operation Stage*. The characteristic of the embryonic period of human-computer interaction is that the computer designers debug and use very clumsy large-scale computers through manual manipulation and binary code. (2) *Language Command Interaction Phase*. At this stage, programmers began to use interactive command language to manipulate the operation of the computer. There are many commands to remember at this stage. At that time, compared with the manual operation stage, the operation of the debugging program has been greatly simplified. (3) *Graphical User Interface (GUI) Phase*. The main features of GUI are desktop metaphor, windows, icons, menus, pointing devices, and other technologies such as direct manipulation and “WYSIWYG.” At this stage, the interface design is very simple, so even users who do not know much about the computer can operate skillfully according to the graphical instructions. At this stage, information technology has made unprecedented development. (4) *Network User Interface Phase*. This stage is represented by web browsers based on Hypertext Markup Language (HTML) and Hypertext Transfer Protocol (HTTP). At this stage, emerging technologies such as search engine, animation, and chat tools began to emerge. (5) *Multichannel Intelligent Human-Computer Interaction Stage*. The main achievements of this stage are the personification of computer system and the miniaturization of computer, for example, virtual reality technology, smartphones, and laptops. Multichannel interaction allows imprecise input, such as using human language, gestures, and actions to interact with the computer, which breaks away from the shackles of traditional human-computer interaction and makes human-computer interaction efficient and natural. The multichannel interaction technology has

developed rapidly in recent years. It not only meets the “people-centered” interaction criteria but also promotes the development of the information industry. The channels in multichannel interaction mainly include user action, expression intention, and perceptual information feedback, such as language, expression, human posture, smell, touch, and taste. At present, this technology has been successfully used in speech recognition, gesture recognition, pen interaction, digital ink, and so on.

With the development of human-computer interaction, the mode of human-computer interaction is constantly updated from the initial keyboard and mouse to touch technology, the emerging somatosensory devices, and virtual reality technology in recent years. The mode of human-computer interaction is more and more close to people’s ideas. The development trend of human-computer interaction is as follows: (1) *The Operation is More Free*. It gets rid of the shackles of contact equipment, and the input and output methods are gradually dominated by voice, camera, and projection contactless input equipment, and human-computer interaction can be realized in any scene, which is no longer limited to indoor. (2) *More Intelligent Interaction*. The traditional human-computer interaction system requires users to transfer interaction information through contact sensors. Now, human-computer interaction can be realized through gesture recognition, speech recognition, and other technologies, realizing the naturalness of human-computer interaction. (3) *The Operation is More Humanized*. The traditional human-computer interaction technology requires people to adapt to the computer, while the current human-computer interaction technology is based on people’s ideas, making full use of people’s actions, language, and vision, and combining the characteristics of the computer to achieve a natural, efficient, and multichannel human-computer interaction.

At present, with the advent of Microsoft Kinect, somatosensory interaction technology has become one of the most popular research directions in the field of human-computer interaction. Kinect gets rid of the traditional handheld remote control. It can achieve the purpose of human-computer interaction by capturing the user’s actions, facial expressions, and voice sequences in real time. The emergence of Kinect has played an important role in promoting the development of contactless human-computer interaction. The research on its application in the field of human-computer interaction is also one of the key research topics in the future. To sum up, the development direction of human-computer interaction technology is to focus on natural and contactless interaction and realize real-time and natural interaction through user’s actions, expressions, languages, etc.

2.2. Research Status of Posture Recognition. Human posture recognition is accomplished by many technical fields such as machine learning, sensor technology, artificial intelligence, and computer vision. According to the different ways of obtaining human posture information, the human posture

recognition system is divided into wearable sensor-based and vision-based recognition systems.

Pose recognition system based on wearable sensors generally refers to embedding microsensors in some carry-on items or close-fitting clothes. This type of sensor can collect human motion data in real time, and the system can analyze and process the motion data in real time. The data can also be sent to the host through wireless network transmission, and the host can set a specific algorithm to analyze the motion data and identify the human posture. There are two kinds of embedded sensors: three-axis gyroscope and acceleration sensor. The gyroscope can detect the angular motion state. This kind of sensor mainly relies on the precession and axial orientation of gyroscope to measure the pose angle formed during human motion. Tapia and Haskell [14] proposed a method for real-time automatic recognition of human posture using wireless acceleration sensors and wireless heart rate monitors. The implementation process of this method is to fix the wireless acceleration sensor at the joints of limbs and hips respectively and then obtain the standard deviation, FFT kurtosis, and other features as processing signals. The collected actions are divided into three groups by dynamic Bayesian classification method, and the recognition rate of the three groups is 94.6%. Zhang et al. [15] used wearable acceleration sensors to capture human motion data and carried out fall detection based on support vector machine algorithm. After testing, the success rate of fall detection reached 96.7%. Bourke and Lyons [16] proposed a fall detection algorithm based on the threshold value of the dual-axis gyroscope sensor. The gyroscope sensor is installed on the experimenter’s body to measure the angular velocity information during the action. After many times of experimental data statistics, the threshold value for distinguishing falls from other daily activities is obtained. The success rate of judging falls based on the threshold value is as high as 100%. The working principle of wearable sensor is to capture the data of human motion with the help of sensors placed at the joints of human body and process the data through analysis. The change rules of human body data in different postures are summarized, and then a specific algorithm is used to achieve the purpose of pose recognition. Although this kind of posture recognition system has high data analysis and recognition ability, this kind of contact sensor can only be placed on the body to collect human motion parameters, which brings great inconvenience to people. Compared with the contact pose recognition system based on wearable sensors, it is obvious that the noncontact recognition system has more universal applicability. This kind of recognition system is mainly based on computer vision technology to obtain human motion information from video sequences for pose recognition. Computer vision technology is actually the simulation of human visual function. With the rapid development of this technology, vision-based pose recognition will become the mainstream direction. The researchers use the pose recognition method of hidden Markov model. First, the cascaded hidden Markov model is used to model the human motion. Its special feature is that the expectation maximization algorithm is used to ensure the reliability and accuracy of the

model. At the same time, the Rao blackwellised particle filter approximate reasoning algorithm with high computational efficiency is also used to analyze human motion, which can effectively recognize human posture. By using the method of inductive reasoning, Granum and Moeslund [17] summarized human motion recognition into four processes: system initialization, bone tracking, pose estimation, and pose recognition. Moselund et al. summarized the research progress of recognition technology based on computer vision based on the four processes of pose recognition.

As the most representative product in the field of computer vision, Kinect has made outstanding contributions to the field of computer vision. In particular, Kinect's function of acquiring 3D depth images of human body in real time makes it a popular direction for researchers to analyze human posture based on depth information. At the same time, the advent of Kinect has also promoted the development of human posture recognition technology. Its accuracy and real-time performance are beyond the traditional recognition methods. At present, researchers have begun to apply Kinect to the research of gesture and human posture recognition.

2.2.1. Gesture Recognition. Kinect is used to obtain the depth image information of the hand, and the depth vector segmentation technology is used to detect the fingertip and palm center. The sign language recognition of deaf mutes based on Kinect was proposed [18]. The human hand movement information was obtained through Kinect and analyzed and compared with the movement data in the standard library, and the recognition results were displayed in the evaluation interface. In the research of hand gesture recognition based on depth image information, the region of hand gesture is extracted from the depth image by using the difference of gray value, and the classification decision tree is established by combining the contour characteristics to realize hand gesture recognition.

2.2.2. Gesture Recognition. A vision-based tracking system [19], which obtains the patient's lower limb movement information by installing Kinect on the wheelchair, analyzes the patient's condition by using the obtained movement data and customizes the training plan for the patient. Shotton et al. obtained the depth image information of the human body through Kinect [20, 21], classified various parts of the human body using the random forest algorithm, and then calculated various joint points of the human body. Schwarz et al. [22] used Kinect to obtain the depth data of human motion for pose estimation and used geodesic distance and depth data of optical flow to track each joint point of human body. In recent years, Kinect has also been widely used in the field of medical rehabilitation to assist patients with limb disorders in rehabilitation training. Da Gama et al. [23] developed a natural interaction system based on Kinect for sports rehabilitation training, developed a scoring mechanism to measure patient performance, set different training parameters for different patients, and prevented patients from secondary injury during rehabilitation training.

Bonnechère [24] developed different game systems based on Kinect to assist patients in rehabilitation training and improve their enthusiasm for training. Experiments show that the Kinect-based rehabilitation training system can not only reduce patients' negative emotions during training but also exercise patients' psychological quality.

At present, there is relatively little research on Kinect in yoga teaching. Only reference [25] evaluated the accuracy of dance movements based on Kinect's bone gap tracking technology. From the above analysis, it can be seen that Kinect can be used not only for local research such as human part recognition and gesture recognition but also for overall research such as human posture recognition. In terms of research methods, different recognition tasks are based on different data types. Gesture recognition mainly relies on depth image data to segment human hand parts from the depth image obtained by Kinect and recognize gesture names. Gesture recognition is more inclined to use the human bone node data provided by Kinect for comparison and analysis with template data.

3. Action Flow Evaluation Algorithm

In order to analyze and evaluate the action of trainers when the system is offline, the system needs to be able to record the coordinate information of bone nodes captured by Kinect in real time. Kinect, a somatosensory device, can capture up to 30 frames of data per second. Assuming that the time of an action is 3 seconds, the system will record up to 90 frames of data, and each frame is a collection of three-dimensional coordinate values of 25 joint points. Taking the 90-frame 3D coordinate point set thus formed as a set of sample data, after matching it with the actions in the standard library, the distance between the two sets of point sets can be calculated. The size of this distance is used as the evaluation standard of training. In this study, the Hausdorff distance measurement algorithm is used to evaluate the matching between the sample data point set and the template data point set.

3.1. Data Preprocessing. The yoga teaching system designed in this study mainly realizes the function of collecting and evaluating the exercise information of trainers. After experimental tests, Kinect will capture some data information with little correlation, namely, interference points, at the beginning of each motion capture, which will reduce the accuracy of the evaluation results. Therefore, it is necessary to regularize the training data before evaluation and intercept the middle data segment of the action data stream as a new action point set to participate in the final matching process. In addition, after the motion capture starts, the captured data points are continuous.

The motion comparison of this system is based on the three-dimensional coordinate information of 25 joint points of the human skeleton model obtained in the process of motion capture. However, differences in body shape or distance from Kinect among different practitioners will lead to great differences in bone data information obtained each time. Therefore, the data obtained in the process of motion

capture cannot be directly used for motion matching, and the obtained bone data model must be normalized first.

3.2. Hausdorff Distance Algorithm. Hausdorff distance is a similarity measure of two given data point sets. This algorithm does not need to establish point-to-point correspondence. It only needs to calculate the maximum distance between two point sets, which can effectively deal with the matching problem between point sets with more feature points.

The traditional mathematical description of Hausdorff distance is as follows: two point sets a and B are given. Then, the Hausdorff distance between a and B is calculated as follows:

$$\begin{cases} H(A, B) = \max(h(A, B), h(B, A)), \\ h(A, B) = \max_{a_i \in A} \left(\min_{b_j \in B} \|a_i - b_j\| \right), \\ h(B, A) = \max_{b_j \in B} \left(\min_{a_i \in A} \|b_j - a_i\| \right). \end{cases} \quad (1)$$

In the formula $\|\cdot\|$ represents the distance norm. The calculation process of $H(a, b)$ is to calculate the minimum distance from each point a in point set a to point set B and sort all the minimum distances obtained. The maximum value in the sequence represents the one-way Hausdorff distance from point set a to B . Similarly, the one-way Hausdorff distance $h(B, a)$ from point set B to point set a can be obtained. The bidirectional Hausdorff distance $h(a, b)$ is the larger of $H(a, b)$ and $H(B, a)$; that is, it represents the distance between two sets. According to the size of $H(a, b)$, the matching degree of two-point sets can be determined. The smaller the Hausdorff distance of two-point sets, the higher the similarity between the two sets of point sets. Therefore, this algorithm can be used to measure the similarity between the template action and the trainer action.

Although the traditional Hausdorff distance algorithm simplifies the process of calculating the matching degree between point sets, the motion matching problem involved in this system is based on the three-dimensional coordinate points captured by Kinect. It is inevitable that frame skipping occurs in the process of motion data acquisition by body sensors, and the collected point sets may be mixed with noise points. If the traditional Hausdorff distance algorithm is used, it may cause large errors, so the improved Hausdorff distance algorithm is explored and verified in this design.

Mean Hausdorff distance (MHD) can further improve the matching accuracy. Similar to the traditional Hausdorff distance and partial Hausdorff distance calculation methods, the mean Hausdorff distance will still calculate the larger one-way Hausdorff distance between two point sets as the final Hausdorff distance, but the calculation form of one-way Hausdorff distance will be different:

$$\begin{cases} H_{\text{MHD}}(A, B) = \max(h_{\text{MHD}}(A, B), h_{\text{MHD}}(B, A)), \\ h_{\text{MHD}}(A, B) = -\frac{1}{N_A} \sum_{a \in A} -\min_{b \in B} \|a - b\|, \\ h_{\text{MHD}}(B, A) = -\frac{1}{N_B} \sum_{b \in B} -\min_{a \in A} \|b - a\|. \end{cases} \quad (2)$$

To sum up, the one-way Hausdorff distance between two point sets is calculated by the average distance from all points in one point set to another point set. This calculation form fully considers the negative impact of interference points, makes all feature points in the set participate in the calculation of the final result, has a certain average effect, and ensures the anti-interference performance of the system. The mean Hausdorff distance algorithm solves the problem of mixing noise points in the process of action acquisition to some extent. Therefore, this algorithm is selected as one of the algorithms to evaluate the matching degree between the template point set and the training point set in this design.

4. Intelligent Yoga Teaching System Based on Internet of Things

The designed yoga teaching system aims to provide a simple, easy to operate, and reliable family teaching service without time and space constraints for the majority of yoga lovers. The system can make an objective evaluation of the training effect, give users more intuitive guidance in the form of voice, and make it more suitable for the training process in the natural environment.

4.1. System Design Principles

4.1.1. Reliability. As the system is a real-time human-computer interaction system, it is the primary condition to maintain stable and reliable operation. Reliability here mainly includes two meanings: first, the system can identify the user's posture as accurately as possible and give a timely and correct response. Because when different users complete the same action, there will be differences in duration and action amplitude. Moreover, even if the same user performs the same action in different time periods, the action data flow is different. Therefore, a good recognition system can recognize the correct name of the action when the difference between the duration and the action amplitude is small. Second, the system can correctly understand the user's intention as much as possible and avoid identifying some unconscious operations of the user.

4.1.2. Ease of Use. The teaching system designed in this study is for yoga practitioners in various fields and ages. Therefore, the teaching platform should have a simple and easy-to-use interface and conform to the operating habits of general users, so that users can adapt independently. At the same time, each action in the template library should be well distinguished from other actions to reduce the false

recognition rate, and the platform has an action evaluation module so that users can timely understand their own training.

4.1.3. Scalability. When designing an interactive system, it is necessary to consider the subsequent scalability of the system, so as to expand the template library and provide more complex functions to cope with changes in requirements.

4.2. Overall System Architecture. The hardware of the system is composed of a Kinect and a windows8.1 computer. Kinect connects to the computer through USB3.0. Kinect is responsible for collecting human motion data stream, and then the computer is responsible for data analysis and processing. The software of this system is developed based on MFC architecture under the integrated development environment of visual studio 2013. The system uses kinect2.0 sensor to monitor the surrounding h environment and converts the collected depth image into bone data. After the PC control end starts to work, it receives the bone data transmitted by kinect2.0 sensor through USB3.0 by means of “pulling” and draws it to the picture control of the dialog interface based on MFC architecture through the two-dimensional graphic API-direct2d for display. The system first normalizes the collected s -dimensional bone data of coaches and students’ actions and then compares and analyzes them using the Hausdorff algorithm to obtain the similarity of the two groups of action sequences. At the same time, the system will calculate the angle of some joint points in real time. According to the similarity and the angle difference of joint points, students can further improve their actions. The overall scheme design of the system is shown in Figure 1.

4.3. System Function. The designed system contains several functions, as listed in Table 1.

4.3.1. Software Interface Design. This article uses SQL server 2013 database engine to store the login information of management trainers. Trainers need to create new personal information when using the system for the first time. During registration, the user name and password entered by the user are written into the created database table through ADO function. When the user logs in, the sales interest entered by the user is compared with the information in the database table. If there is no error, the user logs in successfully and enters the module selection interface.

The module selection interface of the system includes the basic classification of yoga postures, as well as the operations of entering the system, exiting, and logging in. Because there are many yoga postures, yoga can be further divided into standing posture, sitting posture, kneeling posture, lying posture, and hand support according to different postures. When users train, they only need to select the category according to the training posture, enter the system, and only compare it with the posture library. After classification, they can improve the overall recognition rate and work efficiency

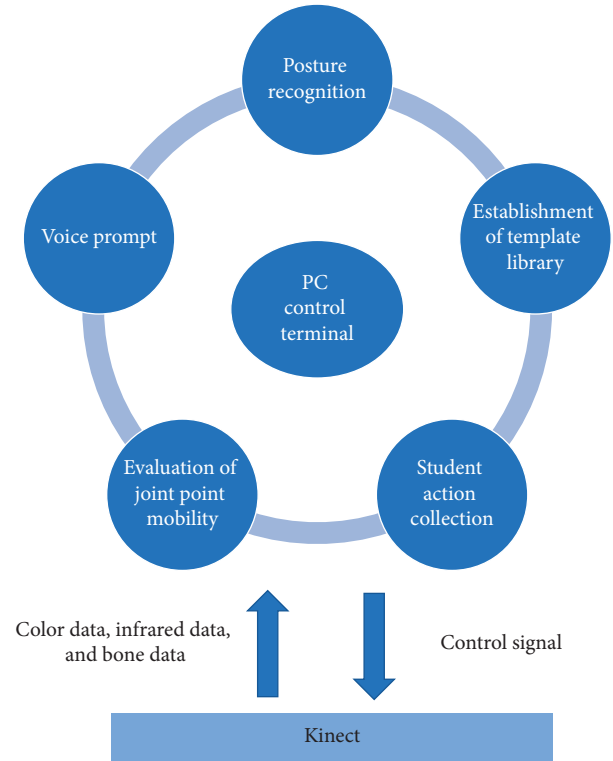


FIGURE 1: The overall project design.

TABLE 1: The designed system contains several functions.

function
Software interface design
Data acquisition module
λ Module library creation module
λ Direct2d drawing module
λ Action recognition module
λ Voice prompt module

of the T system and reduce the pressure of system action analysis. Users need to click to enter the system, and the main interface window will pop up. The main interface is realized by MFC nonmodal dialog box, which controls the startup of the system and realizes the function of human-computer interaction. In the test interface, the largest control displays the human bone image detected by Kinect.

4.3.2. Data Acquisition Module. The system obtains bone data, color data, and depth data through the relevant APIs in the Kinect SDK. Their acquisition is encapsulated into classes for the convenience of calling. All data acquisition is completed by the same Kinect. During encapsulation, the Kinect sensor class will provide some interfaces to manage the acquisition of three types of Kinect data and the switch of the FT body, because if a class object releases resources when the dump is over, the use of other classes will be invalid.

4.3.3. Module Library Creation Module. In order to evaluate the standard degree of user actions, the system must

establish a library containing standard actions as an evaluation template. The design standard library is established by inviting professional yoga instructors to demonstrate yoga movements, using Kinect to collect yoga movement data, saving the data in txt files, and naming them with the corresponding action names, so as to facilitate comparison and call.

4.3.4. Direct2d Drawing Module. The system draws the joint point information collected by Kinect into the picture control through the two-dimensional graphics API-direct2d. Because Kinect collects h-dimensional coordinate information, it needs to use a coordinate mapper to convert 3D coordinates into 2D coordinates. Direct2d enriches the visual effect of Windows applications and enables 2D graphics to be presented with high quality and performance.

When using direct2d to draw bone data into the dialog box, the first task is to create an id2dlfactory interface object. The interface is the root object of direct2d and the root of all other resources. After the interface is successfully created, direct2d resources can be created. Basically, all D2D resources are created by the id2dlfactory interface. Second, the system needs a render site rendertarget. Here, id2dlhwnrendertarget is created and then used to create renderer targets and perform rendering operations.

4.3.5. Action Recognition Module. Motion recognition first extracts the bone data stream of the trainer's action through Kinect and then calculates the matching distance between the trainer's action sequence and the action sequence in the standard library. The distance value is saved in the array until the matching distance with all actions in the standard library is calculated, and then all matching distances are compared with the preset threshold. Therefore, in the process of matching two groups of action sequences, there must be a strict threshold as the evaluation standard. For the setting of this threshold, we collect multiple groups of instructor actions as templates and then collect the actions of multiple professional yoga personnel as templates to be identified. They are compared with the standard template to obtain multiple groups of matching distances and averaged as the threshold. The threshold value obtained from the statistics of multiple groups of experiments takes into account the behavioral differences between different people. The threshold value of each action is different and needs to be set by multiple groups of experiments. According to the experimental verification, the set threshold can make the system get a better recognition rate and better recognition speed.

4.3.6. Voice Prompt Module. In the yoga teaching system designed in this study, the purpose of the voice module is to more intuitively transmit the evaluation results to users, that is, to output the test results in the form of text in the form of voice. This technology mainly solves the problem of converting text information to voice information and makes the machine speak. The language function of the system is

realized by installing the Microsoft Speech SDK Kaia toolkit. The Microsoft Speech SDK contains the speech application program interface (SAPI) and TTS engine compatible with Windows system. The Speech SDK voice development kit in the VC environment is called to develop a text conversion program to realize the fast conversion function from text to voice.

5. Conclusion

The traditional yoga learning can only be completed under the guidance of a fixed time, environment, and coach, which cannot meet the requirements of some professionals. Under this background, this study develops an electronic yoga teaching system based on Kinect, which can capture the movement information of trainers through Kinect. Then, a series of algorithms are used to comprehensively evaluate the trainers' actions, so that the trainers can timely understand the standard degree of their actions.

In this study, first, the principle of motion flow capture using Kinect is described. The somatosensory device has the advantages of noninvasive, not restricting human movement, and the capture accuracy can meet the basic requirements. In the analysis and evaluation of motion flow information, this study uses Hausdorff measure algorithm. The system also evaluates the movement with the help of the joint point angle. This method can more intuitively find the joint points where the movement is not in place. At the same time, this design realizes the voice prompt function of the system through the text-to-voice conversion technology. The biggest advantage of this system is that it will neither be affected by time and space, nor will it involve the privacy of users. It can work for a long time. In the future, the recognition effect of the algorithm can be further improved to further enhance the classification performance.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Construction and Implementation Path of College English Teaching Mode in Big Data Environment

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As a basic course for cultivating innovative and applied foreign language talents in the new era, college English audio-visual courses are facing huge opportunities and challenges in the era of big data. The transformation of the teaching environment under the background of big data is mainly reflected in the role of teachers, the dissemination of the information age, and the improvement of students' self-learning ability. The role of students in teaching has been strengthened, and the education system has undergone certain changes. This paper analyzes the current teaching status of college English audio-visual courses. According to the actual situation, a feasible reform plan is proposed to reconstruct the teaching mode of college English audio-visual courses, to improve the teaching quality of college English audio-visual courses, and to promote the improvement of students' comprehensive ability of college English.

1. Introduction

As a public compulsory course in ordinary colleges and universities, college English courses play a pivotal role in cultivating students' good foreign language communication skills, humanistic quality, and international vision. College English courses are not only the basic requirements for students' academic studies but also an inevitable requirement to keep pace with the times, face the future, and pursue the optimal development of personal careers [1, 2]. The level of foreign language proficiency and cross-cultural competence will directly affect the breadth and height of future competition choices and the starting point and level of personal development.

In the context of big data and the background, traditional college English teaching methods can no longer meet the needs of the increasingly updated big data and cloud technology culture, and we urgently need to implement a new English teaching model. Of course, in the process of English teaching reform, there will be many factors, such as teachers, learning environment, learning materials, and learning media. A change in the traditional English teaching mode helps to improve the English learning level of college students.

The rapid development of network information technology has laid a solid foundation and guarantee for the reform of college English teaching. While bringing new development opportunities to the traditional college English audio-visual course teaching, it also brings great challenges to the traditional teaching mode and thinking. Constructing a new teaching mode of college English audio-visual courses is an inescapable responsibility and obligation of colleges [3–6]. College informatization means take advantage to deeply explore and construct the teaching mode and the teaching evaluation method of college English audio-visual courses that meet the requirements of foreign language talents training in the new era. Further improvement in the teaching quality and effect of college English audio-visual courses cultivate more high-end compound foreign language talents [7].

The influence of modern Internet technology is increasing, and college English education should be appropriately cited to facilitate students to use mobile phones and computers to find their own learning materials and learning channels [8, 9]. Internet teaching models have entered people's field of vision. The emergence of platforms such as open courses in world-renowned schools, open courses in major domestic universities, and MOOC has impacted the

senses and receiving systems of teachers and students [10–12]. This paper takes the college English classroom teaching method and practice under the background of big data as the breakthrough point. In order to provide a theoretical basis for college English education in the future, the new education system constructed in college English teaching is discussed.

2. The Current Situation of College English Teaching

2.1. Insufficient Teaching Objectives. Influenced by the traditional exam-oriented education, for a long time, the teaching of college English courses in colleges and universities has focused on cultivating listening and speaking skills and gave emphasis on reading, writing, and translation as well. The teaching objectives of college English audio-visual courses are generally included in the overall college English teaching objectives, and there are no separate short-term or medium-term and long-term teaching objectives for listening practice and oral training. There is a lack of perfect and reasonable listening and speaking testing mechanism and evaluation system in actual teaching [13].

The audio-visual and oral course has long been taught in the “three-step” mode, that is, listening to the recording, checking the answers, and listening to the recording. This kind of mechanical teaching mode is exam oriented, and it is divorced from the real context. Students in the classroom only accept it passively, and their listening and speaking abilities cannot be effectively improved. This teaching mode is contrary to the requirements goals of foreign language.

The learning resources owned by students in traditional classrooms are mainly “teacher + textbook.” Entering the multimedia era, the learning resources owned by students are mainly “teacher + textbook + courseware.” However, in the limited teaching time in the classroom, there is less classroom interaction and less practice, and it is difficult for students to digest the teaching content of the current class. Coupled with the unified model and unified requirements for after-school homework, this seriously restricts students’ creativity and imagination, and it is also difficult to meet students’ individual development needs.

2.2. Teaching Methods and Forms are Relatively Simple. The current forms are relatively simple, and the teaching methods mainly follow the traditional multimedia equipment. The form of the course mainly includes teacher’s explanation by reading new words and playing audio or video [14]. After checking the audio answers, the teacher will play the video or audio again several times, and briefly explain the important knowledge points and difficulties in the materials. Finally, the students will practice the relevant oral dialogue.

In the whole teaching process, teaching is always centered on the teacher, and students only passively complete each step of teaching according to the teacher’s instructions. College English class hours are relatively small, and the class capacity is large. If teachers want to complete relevant

teaching tasks within limited class hours, students will have few opportunities to participate in listening and speaking exercises [15]. Due to the limitations of class hours, teachers cannot present the real language environment one by one in the class and cannot fully provide students with all kinds of audio and video materials needed for listening and speaking exercises.

Students lack a realistic language environment and a good learning atmosphere when they practice listening and speaking. Some students have a coping mentality in the classroom. Cramming-style teaching makes students gradually lose interest in college English listening and speaking practice, which is not conducive to the improvement of the teaching quality of college English audio-visual courses. Among them, cramming teaching refers to a teaching method in which teachers blindly instill knowledge into students, and the articles are purely memorized by rote, without considering whether students can understand the meaning.

2.3. Teaching Content Is Boring. The content of traditional college English teaching is monotonous and boring, and the teaching content is generally divided into three parts. The first part is new words. The teacher leads the students to learn and explain the rare words that will appear in the audio-visual materials. The second part is listening exercises, mainly including text comprehension, long and short dialogues, and other exercises. The third part is conversation practice. Students can practice dialogue or debate in groups according to their requirements. Some units also have movie excerpt videos or English songs for students to enjoy.

Students are often very interested in the third part, but in most cases, students only pay attention to the entertainment effect they bring when watching short films and listening to music, ignoring the main purpose and task of listening to music and watching videos [16]. Vocabulary learning does not pay attention to the pronunciation of words but only stays on the level of meaning and understanding. Grammar and speaking exercises are unclear for most students.

3. English Teaching and Its Implementation Path

3.1. The Impact of College English Teaching

3.1.1. This Has Triggered the Explosive Growth of English Teaching Resources. Under the traditional college English teaching mode, English teaching resources are mainly textbooks and paper resources, and teaching resources are relatively poor [17]. English teaching resources are not only huge in quantity but also of various kinds, providing a huge amount of resources for college students’ English learning.

The explosive growth of teaching resources has freed English teaching from resource constraints and greatly improved the content of English teaching. It enriches the content of College English teaching, expands students’ English learning horizons, and leads English teaching into the resource era.

3.1.2. Make It Possible to Teach College English Students in Accordance with Their Aptitude. Under the traditional college English teaching mode, English teaching is mainly based on on-site classroom teaching. The English teaching design is mainly designed for students as a whole. Although teachers can realize teaching in accordance with their aptitude and try to implement layered teaching in actual teaching, they are limited by teaching time, teaching space, and other conditions of teaching, and teaching in accordance with their aptitude lacks operability.

In the era of big data, teachers can make use of the advantages of big data and network platform to break the only main position in the traditional classroom for students. Students can make their own choices according to their English ability, English foundation, interests, and hobbies so as to make it possible to teach students in accordance with their aptitude.

3.1.3. The Camp Structure Is Suitable for Students' Self-Learning Environment. Autonomous learning ability is one of the necessary abilities of college English teaching students. English learning is mainly limited to the English classroom. It is difficult for students to obtain effective support from the outside world without classroom teaching.

Students' English learning environment has been further optimized. Not only are there rich learning resources to provide students with a large number of optional autonomous learning resources but also the online learning platform can change the lack of support for students' autonomous learning in the traditional mode. Students can interact with each other and also students and teachers can interact with each other through the online platform. In the age of big data, the environment for students' autonomous learning has been relatively mature.

3.1.4. It Will Lead to a Comprehension in Teaching Methods. Teachers' teaching methods will be transformed from design focusing on teaching to design focusing on learning. Teachers will continue to optimize teaching methods according to the new learning environment and students' learning needs [18]. The teaching content and teaching evaluation have also undergone major changes, and the teaching content has become more abundant.

3.2. Implementation Path and Strategy of Teaching Reform

3.2.1. Clarify Teaching Objectives. The rapid development of network technology not only injects new vitality into the boring language learning but also makes the learning of college English audio-visual courses more colorful. The basic theory of second language acquisition and constructivism believes that the content of language audio-visual course teaching should be diversified [19–21]. Teachers should use different channels to select network resources and information materials related to the teaching of audio-visual courses to provide students with a real learning atmosphere and language environment. Stimulate students' motivation

and interest in language learning and change their learning concepts. Encourage students to truly realize the importance of audio-visual courses from the bottom of their hearts so as to actively study and actively cooperate with relevant teaching activities.

At present, college English audio-visual courses already have textbooks such as *New Horizons English Audio-visual Teaching Materials* and *New Century English Audio-visual Courses*. However, there are few college English audio-visual teaching materials with strong professional targeting and not every major has corresponding industry audio-visual teaching materials. Teachers should not be limited to existing teaching materials and video materials in the process of audio-visual teaching. In addition, according to the actual needs of teaching, the audio-visual courseware should be carefully produced, and the targeted and personalized college English audio-visual courses should be prepared in combination with the students' learning interests.

Improve the main body status of students and enhance the effectiveness of college English audio-visual course teaching. By creating a real language teaching environment, visual and auditory, language and situation, graphics and sound are organically combined. Turn the original abstract knowledge into vivid and easy-to-understand classroom performances.

3.2.2. Enrich Teaching Means. With the arrival of the big data era, the traditional teacher centered audio-visual and oral teaching model no longer meets the requirements of the new era of foreign language talent training. There is an urgent fundamental concept and teaching mode of College English audio-visual oral course, and change the traditional teaching mode dominated by teachers. Classroom teaching takes students as the center and improves students' dominant position [22]. It collects the course content suitable for students at different levels, and it improves students' English audio-visual and oral level.

In the teaching process of college English audio-visual courses, teachers can make full use of modern teaching facilities for auxiliary teaching. The teaching content of audio-visual course include listening and speaking which should be organically combined especially the effective combination of college English audio-visual materials with the interactive teaching method and task-based teaching method. Encourage students to deepen the internalization and understanding of English language knowledge and improve their English language application ability.

Teachers can divide college English audio-visual course teaching into three parts: before class, during class, and after class according to actual needs. Before class, relevant teaching tasks will be released in advance through Rain Classroom, WeChat, Learning Star, and other network platforms, and students will be notified to preview and discuss in advance [23–25]. During this period, teachers can provide necessary technical guidance in the background or maintain timely communication with students through the Internet. In this way, the preparation time for classroom

practice can be greatly reduced, and more students have the opportunity to participate in audio-visual classroom teaching activities.

In the class, teachers can divide students into several study groups and encourage students to actively participate in various classroom display activities of audio-visual and oral teaching in groups. Students can prepare audio and video materials related to the topic in advance according to their own needs for follow-up and imitation exercises to correct word pronunciation. For some news hot spots, students are encouraged to have oral debates or talk shows so as to improve their English viewing, listening, and speaking ability [26]. In the class, teachers mainly provide technical support and learning guidance for students' audio-visual and oral courses and to observe students' participation in various classroom activities. Give timely feedback and comments on the problems, and teachers play a leading and promoting role in the whole teaching activities.

After class, teachers can properly arrange preview tasks or review contents of audio-visual and oral courses and also timely use various existing network communication platforms to maintain interaction with students. Master the latest trends of students, urge students to complete the tasks assigned after class on time, and timely answer for the practical problems encountered in students' after-school learning, so as to ensure the effectiveness of after-school learning.

3.2.3. Repositioning Classroom Teaching. The teaching of college English audio-visual oral course is adversely affected by the traditional exam oriented education. Over the years, the teaching effect of audio-visual and oral courses has not made great progress. From the initial contact with English to entering the University, students' English learning has been mainly based on the evaluation of the answer paper. Although listening is involved in the examination, the visual and oral links are basically in the initial state.

Teachers should reposition audio-visual courses. Adopt the strategy of changing the past one-way output teaching mode and encourage students to actively participate in audio-visual classroom teaching activities [27]. Give full play to the subjective initiative of students and realize the interaction between teachers and students in the audio-visual classroom in the true sense.

Teachers should be the organizers and guides of the classroom in the college English audio-visual classroom. In addition to completing the teaching tasks specified in the textbook, they should also organize different classroom activities and guide students to apply what they have learned in the classroom to practical application. The college English audio-visual course is a highly practical course [28]. Teachers need to organically combine audio-visual in accordance with the rules of English language learning to ensure that students learn with practical tasks every time.

In the classroom, students' thinking is further expanded, and the three links of sight, listening, and speaking are taken into consideration. Emphasis is placed on the organic combination of the three to promote students to develop

good audio-visual habits and to acquire correct English pronunciation, intonation, and speaking speed, thus laying a solid foundation for the improvement of the teaching effect of audio-visual courses.

3.2.4. Establish Diversified Courses. The establishment of a diversified college English audio-visual course evaluation system is mainly to further test the students' course learning effect and teachers' course teaching results. A sound evaluation system for college English audio-visual courses helps English teachers to discover [29]. The evaluation system of college English audio-visual courses should highlight the characteristics of the courses and provide higher-level evaluation and feedback according to the needs of the times for talents. The combination of quantitative and qualitative evaluation shall be implemented, and an evaluation system with diversified evaluation subjects and evaluation objects shall be constructed.

Under the background of big data, college English audio-visual course teaching should pay more attention to students' practice and innovative evaluation, pay full attention to the autonomy and individualization of students, and change the traditional summative evaluation model with teachers as the main body of evaluation. It should establish a more diverse, reasonable, and effective teaching evaluation model so that students will eventually become the main body of course evaluation, so as to fully mobilize the enthusiasm and autonomy of students to study college English audio-visual courses.

4. Construction of College English Teaching Mode in Big Data Environment

Modern new media education methods are mostly based on flipped classrooms, micro classroom, and MOOC. A flipped classroom is the readjustment of time in and out of the classroom, shifting learning decisions from teachers to students. Micro classroom is an interactive learning community centered on group class, in which groups are generated by interest and students' self-study, and small circles generate large circles. MOOC is a large-scale online course, which is the product of the Internet and modern education. It is an open classroom form that has emerged in recent years.

4.1. Flipped Classroom. Flipped classroom has been advocated by many educators because of its unique advantages. First, each video explains specific problems, which is more convenient to find. This is in line with the students' psychological development and can also systematically sort out the framework of knowledge. Second, in order to cooperate with the knowledge explanation, teachers will provide voice over and expand some knowledge points. Let students absorb knowledge more vividly, and let students know the learning purpose of this class. Third, it helps students break the traditional passive learning mode and build their own learning system. Fourth, in the video, the teacher will raise several small questions to highlight the key points of the course, and the students will conduct self-examination

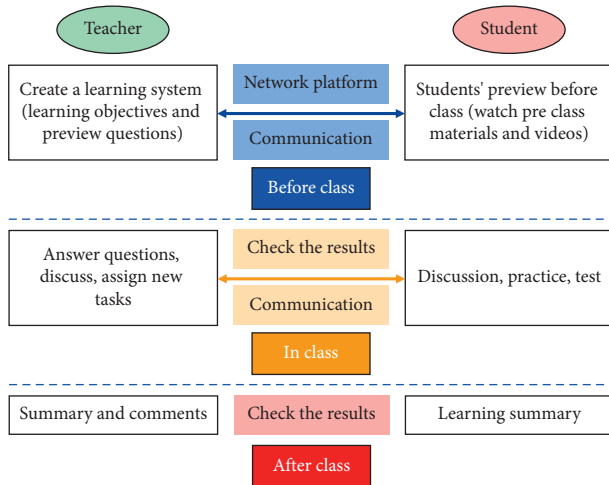


FIGURE 1: Flipped classroom teaching design process.

according to the questions raised [30]. If you find that the answer is not good, you can answer again and repeat the video playback to help students think. Fifth, in the process of preview and review, students could use fragmented time to study because they use multimedia. It saves more time and improves learning efficiency.

In the process of students' learning, teachers can adjust the next class according to the specific situation of students, saving a lot of time for preview before class, observation during class, and reflection after class, improving teaching efficiency [31].

4.1.1. Design Method of Flipped Classroom. Select 40 students from a class in a university, and these 40 students have completed 16 weeks of teaching tasks. According to the situation of college English teaching in the previous academic year, teachers used the flipped classroom model to teach these 16 weeks. Students work in groups of four, each in groups of two. Students work in groups of four in different tasks and activities to establish a class WeChat group and a four-person WeChat group. Teachers distribute videos and related materials in the group to facilitate group members to participate. This will help teachers to rectify teaching and facilitate discussions among students. The specific flipped classroom design process is shown in Figure 1.

4.1.2. Application Effect of Flipped Classroom. In the teaching process, each group should preview the knowledge within the specified time. The teacher observes the student's preparation in the background and records it. In the class, teachers should give targeted explanations for the effect of preview. Students focus on questions and discussions based on questions they did not understand during the preview. After the class, teachers formulate homework based on students' reactions and discussions among students in the class and conduct exams within one week to test the effect of the class.

The effect analysis is as follows: (1) the video preview before the class can help students understand the significance of the teaching content and the required effect and allow students to have a more systematic thinking

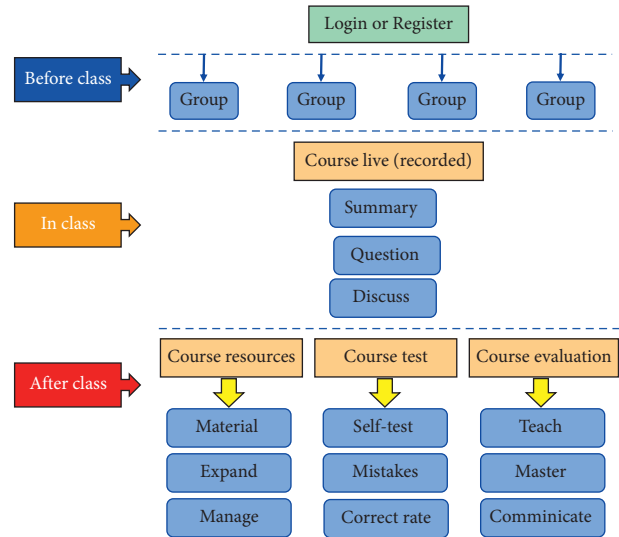


FIGURE 2: Micro classroom teaching design process.

construction; (2) the interaction with teachers in the class has increased, and the opportunities to communicate in English have also increased; (3) the efficiency of students' problem-solving in the discussion process is improved, and the role of mutual supervision is obvious; (4) each member of the cooperative group has made different contributions to the group study, which increases the students' sense of achievement and helps build the students' self-confidence in English learning; and (5) the effect of students' review after the class is obvious.

4.2. Micro Classroom. Micro classrooms do not have the complex teaching process and huge construction system of flipped classrooms nor do they have many educational objects. Although it does not look so comprehensive, it is possible to teach one or two knowledge points in a class. The purpose of micro classroom teaching is clear, the content delivered is short and concise, and it has a certain systemic nature.

The teachers of the micro classroom appeared in the whole process and explained the knowledge points clearly. Taking video animation as the network communication point, each video is 10 minutes, highlighting the characteristics of the discipline. There are real cases as an aid, and the digestion speed is faster. The course is one-to-one, which promotes students to learn independently, with matching exercises and evaluation methods.

4.2.1. Design Method of Micro Classroom. Taking an online platform as a practical case, an "English Micro Classroom" was built on the platform. Teachers build a knowledge system according to the knowledge network, upload shared resources, create new columns, and develop an interactive platform for micro classrooms. The test selected a non-English major class on the network platform with a total of 40 students. Among them, the selected students scored between 115 and 125 in the college entrance examination, with an

TABLE 1: The proportion of students in the scores and sections of the after-school test.

Score	Control group/person	Test group/person
100–90	3	4
89–80	7	10
79–70	10	12
69–60	15	12
59–50	5	2
Total number	40	40

TABLE 2: After-school test scores.

Project	Control group	Test group
Highest score	3	4
Lowest score	7	10
The average score	10	12

TABLE 3: Post-MOOC survey results.

Project	The average score	Standard deviation
The resources provided by the MOOC helped me a lot	4.21	0.563
Satisfied with the teaching of the teacher	4.45	0.256
I approve of the assessment of classroom performance and test scores by classroom teachers	4.12	0.231
I love interacting with the teacher in the classroom	4.25	0.458
I am satisfied with this MOOC learning experience	4.56	0.215
The MOOC learning experience has improved my self-directed learning ability	4.32	0.367
I am satisfied with the teaching process of the teachers	4.24	0.369
I will continue to take MOOC courses	4.26	0.562
I agree with the postcourse assessment mechanism of MOOC	4.51	0.647
The online interactive communication of MOOC helped me a lot	4.36	0.652
I have benefited a lot from the peer review system for after MOOC assignments	4.52	0.547

average level. Another 40 students in the control class were selected, and these 40 students did not attend classes.

According to the specific content of the micro classroom teaching, teachers sort out knowledge points in the class and provide data sources for students to download after the class, and the students are divided into groups in the way of group assignment so that the students can practice the trial lectures so that the knowledge can be fully mastered. The specific micro classroom design process is shown in Figure 2.

4.2.2. Practical Results of the Micro Classroom. According to the after-school test results in Table 1, 65% of the students in the experimental group scored above 70, and 50% of the students in the control group scored above 70. Students can take English and exams seriously, and their ability to master knowledge has been improved.

In Table 2, the highest score of the control group was 93, which was 3 points lower than that of the experimental group, and the lowest score of the experimental group was 3 points higher than that of the control group. The number of people below 70 points in the control group is 6 points higher than the experimental group. This shows that the learning effect of the experimental group is better than that of the control group.

4.3. MOOC. MOOC is an emerging online course method in modern education. It is a large-scale network open course. It mainly advocates the spirit of sharing and collaboration. It is an open class initiated and organized by individuals. MOOC is a public course, so the service objectives are larger and the scope is wider. The openness of the course is strong, and the teaching purpose of the course is more obvious. Although open, there are no restrictions on where classes can be held and no significant investment is required.

4.3.1. Design Method of MOOC. Taking the English course of a university as an example, a MOOC can be divided into three stages, namely, the preclass preparation stage, the teaching explanation stage, and the summary evaluation stage. Before the class starts, teachers make plans for the course, including course design, course recording, and platform playback. Among them, the entire video course will not exceed 25 minutes, but the learning period can be extended, generally controlled within two months. The frequency of teaching videos is issued twice a week, and there is a lot of time for students to digest and understand. At the same time, teachers will assign classroom assignments, problem discussions, and self-assessment questions after the class.

4.3.2. Post-MOOC Survey. The census results are shown in Table 3. Students have a high degree of recognition for the course help provided by MOOC, and their attitudes towards this course have changed. They are also more satisfied with the interactive effect with teachers in the class. Some students also said that offering MOOC helped them learn the course independently to a great extent and explained about the boring course more thoroughly. Some students said that although the course time is short, the effect is remarkable and the overall satisfaction is high.

5. Conclusion

The advent of the era of big data has had a strong impact on college English education for cultivating applied and innovative foreign language talents. We can promote the deep integration of college English audio-visual course teaching and network technology so as to realize the extraction of valuable things from massive information for audio-visual course teaching. Based on students' formative evaluation, we can make full use of big data and network platforms to optimize student learning. We can scientifically build a classroom teaching evaluation system and optimize the teaching mode in order to improve students' English application ability and autonomous learning ability. We can reconstruct the evaluation model of college English audio-visual courses, that improved the teaching quality and effect of college English courses and promotes the improvement of students' comprehensive English ability.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Retraction

Retracted: Three-Dimensional Numerical Simulation of Soil Deformation during Shield Tunnel Construction

Mathematical Problems in Engineering

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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] C. Liu, S. Yang, W. Liu et al., "Three-Dimensional Numerical Simulation of Soil Deformation during Shield Tunnel Construction," *Mathematical Problems in Engineering*, vol. 2022, Article ID 5029165, 11 pages, 2022.

Research Article

Three-Dimensional Numerical Simulation of Soil Deformation during Shield Tunnel Construction

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In order to effectively control the ground deformation and ground subsidence during subway construction, three-dimensional numerical simulation of soil deformation during shield tunnel construction is proposed. Based on a subway tunnel project, this essay firstly divides the shield construction process into several stages and analyzes the vertical displacement of soil in each stage. FLAC 3D was used for three-dimensional finite difference numerical simulation. By comparing the numerical simulation results with the field measured data, the soil settlement caused by shield tunnel excavation is studied deeply. The simulation results show that the maximum settlement value of the monitoring data is 0.59 mm, and the maximum settlement value of the numerical simulation is 0.82 mm, with a difference of 0.23 mm. The maximum value of uplift on both sides of the tunnel is 0.41 mm in monitoring data and 0.29 in numerical simulation, with a difference of 0.12 mm. The maximum settlement value of monitoring data is 2.59 mm, and the maximum settlement value of numerical simulation is 3.05 mm, with a difference of 0.46 mm. The maximum value of uplift on both sides of the tunnel is 0.32 mm in monitoring data and 1.89 mm in numerical simulation, with a difference of 1.57 mm. The settlement value of numerical simulation is slightly larger than that of monitoring data. *Conclusion.* The simulation can well simulate the state of soil uplift on both sides, and the width of settlement groove is in good agreement with the monitoring data.

1. Introduction

Since the 21st century, with the rapid development of China's economic society and urban infrastructure construction, the scale of cities is gradually expanding, resulting in increased pressure of urban public transport. In order to relieve the pressure of urban public transportation, the utilization and development of underground space is particularly important. Subway has become a representative of green transportation due to its large volume and low emission [1]. The construction methods of urban subway tunnels at home and abroad mainly include open excavation method, shallow excavation method, and shield tunneling method. Among them, the shallow excavation method and the open excavation method cause great interference to commercial and road traffic, and the shield tunneling

method has the advantages of low noise and little influence on the surrounding environment and economic production and life. The advantages of shield tunneling will become more and more obvious as the difficulty of road traffic distribution increases and the cost of urban commercial, industrial, and residential demolition increases. At present, the shield tunneling method has become the preferred tunneling method for subway construction in China. Even in third-tier cities, the shallow excavation method and the open excavation method are often only adopted in the hard rock and suburban areas. In addition, a shield tunnel is also widely used in hydraulic tunnel construction because of its good waterproof effect in construction, such as the undercrossing Yangtze River tunnel in Nanjing, Wuhan, and Shanghai, and the Qingchun Road tunnel in Hangzhou [2]. Moreover, in developed cities with dense subway lines, there

have been frequent instances of new tunnels penetrating existing tunnels, which poses challenges to the evaluation of internal force redistribution caused by the construction disturbance of existing tunnels, as well as the development of transverse and longitudinal design methods of shield tunnel structures. According to the structure of shield head, it can be roughly divided into closed chest type and open type. Shield machine can be divided into compressed air-type, mud water-type, and Earth pressure balance-type shield machine according to the different soil quality and working mode (see Figure 1).

Closed chest shield is a shield configuration that forms a pressure chamber between the diaphragm and the excavation surface by closing the diaphragm to maintain the pressure in the pressure chamber full of mud and sand or mud water, so as to ensure the stability of the excavation surface. Open shield tunneling refers to the shield configuration with all or most of the excavation face open, on the premise that the excavation face can be self-stable.

2. Literature Review

Ma et al. discussed the possibility of simulating stratum displacement, stress conditions, various stages of tunnel excavation, and lining segment installation by using the finite element method and believed that two-dimensional plane strain analysis was the most effective and simplest method to simulate stratum displacement [3]. Yahi et al. considered the influence of the soil displacement in front of the working face and the soil displacement to the tail pore in two independent two-dimensional analyses. The hyperbolic model is adopted, and it is assumed that the initial stress and shear strength in the soil layer change linearly with burial depth. By studying several geometric and mechanical parameters, the analysis results can be expressed into a simple dimensionless relation [4]. Hosseini Mobara et al. introduced clearance parameters to describe the stratum losses caused by shield tunnel construction and first allowed the soil around the tunnel to freely deform towards the excavation zone. When the radial convergence value of soil reaches the predetermined total clearance parameter value, the shield-lining element is activated and the contact between soil and shield lining is assumed, and the interaction between soil and lining is considered. The prediction of surface settlement caused by lining tunnel construction in soft clay under drainage condition is studied by using plane strain elastic-plastic finite element program. The influences of elastic modulus and thickness of the soil layer under tunnel, static lateral pressure coefficient of soil K_0 , grouting pressure, dead weight of soil, anisotropy, and other factors on the plane analysis results were analyzed [5]. Yang et al. used the planar finite element method to study the stratum displacement and Earth pressure in the process of shield construction, and simulated the process of shield excavation, shield tail grouting, and lining segment support through the element "life and death." On the basis of laboratory tests on the mechanical properties of grouting materials at different hardening stages, a variable stiffness body was used to simulate the solidification process of grout. The influences of

grouting body thickness, soil condition, lining stiffness, and tunnel relative buried depth on stratum displacement and lining pressure distribution are analyzed [6]. Ma et al. used the highly adaptable finite element method to conduct finite element simulation on the construction steps of the shield tunnel, the contact surface between segment and soil layer, and the release of ground stress during excavation. The influence of shield construction on adjacent structures and the changes in the stratum were analyzed by using Tongji Shuguang software [3]. Xia et al. proposed a plane finite element simulation method that divided shield tunnel construction into four stages: cutter head excavation and lining support, shield tail filling grouting, initial setting of grouting materials, and final setting of grouting materials. Curved beam element and joint element are used to simulate lining, and different stress release coefficients are used for different curing stages of grouting materials [7].

In this essay, the ground surface settlement caused by the shield tunnel is analyzed in detail by comparing the numerical simulation results with the field measured data of the shield tunnel.

3. The Research Methods

3.1. Introduction to the Soil Constitutive Model. Mohr-Coulomb soil constitutive model (MC model) is a common constitutive model in soil simulation. As an ideal elastoplastic model, it is considered that the stress and strain conform to Hooke's law before the soil reaches shear strength [8, 9]. Therefore, the elastic deformation of soil is controlled by elastic modulus and Poisson's ratio. Soil failure satisfies the Coulomb failure criterion and is controlled by effective cohesion and effective internal friction angle of parameters. The specific formula is shown in the following equation:

$$\tau_f = c + \sigma \tan \varphi. \quad (1)$$

The soil hardening constitutive model (HS model) uses the MC failure criterion, as shown in the following equation:

$$\sigma_1 = \sigma_3 \tan^2 \left(45^\circ + \frac{\varphi}{2} \right) + 2c \tan \left(45^\circ + \frac{\varphi}{2} \right). \quad (2)$$

The yield criterion is divided into shear yield and volume yield. Shear yield is shown in the following equation, and volume yield is shown in equation (6):

$$F_s = \frac{q_a}{E_{50}} \frac{q}{q_a - q} - \frac{2q}{E_{ur}} - \gamma^p. \quad (3)$$

Among them, formulas (4) and (5) are as follows:

$$E_{ur} = E_{ur}^{ref} \left(\frac{\sigma_3 + c \cot \varphi}{\sigma^{ref} + \cot \varphi} \right)^m, \quad (4)$$

$$\gamma^p = \varepsilon_1^p - \varepsilon_2^p - \varepsilon_3^p = 2\varepsilon_1^p - \varepsilon_v^p \approx 2\varepsilon_1^p, \quad (5)$$

where F_s is the shear yield function; q_a is the progressive value of shear strength; E_{50} is the secant modulus at 50% strength under confining pressure; E_{ur} is the secant stiffness of unloading and reloading; E_{ur}^{ref} is the reference secant

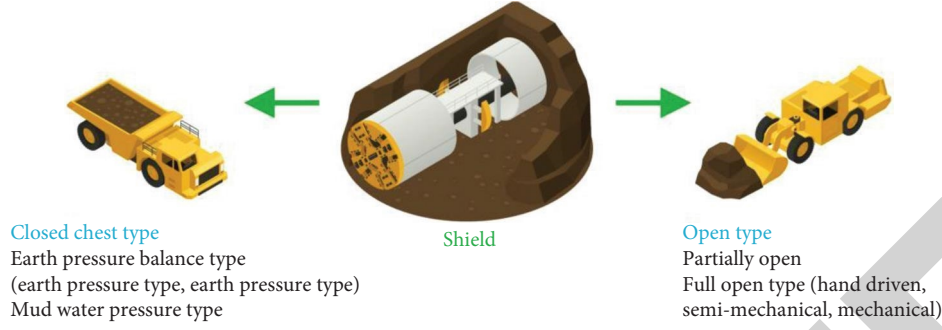


FIGURE 1: Classification of shield tunneling.

stiffness under unloading and reloading; γ^p is the plastic shear strain; ε_1^p , ε_2^p , and ε_3^p are the first, second, and third plastic principal strains, respectively; and ε_v^p is the plastic volume strain.

Volume yield is shown in the following equation:

$$F_c = \frac{\bar{q}^2}{M^2} + p^2 - p_c^2, \quad (6)$$

where

$$\begin{aligned} p &= \frac{\sigma_1 + \sigma_2 + \sigma_3}{3}, \\ \bar{q}^2 &= \sigma_1 + (\alpha - 1)\sigma_2 + \alpha\sigma_3, \\ \alpha &= \frac{3 + \sin \varphi}{3 - \sin \varphi}, \\ M &= \frac{6\sin \varphi}{3 - \sin \varphi}. \end{aligned} \quad (7)$$

Here, F_c is the volume yield function; \bar{q} is the calculation of deviatoric stress; p_c is the isotropic preconsolidation stress; p is the principal stress; and M is the friction constant, which controls the flatness of the cap yield surface in the P-Q plane.

The HSs model is improved on the basis of HS model to reflect the characteristics of small strain of soil. On the basis of 11 parameters in the HSs model and HS model, the other two parameters are used to control the small-strain characteristics of soil [10].

The expression of the initial shear modulus is shown in the following equation:

$$G_0 = G_0^{\text{ref}} \left(\frac{c \cos \varphi + \sigma_3 \sin \varphi}{c \cos \varphi + p^{\text{ref}} \sin \varphi} \right)^m, \quad (8)$$

where G_0^{ref} is the reference pressure corresponding to the initial shear modulus.

The soil hardening constitutive model (HS model) has a total of 11 parameters, including 3 strength parameters, 4 stiffness parameters, and 4 advanced parameters. The parameters are summarized as shown in Table 1 [11]. On the basis of 11 parameters of the HSs model and the HS model, two other parameters are used to control the small-strain characteristics of soil. The specific parameters of the HSs model are shown in Table 2, and the pair of the two models is shown in Table 3.

The HS model uses the MC failure criterion, whereas the HSs model uses the Nakai–Matsuoka failure criterion (SMP criterion) [12]. MC criterion is a two-dimensional friction criterion determined by two principal stresses, while SMP criterion is a three-dimensional friction criterion. The yield surface of HSs constitutive model is smoother than that of the HS constitutive model. The expression of SMP failure criterion is shown in the following equation:

$$\frac{\tau_{\text{SMP}}}{\sigma_{\text{SMP}}} = \frac{2}{3} \sqrt{\left(\frac{\sigma_1 - \sigma_2}{2\sqrt{\sigma_1 \sigma_3}} \right)^2 + \left(\frac{\sigma_2 - \sigma_3}{2\sqrt{\sigma_1 \sigma_3}} \right)^2 + \left(\frac{\sigma_3 - \sigma_1}{2\sqrt{\sigma_1 \sigma_3}} \right)^2}. \quad (9)$$

3.2. Project Summary. The initial mileage of a subway shield tunnel is K11+591.899, and terminating mileage is K12+422.189. The slope shape of the shield tunnel line is V-shaped, and the maximum longitudinal slope is 30%. The depth of the tunnel is 8.0~14.5 m. The tunnel is located below the Central road, which is the main road with busy ground traffic and more buildings on both sides and directly above the road. In the process of shield construction, the ground settlement should be strictly controlled to ensure the normal operation of ground traffic and the safety of the surrounding environment. The stratum where the shield tunnel is located is mainly silty clay and silty sand [13]. The driving parameters of the shield tunneling machine are as follows: the upper soil pressure is 0.13–0.21 MPa, the lower soil pressure is 0.19–0.28 MPa, the rate is 60 mm/min, the tail grouting pressure is 0.25 MPa, and the grouting volume is 3.2/ring.

3.3. Three-Dimensional Numerical Simulation

3.3.1. Refined Modeling Steps. The specific steps of shield tunnel excavation are shown as follows.

The first step is as follows: first, excavate a range of 8 m for the total length of the shield machine and then apply support force of trapezoidal distribution on the face of the shield head. A trapezoidal distribution support force with a slope of 9 kPa and a support force of 33.73 kPa at the center point was set according to Dias. Due to the high strength and stiffness of the shell of the actual shield machine, it is considered in the simulation that when the displacement of the soil on the surface reaches the position of the shell of the shield machine, it will be fixed, and no displacement will

TABLE 1: HS model parameters.

The parameter types	The serial number	Symbol	Name
Strength parameters	1	c	Effective cohesion
	2	φ	Effective internal friction angle
	3	Ψ	The dilatancy angle
The stiffness parameters	4	E_{50}^{ref}	Three weeks drainage test reference secant stiffness
	5	E_{oed}^{ref}	Reference tangent stiffness of consolidation test
	6	E_{ur}^{ref}	Unloading and reloading reference secant stiffness
	7	m	Power index of stiffness stress level correlation
Advanced parameters	8	p^{ref}	Reference stress
	9	ν_{ur}	Unload and reload Poisson's ratio
	10	k_0	Lateral pressure coefficient under normal consolidation condition
	11	R_f	Ratio of damage

TABLE 2: HSs model-specific parameters.

The parameter types	Symbol	Name
The stiffness parameters	G_o	Initial shear modulus
	$Y_{0.7}$	The initial shear modulus is the shear strain corresponding to the initial 70%, also called threshold shear strain

TABLE 3: Comparison between the HS model and the HSs model.

Constitutive model	Shear hardening of soil	Compressive hardening of soil	Small strain of soil	Yield criterion
HS	Yes	Yes	No	MC
HSs	Yes	Yes	No	SMP

occur to the inside of the tunnel. In this step, the displacement of all points on the excavation surface is controlled by the FISH language, so that the displacement of the point 2 m inside the shield head of the shield machine is 0, and the displacement of the shield machine within 3 m is 0.01 m. The displacement of the point within 3 m at the tail of the shield machine shows a linear change, and the displacement of the last end is 0.015 m. After the completion of the first step of excavation, the settlement diagram at the top of the shield machine along the excavation direction is shown in Figure 2.

The second step is as follows: the length of the lining width of a ring excavated forward by the shield machine. In this essay, the lining width is 1 m, that is, 1 m excavated forward [14, 15]. At this moment, the shield head of the shield machine is located at 9 m. At this moment, the support force applied at 8 m in the first step is removed, and the trapezoidal support force is applied at 9 m. Since the displacement at each point of 0–8 m tunnel excavation has been fixed in the first step to form the shape of conical shield machine, the fixation at each point of 0–8 m tunnel excavation needs to be solved in the second step. Then, fish language was used to control the soil displacement on the surface of 1–9 m, thus forming the conical shape of the shield machine again. Because of the initial excavation of the actual tunnel, the initial excavation surface will be strengthened. Therefore, when the excavation direction of the model is 0 m, that is, on the boundary of the excavation, the diameter of the tunnel opening is fixed as the diameter of the shield tail of the shield machine in the simulation. As the shield machine excavates one step forward, the soil at 0–1 m in the

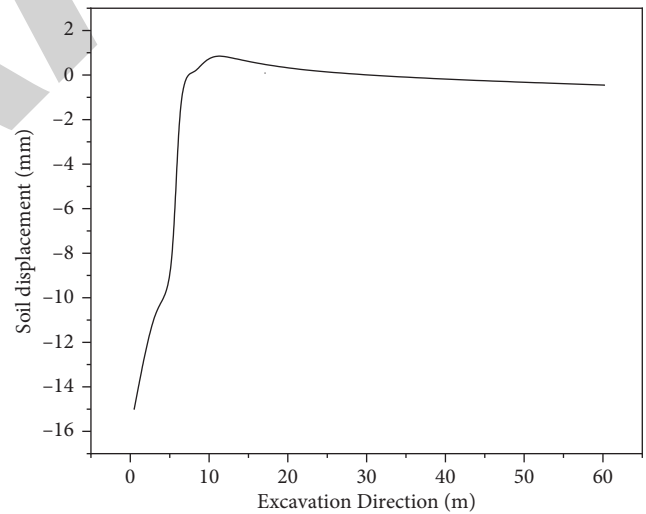


FIGURE 2: Soil displacement of the vault during the first three steps of excavation (the first step).

excavation direction is in an empty state. At this point, the trapezoidal distribution grouting pressure is applied on the surface, and the trapezoidal distribution grouting pressure at the center point is set as 260 kPa and the slope is 11 kPa according to Dias. After the completion of the second excavation, the settlement diagram of the shield top along the excavation direction of the shield machine is shown in Figure 3.

The third step is as follows: the shield machine excavates 1 m forward. At this moment, the shield head of the shield machine is located at 10 m. At this moment, the support

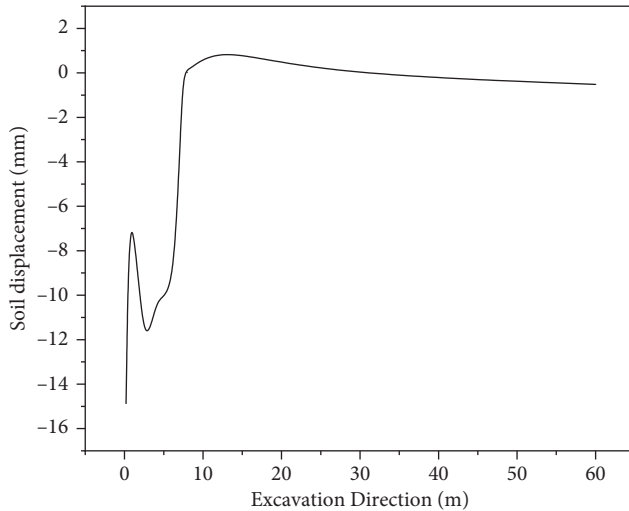


FIGURE 3: Soil displacement of the vault during the first three steps of excavation (Step 2).

force applied at 9 m in the first step is removed, and the trapezoidal support force is applied on the face at 10 m. The fixation at each point of the excavation of the 1–9 m tunnel was solved, and then, the soil displacement on the surface at 2–10 m was controlled by USING FISH language, thus forming the conical shape of the shield machine again. The soil at the excavation direction of 1–2 m is in an empty state, and the trapezoidal grouting pressure is applied on the empty surface. The grouting pressure on 0–1 m soil surface was removed, and the lining unit and grouting unit were installed [16]. After the completion of the third step of excavation, the settlement diagram of the shield top along the excavation direction is shown in Figure 4.

The overall tunnel excavation cycle is as follows: excavate one meter forward → remove the supporting force of the previous step → apply the supporting force of the present stage → release the fixed soil displacement within the range of the shield machine at the last step → control the soil displacement within the range of the shield machine at the present stage to form a conical shape of the shield machine → apply grouting pressure within the range of 0–1 m at the current stage of shield tail → remove the grouting pressure applied at the last step, that is, the range of 1–2 m behind the current stage of shield tail → within the range of grouting pressure removal, the lining unit and grouting unit are installed [17]. The cycle continues until the whole tunnel excavation is completed, which is 60 meters in this essay.

3.3.2. Model Overview. In this essay, FLAC 3D is used to simulate the excavation process of the shield tunnel. There are 190560 entity units and 198372 nodes in the model. The upper surface of the shield tunnel model is set as free constraint, while the lower surface is set as full constraint. Normal constraints are imposed on the left and right sides of the tunnel along the direction of excavation, and on the front and rear surfaces along the direction of section. The vertical downward gravity is applied to the whole shield tunnel model.

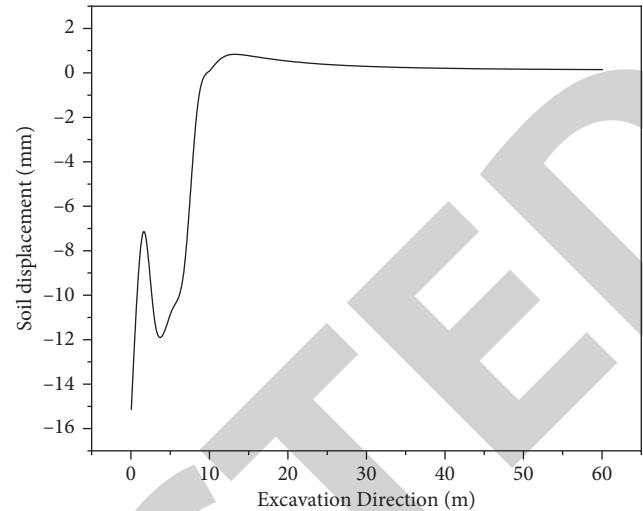


FIGURE 4: Soil displacement of the vault during the first three steps of excavation (Step 3).

The whole shield tunnel excavation model is composed of four parts: the cylinder element of tunnel excavation, the shell element of the grouting body, the shell element of lining, and the surrounding soil part. The soil near the excavation of the tunnel has a dense grid division, while the soil far from the excavation of the tunnel has a sparse grid division.

4. Results Analysis

4.1. Soil Displacement on the Top of the Shield. Along the excavation direction, the soil displacement at the top of the shield machine (i.e., at the depth of 10.465 m) is shown in Figures 5–7.

With the continuous tunneling of the shield machine, the displacement of the soil vault at the excavation of the tunnel is in constant change [18, 19]. Figure 5 shows the displacement at the soil vault (buried depth -10.465 m) when the shield head of the shield machine is excavated to a 30 m section (halfway along the excavation direction of the 3D model):

- (1) In front of the shield head of the shield machine: a relatively obvious uplift occurs within 10 mm in front of the shield head of the shield machine, with the maximum uplift value approaching 2 mm and the uplift range of about $1.6d$ (d is the diameter of the shield head of the shield machine). The reason for the slight uplift here is that the supporting force applied on the target palm surface is slightly greater than the lateral pressure of the original soil, so the uplift of the soil in front is caused.
- (2) Position of the shield machine: the displacement at the soil vault at the position of the shield machine can be divided into three sections at the shield head of the shield machine (28–30 m), and the soil displacement is 0. When the shield is located at 25–28 m, the soil settlement is 10 mm. At the tail of

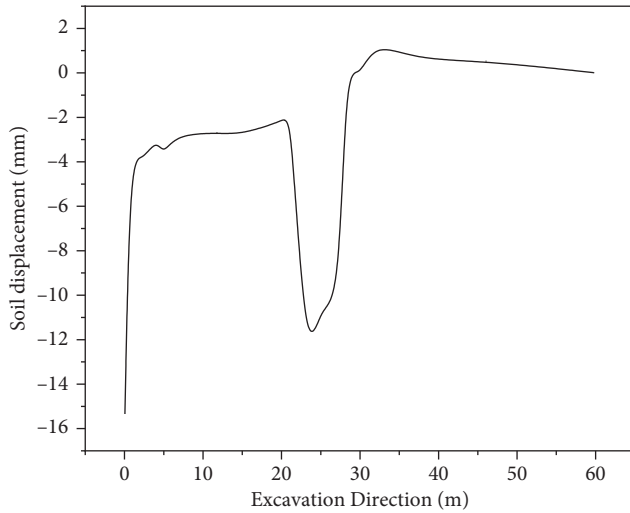


FIGURE 5: Soil displacement at the top of shield along the excavation direction (shield head A is located at 30 m section).

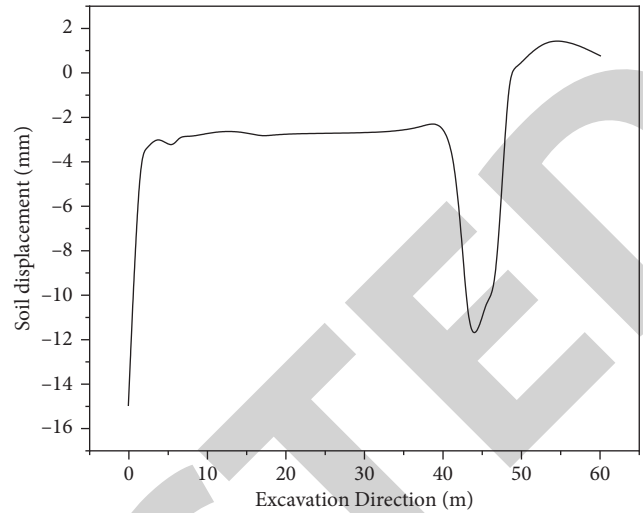


FIGURE 7: Soil displacement at the top of shield along the excavation direction (shield head C is located at 50 m section).

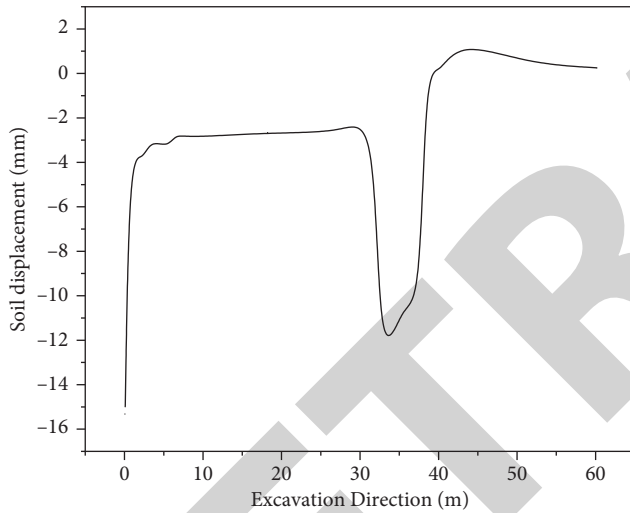


FIGURE 6: Soil displacement at top of shield along excavation direction (shield head B at 40 m section).

shield (23–25 m), the soil settlement changes linearly from 10 mm to 13.4 mm.

Reasons for displacement changes: the radius at the shield head of a shield machine is 3.135 m, namely, the excavation radius. Because of the support of the shield head, the soil displacement within the shield head is 0. B. The radius of the shield is 3.125 m, which differs 10 mm from the excavation radius, so the soil displacement within the shield body is 10 mm. The radius of the tail of the shield machine is 3.125 m at the junction of the tail and the body, and 3.12 m at the end of the tail. Therefore, the settlement of the soil at the junction of the tail and the body is 10 mm, while the settlement of the soil at the end of the tail should be 15 mm, but the range of grouting pressure applied at the tail of the shield is 21–22 m. Therefore, the displacement of soil at 22 m generates 1.98 mm

settlement under the action of grouting pressure, while the displacement of soil at 23 m still maintains 13.4 mm at the shell position of the shield machine.

- (3) Behind the shield tail of the shield machine: within 2–4 m (18–22 m) behind the shield tail, the soil displacement changes from small to large, and the settlement generated at the highest point is about 1.98 mm, at the 22 m position. After 4 m (6–18 m) behind shield tail, the soil displacement tends to be stable, and the soil settlement is between 2.6 and 3 mm. Under the comprehensive influence of boundary fixed displacement, grouting pressure, and grouting body deformation, the soil settlement gradually decreases, and the settlement varies within 3–3.8 mm [20, 21].
- (4) Boundary surface of initial excavation: the displacement on the boundary surface (0 m) is fixed at 15 mm. This fixed value is related to the actual excavation process of the shield machine. In actual tunnel excavation, when the shield machine enters the soil for the first time, it will reinforce the initial excavation surface and then excavates forward step by step [22]. Therefore, in 3d simulated excavation, the boundary surface is pretreated before the second step of excavation; that is, the diameter of the open surface on the boundary of the excavated tunnel is fixed as the diameter of the tail end of the shield machine.

By comparing the soil displacement curves in Figures 6 and 7 with Figure 5, we obtain the following:

- (1) The soil displacement curves of the three figures can be obtained by horizontal translation. The difference of the vertical displacement data is small, about 0.1 mm, and the whole excavation process maintains a certain continuity.
- (2) Along the excavation direction, the law of soil displacement of the vault is similar in each stage: when

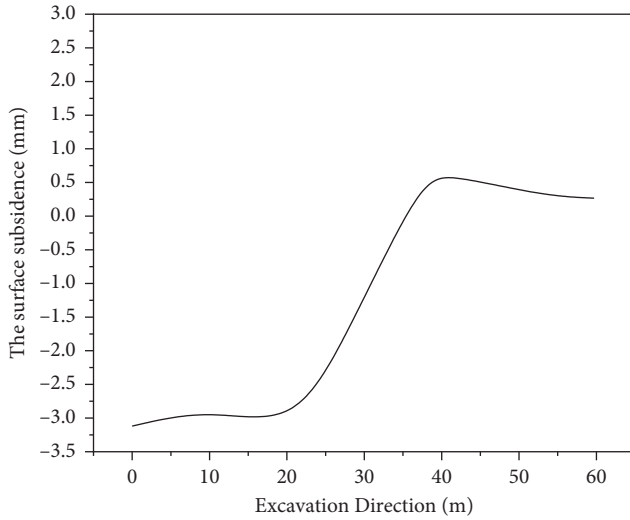


FIGURE 8: Surface soil displacement along excavation direction (shield head A is located at 30 m section).

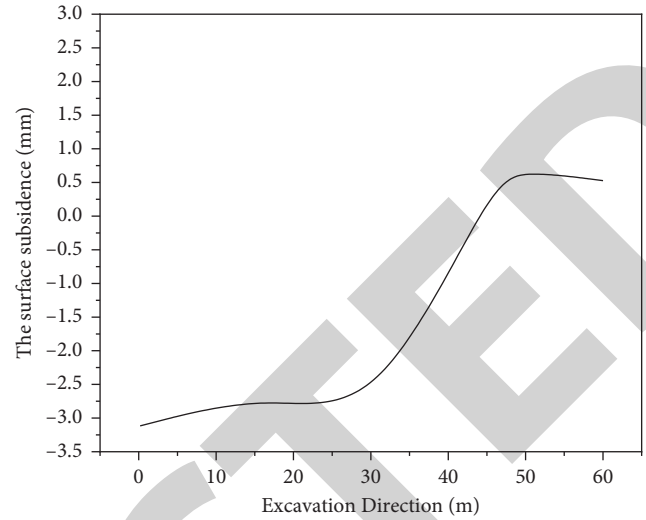


FIGURE 9: Surface soil displacement along excavation direction (shield head B at 40 m section).

the shield reaches the target face, the soil is uplifted in a certain range in front of the target face; the cone shape of the shield machine causes the displacement of the vault. The grouting pressure of shield tail reduces the soil settlement of the vault. The application of grouting and lining makes the settlement of soil relatively stable.

4.2. Surface Soil Displacement. Along the excavation direction, the surface soil displacement is shown in Figures 8–10.

Figure 8 shows the displacement of surface soil along the excavation direction when the shield head is excavated to 30 m section:

- (1) In front of the shield head of the shield machine: at this time, the shield head of the shield machine is located at 30 m, and in front of it, small settlement occurs on the surface within the range of 30–33 m; small surface uplift occurs in the range of 33–35 m; obvious uplift occurs in the range of 35–50 m; small ridges occur in the range of 50–60 m. The obvious uplift range was about $2.4D$. Compared with the displacement changes at the soil vault shown in Figure 5, the influence range of a surface uplift is larger than that at the soil vault, about $0.8d$ larger. The maximum value of the surface uplift is about 1.4 mm smaller than that of the soil vault.
- (2) Position of the shield machine: the soil settlement generated by the position of the shield machine (22–30 m) is approximately an inclined straight line. Compared with the displacement change of the soil vault shown in Figure 5, the settlement generated on the surface is much smaller than the position of the shield machine. This is because the shield machine is conical, and the radius difference between the shield head, body, and tail will form gaps, which increase the settlement of the soil at the vault.

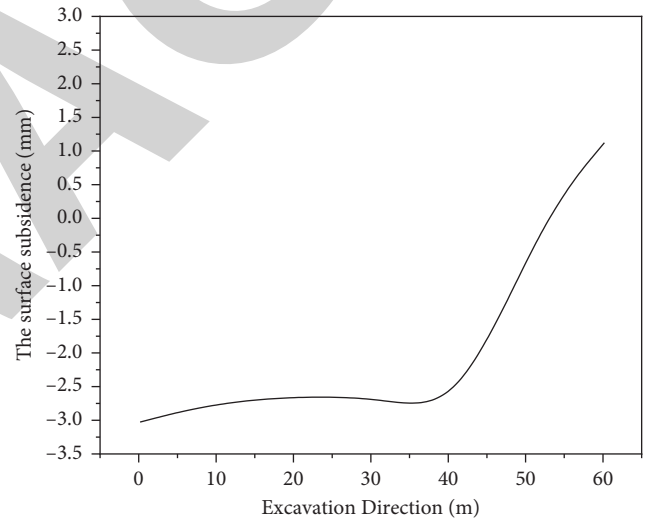


FIGURE 10: Surface soil displacement along excavation direction (shield head C is located at 50 m section).

- (3) Behind the shield tail of the shield machine: in the range of 1–8 m, the soil settlement gradually decreases from large to small, and the variation range (maximum to minimum) is about 0.3 mm. In the range of 8–14 m, the soil settlement curve is approximately a horizontal straight line. In the range of 14–22 m, the soil settlement changes from small to large, and the settlement difference range is 0.25 mm. Compared with the change of soil vault displacement in Figure 5, the change rule of the two is similar: the settlement at the beginning of Figure 5 decreases from large to small; after Figure 6, there is a relatively stable settlement in a horizontal straight line; the soil displacement within the shield tail grouting range of Figure 7 decreases and becomes stable gradually. The slight difference is that under the direct action of grouting pressure, the soil settlement of the vault

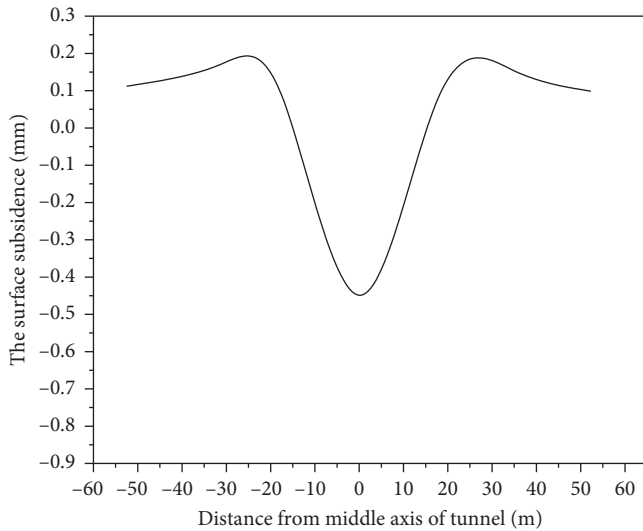


FIGURE 11: Surface soil displacement at 30 m section (shield head A is located at 30 m section).

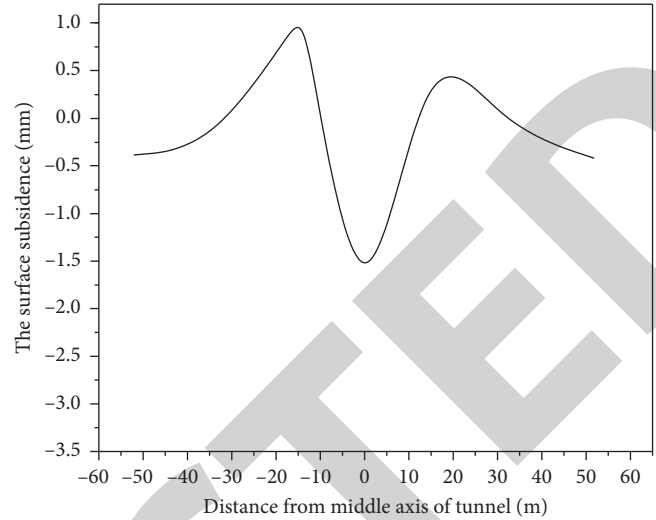


FIGURE 13: Surface soil displacement at 30 m section (shield head C is located at 50 m section).

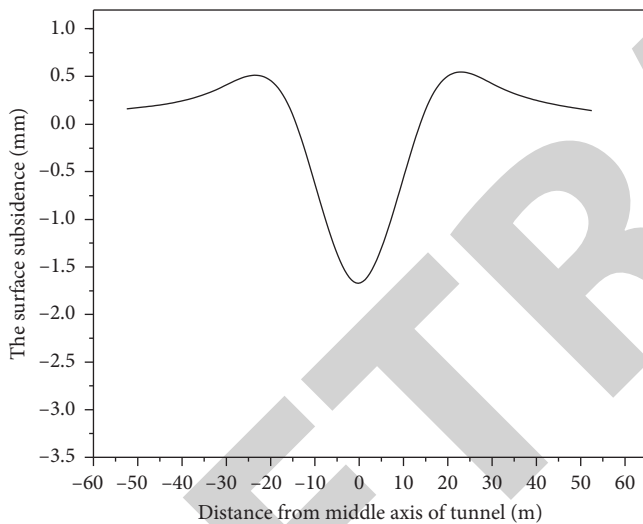


FIGURE 12: Surface soil displacement at 30 m section (shield head B at 40 m section).

decreases rapidly and changes from 15 mm to 2 mm, and then gradually increases and becomes stable, while the surface settlement decreases and becomes stable gradually [23].

- (4) Initial excavation boundary surface: the maximum surface settlement at 0 m is about 3.13 mm in the whole excavation direction. Compared with the vault soil displacement in Figure 5, both are the maximum values of settlement along the excavation direction.

The soil displacement curves in Figures 8–10 can be obtained by comparison:

- (1) Along the direction of tunnel excavation, the displacement curve of surface soil gradually moves upward as a whole, while the displacement curve shown in Figures 8 and 9 is basically stable.

This is because when 0 m is in the simulation, only the displacement of the soil around the hole is fixed, but the displacement of all the soil above the hole is not fixed. This is similar to the actual excavation and reinforcement of the tunnel. The actual reinforcement scope is also the soil near the entrance, rather than all the soil above the entrance [24]. With the progress of excavation, the settlement at the depth of 0 m increases slowly. The comparison between the 30 m surface settlement diagram and the 50 m surface settlement diagram shows that the ground settlement at 0 m gradually increases from 3.13 mm to about 3 mm. The settlement of the stable zone ranges from about 2.85 mm to about 2.6 mm.

- (2) Along the excavation direction, the law of surface settlement is similar in each stage: when the shield reaches the target face, the soil in a certain range in front of the target face is uplifted, and small settlement occurs at the target face. The conical shape of the shield machine causes the displacement of the ground surface. The grouting pressure of shield tail reduces the settlement of soil. The application of grouting and lining makes the settlement of soil relatively stable.

4.3. Surface Soil Displacement in Section. Surface settlement at 30 m section is shown in Figures 11–13.

Figure 11 is the surface settlement diagram of soil mass at 30 m section when the shield head of the shield machine reaches 30 m.

- (1) The maximum value of surface settlement is about 0.82 mm, and the maximum value of uplift on both sides is about 0.28 mm
- (2) The range of surface subsidence is –9–9 m, which is about within the 3D range

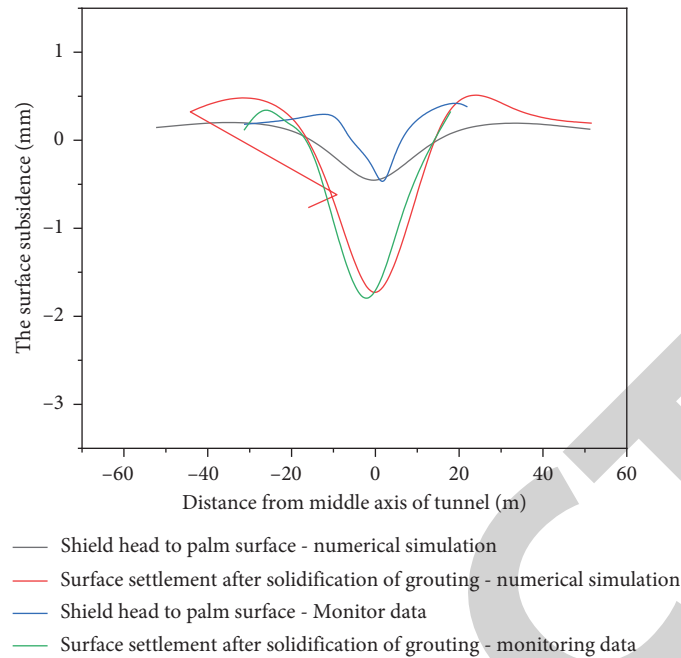


FIGURE 14: Comparison of monitoring data and numerical simulation results.

Figure 12 shows the surface settlement of soil at a section of 30 meters when the shield head of a shield machine reaches 40 meters. At this point, solidified grouting body and lining were applied at 30 meters (8 m shield machine length +1 m grouting pressure +1 m grouting body and lining), as shown in the figure:

- (1) The maximum value of surface subsidence is about 3.05 mm, and the maximum value of uplift on both sides is about 0.93 mm
- (2) The range of surface subsidence is $-9-9$ m, which is about within the 3D range

Figure 13 shows the surface settlement of soil at a section of 30 meters when the shield head reaches 50 meters. At this time, the solidified grouting body and lining were applied at 30 meters, as shown in the figure:

- (1) The maximum value of surface settlement is about 2.67 mm, and the maximum value of uplift on both sides is about 1.89 mm
- (2) The range of surface subsidence is $-7-7$ m, about 2.2 d

4.4. Comparison of Numerical Simulation Results and Monitoring Data. The comparison between monitoring data and numerical simulation of surface subsidence is shown in Figure 14.

When the shield reaches the target palm surface, the maximum settlement value of monitoring data is 0.59 mm. The maximum settlement value of numerical simulation is 0.82 mm, with a difference of 0.23 mm. The maximum value of uplift on both sides of the tunnel is 0.41 mm in monitoring data and 0.29 in numerical simulation, with a difference of 0.12 mm. The settlement

value of numerical simulation is slightly larger than that of monitoring data.

Comparison of surface settlement after grouting solidification: the maximum settlement value of monitoring data is 2.59 mm, and the maximum settlement value of numerical simulation is 3.05 mm, with a difference of 0.46 mm. The maximum value of uplift on both sides of the tunnel is 0.32 mm in monitoring data and 1.89 mm in numerical simulation, with a difference of 1.57 mm. The settlement value of numerical simulation is slightly larger than that of monitoring data.

4.5. The Results of 3D Numerical Simulation Are Compared with Those of 2D Numerical Simulation. As can be seen from the comparison diagram of results shown in Figure 15, the results of three-dimensional numerical simulation have the following advantages compared with those of two-dimensional numerical simulation:

- (1) Compared with the results of 2d numerical simulation, the width of the settlement trough is narrower and closer to the monitoring data
- (2) It can simulate the state of soil uplift on both sides, while two-dimensional numerical simulation can only simulate the effect of settlement

The results of three-dimensional numerical simulation have the following shortcomings compared with those of two-dimensional numerical simulation:

- (1) The results of three-dimensional numerical simulation of the maximum value of surface subsidence are relatively large. When the shield reaches the palm surface, the maximum surface settlement in the monitoring data is about 0.6 mm, while the

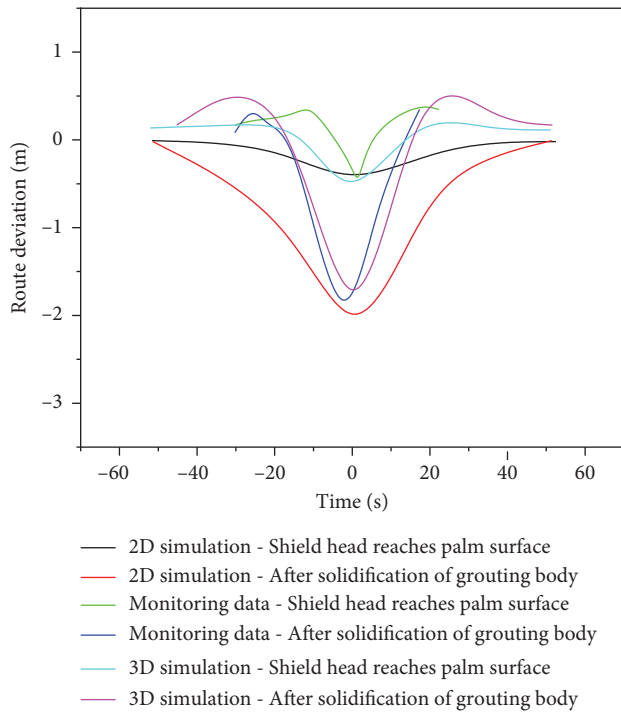


FIGURE 15: Comparison of 2D and 3D numerical simulation results.

maximum settlement in the 3D simulation results is 0.9 mm. After the solidification of the grouting body, the maximum surface settlement in monitoring data is about 2.6 mm, while the maximum settlement in 3D numerical simulation is about 3 mm.

- (2) After the solidification of the grouting body, the simulated uplift value of soil on both sides of 3D numerical simulation is relatively large.

5. Conclusion

In this essay, three-dimensional finite difference software FLAC 3D is used to establish a three-dimensional modeling method with fine modeling. The effects of trapezoidal support force, cone shape of the shield machine, trapezoidal grouting pressure, solidification of the grouting body, and timely application of lining on soil displacement are considered comprehensively. The main conclusions are as follows:

- (1) The soil deformation caused by shield construction is a dynamic process with obvious three-dimensional characteristics. Along the excavation direction, the displacement characteristics of soil mass in tunnel vault and ground surface change with the different excavation stages.
- (2) Fine three-dimensional numerical simulation can accurately simulate the characteristics of soil displacement in each stage.
- (3) The conical shape of the shield machine will make the gap between the shield head and the shield body,

and between the shield body and the shield tail, which will cause the displacement of the soil at the tunnel vault, and then affect the surface settlement.

- (4) The application of trapezoidal grouting pressure can reduce the large soil settlement caused by excavation in the early stage, which is a method to reduce the soil settlement in shield construction.
- (5) Timely application of lining will stabilize soil settlement within a certain range, so timely application of lining is very important in actual construction.
- (6) Compared with the two-dimensional numerical simulation results, the three-dimensional numerical simulation can not only simulate the surface settlement of the section, but also simulate the soil displacement along the excavation direction.
- (7) In the numerical simulation of surface settlement in section, the three-dimensional numerical simulation can simulate the state of soil uplift on both sides, and the width of settlement groove is in good agreement with the monitoring data.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Application of Ergonomics in Product Design Based on Computer-Aided Design

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At present, China's social economy has entered a new state of normalized development. Since green economy is the strategic goal pursued by sustainable economic development and the core development trend of the economy, industrial product design focuses on design humanization and green production above. The principle of ergonomics is applied in the design of industrial products, which has the function of optimizing the scientificity of industrial products, which makes industrial products more humanized. This paper firstly analyzes the basic concept of ergonomics, then expounds the thinking of ergonomics in industrial product design, and expounds the specific application of ergonomics in industrial product design.

1. Introduction

Ergonomics is mainly the study of the theory of the relationship between people, the environment, and products. With the development of my country's economy, the green economy has gradually become the core of economic development, and the humanization and greening of industrial product design has become the focus of product design. Therefore, this paper analyzes and expounds on the specific application of ergonomics in industrial product design, and its main purpose is to optimize industrial products. As a necessary theory to achieve the goal of sustainable human development, ergonomics mainly studies the cross-theory of the relationship between people and the environment, people and products, and the environment and products [1]. Ergonomics integrates various types of scientific theories such as psychology, bloodless, engineering technology, and ecological concepts and organically combines the objective requirements of the ecological environment, the actual needs of human beings, and product functions, so as to realize the real environment. Industrial products can be more ecological, scientific, and humanized. The application of ergonomics in the process of industrial product design is mainly to guide the design process of industrial products and to determine the design results of industrial products. Faced

with the background of continuous social and economic development, the demand for industrial products continues to increase, and the concept of ergonomics has been developed simultaneously. The concept of ergonomics is applied to the design of industrial products, and it is used in the application of industrial product design. Considering the strategy to be studied, the premise is to master the concept of advanced nature [2]. At present, in the design of industrial products in my country, green design is mainly used. There are two ergonomics concepts in virtual design, among which virtual design is the most widely used concept. The reason is that the design effect of virtual design can meet the needs of humanization and capital saving.

With the help of computer virtual technology, not only can the industrial product design be adjusted more accurately, but also the design time and material cost can be effectively saved. The concept of green design is based on the application of scientific principles, combined with the relevant national economic development policies and environmental factors, and its main purpose is to upgrade the humanized service function of industrial products from the individual level to the social level. Adopt the green design concept as the core of industrial product design guidance, and then design industrial products that meet the needs of the actual environment first, thereby significantly improving

the use value of industrial products in real life. The core principle of green design is to comprehensively coordinate the relationship between industrial products, the ecological environment, and human beings and to surpass human-centered design with people as the center, so the designed industrial products can keep pace with the development of the times [3].

The basic link of industrial product design is the product appearance design. The basis of product appearance design mainly includes the practical application and internal structure of the product. After the application of ergonomics in the appearance design of industrial products, it not only realizes the aesthetic requirements of product appearance but also realizes the requirements of modern fashion trends, thereby reducing the loss caused by fashion trends to product replacement [4]. The application of ergonomics in the design of industrial products makes industrial products conform to the long-term aesthetic requirements of human beings, thereby providing a guarantee for the lasting competitiveness of products in the market environment. For example, the design of Apple series products, whose appearance looks relatively simple, is still loved by many consumers around the world and has maintained a long-term competitive advantage in the fierce market. According to the principle of mechanical engineering, although the appearance of the designed product seems simple, it lacks a very rich connotation. The Apple series of products designed by the company can induce people to feel joy from the heart and ensure that consumers can use them for a long time, so it not only meets the needs of humanization but also meets the needs of saving product consumption costs [5].

As far as industrial products are concerned, they are in a dynamic state or in a static state, and industrial products can still convey some kind of information just like human beings. Such information comes from the active observation of human beings rather than the active behavior of industrial products. People observe things through the senses of sight, hearing, smell, and touch. Therefore, the application of ergonomics in industrial product design should include all the above dimensions, and then three-dimensional and multidimensional industrial product design should be carried out. The main purpose of this is to ensure that industrial products can convey positive information to people and to achieve the consistency of the information transmission process with the human body's receiving habits, so as to prevent the troubles caused by receiving information [6].

The key part of the direct contact between industrial products and people is the operating device. On the one hand, the humanized design can provide convenience to the operator, and on the other hand, it can effectively exert the performance of the industrial product itself. Most industrial products use human hands as the design basis to carry out product design work in the design of operating levers, touch screens, and other links [7]. Taking ergonomics as a consideration, the industrial product operating device fully demonstrates the added value beyond the product's own function, and in terms of the product's own added value, it mainly reflects fairness and convenience. Among industrial products, there are some products with complex operability

that better meet the requirements of humanized product design, and such products are more competitive; that is, they are more suitable for the needs of the market environment [8]. For example, there are too many complex operations in agricultural machinery and equipment. These operations are difficult for farmers to master. Therefore, agricultural machinery and equipment with simple and convenient designs are more in demand in the market. For example, the shape design of the position of the backpack is mainly based on the shoulder structure and bearing capacity of the human body. Such a detailed design can better reflect humanization and provide the convenient application. Therefore, this type of engineering product has significant market competitiveness [9].

2. An Overview of Ergonomics Theory

2.1. The Concept of Ergonomics. Regarding the International Association of Ergonomics (IEA), ergonomics is the study of various factors in human anatomy, physiology, and psychology in a certain working environment. Interaction with machines and the environment in which they are used is a discipline that studies how to consider issues such as work efficiency, human health, safety, and comfort at work, in family life, and on vacation [10].

Ergonomics is a comprehensive frontier discipline that studies the interaction between people, machines, and their working environments and has an extremely wide range of research and applications. In the course of its own development, the discipline has continuously improved its basic theories, theoretical systems, research methods, and technical standards and norms, gradually breaking the boundaries between various disciplines, and organically integrating the theories of various related disciplines. In addition to being closely related to related engineering technology disciplines, ergonomics is also closely related to physiology, psychology, anthropometrics, environmental protection, cybernetics, and information theory [11].

Ergonomics is based on people's physiological and psychological characteristics, aiming to improve people's work and life quality, using the viewpoints and methods of systems engineering and information processing psychology to study people and machinery, people and environment in the field of production. The interaction between machinery and the environment provides a more comprehensive basis for the design and use of the human-machine system by revealing the law of the relationship between the three elements of human, machine, and environment, thereby ensuring the optimization of the overall performance of the human-machine system. It provides a theoretical basis and method for designing a "man-machine-environment" system that is easy and labor-saving, accurate, safe, efficient, and comfortable [12].

2.2. The Origin and Development of Ergonomics. As an independent discipline, modern ergonomics originated in Europe in the 20th century, formed in the United States, and developed during the Second World War. The development

of industrialized mass production prompted the gradual formation of this discipline. In the process of formation and development of this discipline, it has experienced three periods: empirical ergonomics, scientific ergonomics, and modern ergonomics.

2.2.1. Experience Ergonomics. Beginning at the end of the 19th century, in order to improve production efficiency, a group of pioneer scholars represented by Taylor in the United States began to study the relationship between people and tools, operation methods, and work efficiency. At that time, most of ergonomics scholars were psychologists, and their research also focused on psychology. In production practice, they advocated the use of psychological methods to select and train workers. To improve labor conditions and increase production efficiency, the research focuses on “how people adapt to machines” [13].

2.2.2. Scientific Ergonomics. During World War II, weapon systems became increasingly large and complex. However, due to the one-sided focus on the functional research of new weapons and equipment, personnel have been unable to adapt to the performance requirements of new weapons that are constantly developing, so a large number of accidents are often caused due to operational errors, resulting in great material and personnel losses [14]. Through analysis and research, people realize that to design high-efficiency equipment, only engineering and technical knowledge is far from enough, and knowledge of physiology, psychology, anthropometrics, biomechanics, and other disciplines is also necessary. The research and application of “human factors” in the military field have had a huge impact on automobiles, aircraft, electronic equipment, household appliances, highway signs, aerospace medicine, and other disciplines and industries, so ergonomics gained rapid development in the 1950s. Development of scientific ergonomics was as follows. In 1949, the United Kingdom first established the Ergonomics Research Society, which issued the journal “Ergonomics” in 1957, which has now become an international publication. The International Ergonomics Association (IEA) was established in 1960, the first International Ergonomics Conference was held in 1961, the All-Soviet Institute of Technical Aesthetics of the former Soviet Union was established in 1962, and the Department of Ergonomics was established in 1963. In the same year, Japan established the Ergonomics Society, and France also established the Ergonomics Society in the same year. These institutions and academic exchange conferences have played a strong role in promoting the research and development of ergonomics, bringing international ergonomics research to a new level. At this stage, the two elements of “human” and “machine” have simultaneously become the focus and main content of ergonomics research [15].

2.2.3. Modern Ergonomics. In the late 1960s, due to the advancement of science and technology, such as the establishment of new theories such as cybernetics, information

theory, and system theory, it provided a new theoretical basis for human engineering and also put forward new requirements for the research of this discipline. The subject of ergonomics has entered the research stage of the system; that is, the development stage of modern ergonomics [16]. At this stage, people have carried out new research and interpretation on the three elements of human, machine, and environment in ergonomics through various aspects of human science, behavioral science, technical science, environmental science, and social science. The overall coordination and interaction among several elements are emphasized to maximize the comprehensive effect.

My country's ergonomics as a discipline started late but developed rapidly. In 1980, the National Ergonomics Standardization Technical Committee was established, and in 1989, the Chinese Society of Ergonomics (CES) was established, under which the Ergonomic Professional Committee was established. The Institute of Psychology of the Chinese Academy of Sciences and some institutions of higher learning have established ergonomics research institutions. At present, the application of ergonomics in various fields in China is also increasingly extensive and in-depth.

In recent years, with the widespread application of computer technology, especially the development of computer graphics, virtual reality technology, and high-performance graphics systems, a large amount of new experimental equipment and methods have emerged, and people's research on ergonomics is not easy. It is limited to simple applications based on data accumulation and statistics, but makes full use of the high-performance graphics computing capabilities of computers to establish a graphical, interactive, realistic, physical model-based virtual environment design evaluation and simulation verification platform [17]. The research direction of international ergonomics focuses on workload research, work environment research (physiological and psychological effects of people in the work environment), information display, especially computer terminal, human factors research in the terminal display, computer design and use of people Mechanical engineering research, safety management and human reliability research, measurement and evaluation of work effectiveness, intelligent simulation of robot design, etc. [18].

2.3. The Research Content of Ergonomics. The main content of ergonomics research is the “human-machine-environment” system, referred to as the human-machine system. Human, machine, and environment, which constitute the three major elements of the human-machine system, can be regarded as three relatively independent subsystems in the human-machine system, which belong to the research categories of behavioral science, technical science, and environmental science, respectively. According to the first law of systematics, we know that the overall attribute of the system is not equal to the sum of the attributes of each part, and its specific situation depends on the organization of the system and the degree of synergy within the system [19]. Therefore, the study of ergonomics should not only study the properties

of each subsystem of human, machine, and environment, but also study the overall structure and properties of the human-machine system. The ultimate goal is to make the overall performance of the human-machine-environment system reach the best state, that is, to meet the indicators of comfort, pleasantness, safety, efficiency, and economy. Figure 1 shows the three elements of ergonomic design.

The research content of ergonomics includes several aspects.

2.3.1. The Study of Human Characteristics. It mainly studies human body morphological characteristics, human perception characteristics, human response characteristics, and human psychological characteristics in labor. It is the basis for human-machine system design.

2.3.2. Research on the Overall Design of Human-Machine System. It is to adapt the “machine” to the human body as a whole and reasonably allocate the functions of the human and the machine according to the respective characteristics of the human and the machine, so that they can play their respective strengths in the human-machine system, learn from each other’s strengths and weaknesses, and organically cooperate to ensure the system function is optimal.

2.3.3. Design Research on Workplaces and Information Delivery Devices. Workplace design generally includes workspace design, seating design, workbench and console design, and the overall layout of the workplace. The purpose of studying the design of the workplace is to ensure that the physical environment is suitable for the characteristics of the person, so that people can work in a posture that is not harmful to health. The information exchange between man, machine, and environment is accomplished through the display and controller on the man-machine interface [20]. In order to exchange information between man and machine quickly and accurately and not to easily make people tired, it is necessary to study the display to match the characteristics of the human sense organs, the controller to match the human effector, and the relationship between their inter-ordination issues.

2.3.4. Environmental Control and Safety Protection Design. In terms of environmental control, it should be ensured that common operating environments such as temperature, humidity, lighting, noise, vibration, color, and air quality are suitable for the requirements of operators. The safety protection design shall ensure that the operator is protected from pain, disease, injury, or casualty caused by the operation.

2.4. Research Methods and Application Fields of Ergonomics. The common methods of ergonomics research are observation method, actual measurement method, experimental method, simulation and model test method, computer

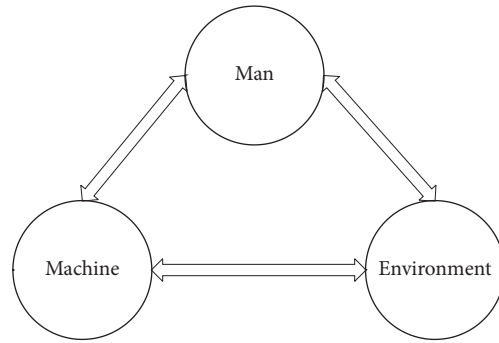


FIGURE 1: Three elements of ergonomic design.

numerical simulation method, analysis method, investigation and research method, etc. In practical research and application, it is generally a comprehensive application of a variety of methods. As modern man-machine systems become more and more complex, not only is the use of physical simulation and model methods to study complex man-machine systems costly and time-consuming, but also it is difficult to modify and change the simulation and model devices once they are finalized. With the help of modern computer technology and sensor technology, the method of virtual simulation analysis of 3D measurement has become a scientific and efficient means of ergonomics research [21].

Ergonomics has a dual role in product system design, not only applying the collected empirical data to product design, but also evaluating the quality of the design. Therefore, ergonomics has been applied to varying degrees in the following fields: (1) work accidents, health, and safety; (2) human work behavior anatomy and anthropometric measurements; (3) human-machine interface design and evaluation; (4) display and control layout design; (5) office ergonomics and design; (6) user requirements and user guidance; (7) vehicle, aircraft, traffic ergonomics, etc.

3. Research Methods and Ideas

3.1. Research Methods. This paper focuses on theoretical research, analyzes the problems of actual products, discusses the influence of modern product design ideas on products and the environment in design and development, and has guiding significance for the future development of products. By analyzing the products under the standardized commercial production mode, the feasibility study of product customization and individualization is realized, and the relationship between family product design, environment, and living space is explored, and theoretical research is carried out to build a more harmonious dialectical relationship between product function and artistic design [22].

This paper hopes to provide product designers with help in the theoretical research of human-machine design methods in the design process and also hopes to find a method of organically combining product design and human-machine design, hoping to bring people a new design concept. Figure 2 shows the research method and technology roadmap.

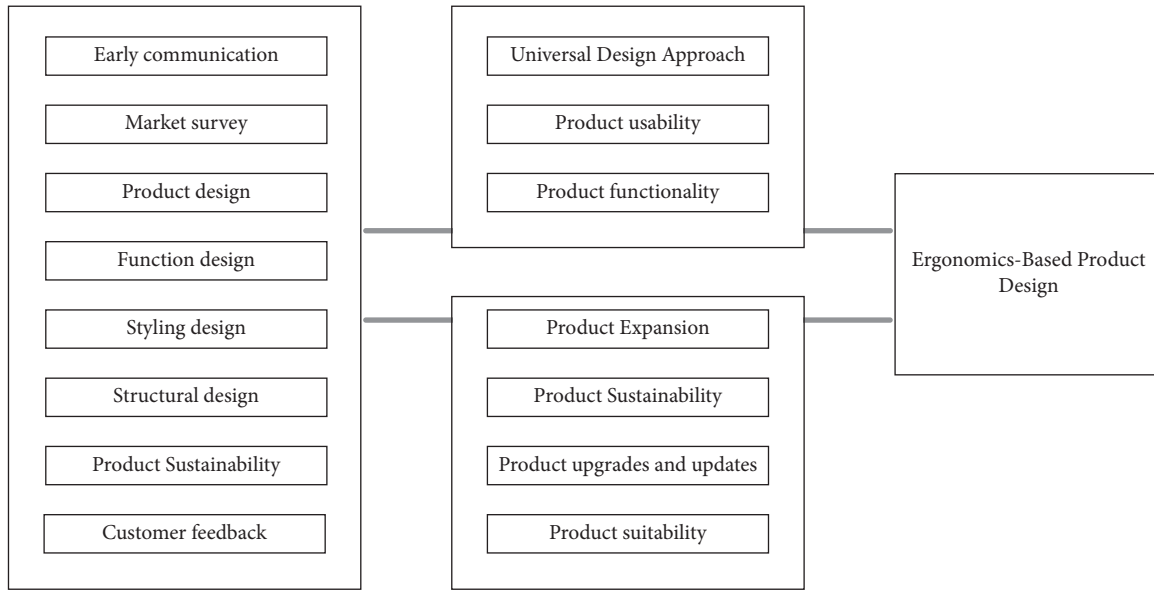


FIGURE 2: Research methods and technology roadmap.

3.2. Research Ideas. As a highly interdisciplinary subject, ergonomics has become an important scientific basis for guiding design disciplines to conduct design research. In the case of satisfying human perception, considering the load capacity of physical and mental strength, combined with the influence of environmental factors, the design of ergonomics will play a more active role in various fields. Figure 3 shows the systematic study of ergonomics.

- (1) The main research contents include the following:
 - (1) In realistic design, consider the relationship between human and machine in terms of division of labor and cooperation.
 - (2) In the actual design, consider the design of information transmission, man-machine interface, and controller.
 - (3) In the actual design, consider realizing the most perfect cooperation between machines and people in a certain environment.
2. The main method in ergonomics in solving the “human” problem of the system is as follows:
 - (1) Create machines and environments suitable for people to use.
 - (2) Design better machines to adapt to the environment. In the process of the development of ergonomics, consider changing the way of thinking and adjusting the ideological foundation, taking people as the premise for optimization consideration, which greatly reflects the interests of human beings and puts forward the concept of “interaction,” which is more prominent and in line with the trend of ergonomic development.

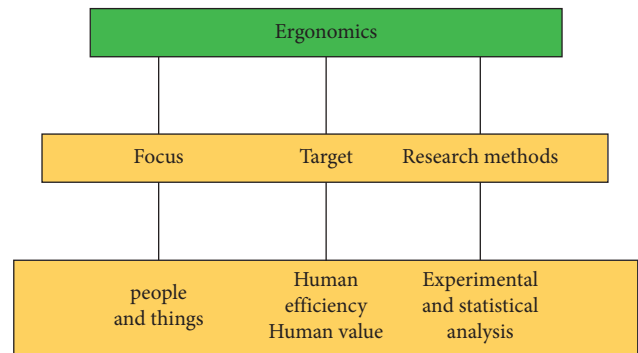


FIGURE 3: Systematic study of ergonomics.

4. Basic Theoretical Models of Ergonomics

4.1. Theoretical Model. The existing theoretical models of ergonomics are mainly set from three aspects: the operating system, the human-machine interface, and the work efficiency of people in the system.

The important concept of ergonomics is “operating system,” which is also the ideological basis of ergonomics. One of the characteristics of ergonomics is that it does not isolate people, machines, and the environment. The system regards people, machines, and the environment as interactive content with specific goals, interdependent, and restrictive [23]. As an organic whole, “system” has its special functions and goals and is composed of multiple components, which interact and depend on each other. Ergonomic research is divided into four levels in the system: comfort, safety, sensitivity, and efficiency. Figure 4 shows the relationship between interaction design and various disciplines.

As the direct contact level of human-machine relationship, its form and content serve as the representation of

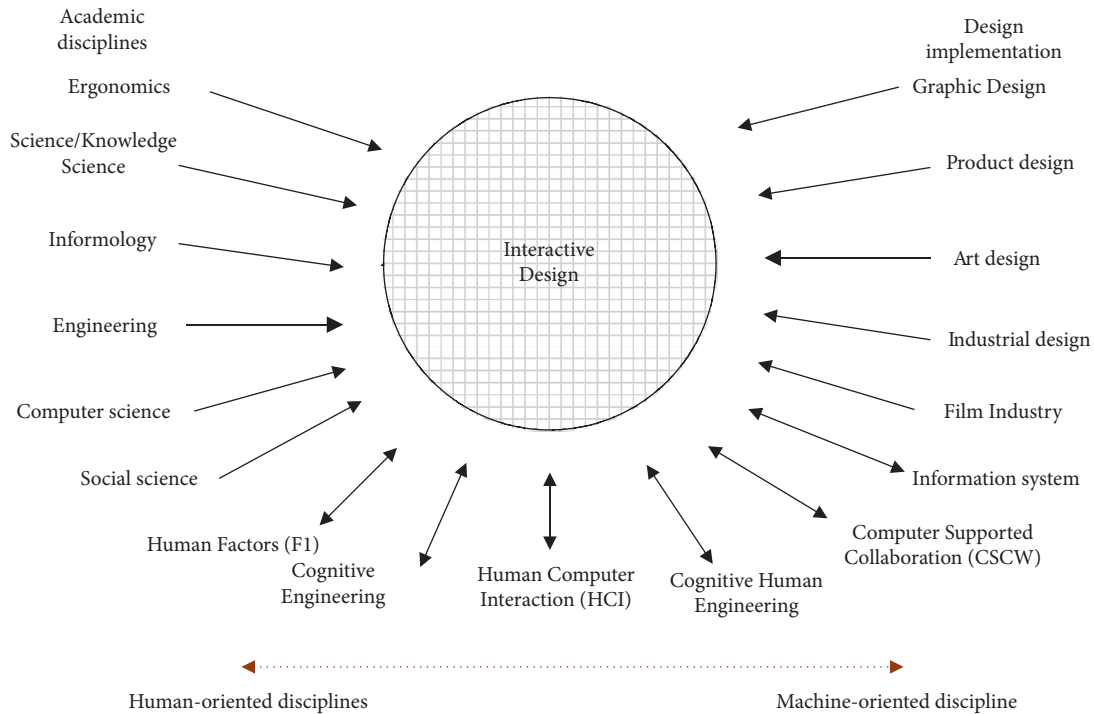


FIGURE 4: The relationship between interaction design and various disciplines.

human-machine relationship, and it is also the core content of ergonomics research. In terms of human-machine interface, ergonomics research can be divided into focus on the perception of human body, cognition, and emotion [24].

As one of the criteria for judging the pros and cons of products, human work efficiency can be divided into three forms: the first is the high-efficiency work form, which is characterized by the “people” with the highest skills, who can complete the most efficient work under the most favorable “conditions.” “Skilled” work: this is the “expectation in advance” that is expected to be achieved in the design; the second is the best efficiency form; the best efficiency is the effect of basically satisfying the system operation requirements under normal “people” under normal “conditions.” The third is acceptable efficiency [25]. Although the system design is optimally designed, the optimal human-machine system matching level cannot usually be obtained. Therefore, “fault tolerance” is an important concept and technology in system design. As long as the errors that appear are within the acceptable and accommodating range of the system, “people” can make mistakes, “conditions” may not be met, but “ability” is not the strongest. Under the different psychological and physiological states of different “people,” according to the different “environments and conditions” used in the work and the differences in the requirements of the task, a work efficiency model of someone, a certain time, and something will inevitably be formed.

In the process of interaction design, we understand user needs and consider how to interact and respond to specific events and consider how users and events interact with each other, which is a very important key in interaction design.

Since interaction design is closely related to various disciplines, the entire design process requires the participation of various people from many disciplines. For example, when considering user psychology and feelings, we need to invite psychologists and sociologists to participate; in order to provide better effect. We also need to ask software engineers to design various types of interactive media; in order to reflect the visual beauty and provide an effective and beautiful interactive interface, we need more artists to participate. At the same time, more needs require the participation of more experts, and more accurate designs have been provided. Conduct psychological pleasure factor research on users who use this type of product, and summarize the user experience factors in the research. The experience content includes satisfaction, excitement, entertainment, freedom, self-confidence, pride, and safety; at the same time, some users do not like it for factors such as being cheated, invaded, anxious, and troubled.

The memory system is composed of three subsystems, including sensory memory, short-term memory, and long-term memory. These three subsystems are in different stages of information processing. The information that enters the short-term memory comes from the sensory memory and the long-term memory. Sensory memory and short-term memory processing must occur first, and in each case, different stages must be processed to adapt to the next stage.

There is a certain contradiction between the user’s experience and usability, which requires a balance in the design, and the actual design is particularly important. Of course, in actual interaction design, there will be products whose usability and experience are mutually exclusive, so the

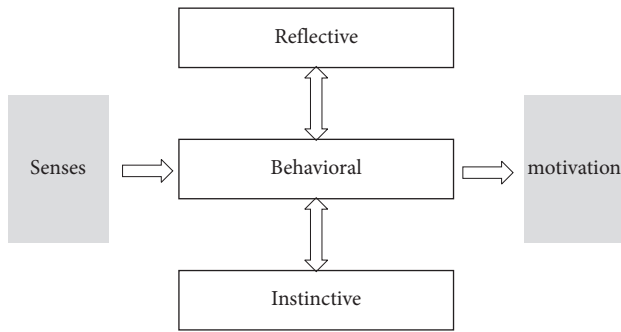


FIGURE 5: The three levels of emotional design.

most important goal in design is user needs, and the design should be suitable for the environment. In order to achieve some specific goals in the design, designers and users have to sacrifice other goals to increase the design cost. In the design, according to the specific requirements of the task and the specific environment of the user, the two goals are balanced to meet the needs of the user to the greatest extent and truly achieve the goal of interactive design.

4.2. Emotional Design and Product Design. Emotional design is the personalized needs of product design, people's pursuit of the spiritual world, the difference in the emotional nature of different human personalities, and an outstanding performance of the human spiritual world, as shown in Figure 5.

The beginning of personalized consumption means the end of material homogenization. The popular consumption patterns in the original industrial age have been gradually replaced, and the existing personalized consumption has become a new consumption hotspot. The market retention rate of customized products is increasing year by year, and people's spiritual and cultural needs have highlighted the importance of emotional design in product design. When designing products, fully consider the individual requirements of users, carry out personalized designs according to the differences of users in various aspects such as age, gender, social experience, etc., and focus on emotional design, so as to truly achieve the "people-oriented" design.

Emotional design is divided into three levels, namely, reflection level, behavior level, and instinct level, which is mentioned by Professor Donald A. Norman in the book *Emotional Design*: instinct level (visceral level) is the automatic preset level; the behavioral level (behavioral level) contains the part that controls the daily behavior of the brain activity; the reflective level (reflective level) is the part of the brain thinking. Through the above part, we have learned that "people's emotional needs are actually expectations that objective things conform to their own physiology, behavior, thinking and judgment standards, so as to achieve perceptual identity and obtain a good overall experience." As psychologist BN Donohoff said, "Human emotion is a complex state formed by the integration of various emotions of appropriate intensity, and the pursuit of personality is actually part of the emotional pursuit."

5. Conclusion

After decades of development, ergonomics has formed a relatively mature concept system, and various types of application methods have appeared in practical applications, which not only provide auxiliary functions for industrial design, but also effectively promote the development of industrial design. With the goal of the development of science and technology and the improvement of economic level, the theory of ergonomics has been perfected, and it has included a variety of disciplinary research methods to carry out research on the characteristics of human body structure and skill characteristics. The influencing factors of psychological state and work efficiency are discussed.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Retraction

Retracted: Quantitative Evaluation Model of Stock Market Liquidity by Macroeconomic Factors

Mathematical Problems in Engineering

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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] K. Wang, "Quantitative Evaluation Model of Stock Market Liquidity by Macroeconomic Factors," *Mathematical Problems in Engineering*, vol. 2022, Article ID 5259955, 12 pages, 2022.

Research Article

Quantitative Evaluation Model of Stock Market Liquidity by Macroeconomic Factors

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In order to further understand the effects of macroeconomic factors on the stock market volatility and liquidity and solve the problem that the traditional volatility measurement model loses high-frequency data information in the modeling of the influence of macroeconomic factors on stock market volatility, monthly consumer price index, daily exchange rate, and monthly money supply are taken as the main indicators to investigate the stock market liquidity in the research. Meanwhile, CARCH-MIDAS model is used to investigate the factors affecting stock market liquidity. Through the model test, it is found that the H value of the volatility effect model of the three factors is 0.0307, and the H value of the horizontal effect model is 0.0220, and the result of the horizontal effect model is closest to 1%. The results show that CARCH-MIDAS model is relatively accurate in quantitative evaluation and prediction of the stock market liquidity and volatility.

1. Introduction

The stock market has always been the “barometer” for the prediction of macroeconomic changes in a country and a region, and it is an important part of a country’s economy [1]. The stock market plays a crucial role in financing, resource allocation, and risk avoidance of a country. However, its internal mechanism and corresponding rules and regulations are still not perfect from the perspective of the development status of China’s stock market. This also leads to the fact that the country’s macroeconomic regulation policies must be used to avoid the large fluctuations in the stock market to a large extent [2]. In the process of traditional stock market volatility measurement model in the research of macroeconomic factors on the impact of the stock market liquidity and volatility, the same frequency data are mostly used to model. This method actually loses valuable information of high frequency data contains data, which are not conducive to explore the practical impact of macroeconomic for the stock market liquidity from the angle of the objective. Therefore, the method of constructing CARCH-MIDAS model is proposed to better investigate the influencing factors of stock market liquidity and provide scientific data

reference for the quantitative evaluation and prediction of the stock market liquidity and volatility [3].

2. Literature Review

Hyeon connected the realized measure with the return rate and the volatility of stocks and constructed the realized GARCH model [4]. The GARCH model based on high-frequency data is studied to improve the prediction ability of volatility. The prediction effects of GARCH model on the stock market volatility under different distributions are compared with the empirical results. Because of the normal distribution we cannot describe the volatility “sharp peak and thick tail” characteristics effectively.

Zkul proposed the realized GARCH model in which the residual distribution was subject to the standard T-distribution and partial T-distribution and proved that compared with the standard normal distribution, the model of the standard T-distribution and partial T-distribution was more accurate in the prediction effect [5]. EGARCH model was superior to GARCH model in predicting the volatility. Yoon put forward the realized EGARCH model considering the leverage effect of the volatility and proved that the realized

EGARCH model could significantly improve the prediction ability of the stock market volatility [6]. The tail correlation between financial industries was studied by the realized EGARCH and time-varying Copula models. It was proved that the EGARCH model based on partial distribution had the best fitting effect and prediction. Considering that selecting different realized measures could change the prediction effect of the model, by comparing different realized measures, it was found that more accurate prediction results could be obtained by using the realized kernel with market noise removed. In addition, the realized volatility was combined with GARCH model. Yu considered the leverage effect of the volatility on the basis of stochastic volatility (SV) model and constructed the realized SV(RSV) model to discuss the prediction effect of the volatility [7].

Kim used Spline GARCH-MIDAS, the volatility component decomposition model of the stock market, to analyze the relationship between macroeconomy and stock market volatility in multiple regions. The findings suggest that some macroeconomic changes, such as GDP and CPI, correlate with the long-term effects of changes in the stock market [8].

Zaidanin analyzed the Shanghai Composite index and macroeconomic variables such as money supply, retail sales of consumer goods, and IP based on multiple regression model, and empirically showed that the Shanghai Composite Index was positively correlated with macroeconomic variables such as money supply and retail sales of consumer goods, while negatively correlated with household savings [9].

Viktorov used the GARCH-MIDAS model to study the relationship between industry volatility and macroindustry, and the results show that both the level and change of income value are positive. The level of CPI, the level of exchange rate, and the constant fluctuation have all had a negative impact on the exchange rate of China's bulk commodities [10].

3. Mixed-Frequency Data Volatility Model

3.1. Mixed-Frequency Data Sampling (MIDAS) Model. In order to solve the problem of data frequency in modeling, a compound regression model (MIDAS) regression model was prepared by the method of commercial modeling [11, 12]. The expression of the distributed lag model is as follows:

$$Y_t = \beta_0 + \beta_1 B(L)X_t + \varepsilon_t. \quad (1)$$

In (1), $B(L)$ is a multimarket function, but business models are often used to analyze relationships over time.

Different from the distributed lag model, MIDAS model describes the relationship between explanatory variables and explained variables at different frequencies, and the weight function is introduced to the hysteresis polynomial to better deal with data with different frequencies and significantly improve the prediction ability of the model. The MIDAS model can be expressed as follows:

$$Y_t = \beta_0 + \beta_1 B(L^{1/m}; \omega)X_t + \varepsilon_t. \quad (2)$$

In Formula (2), $B(L^{1/m}; \omega)$ is a weighted polynomial function, namely:

$$B(L^{1/m}; \omega) = \sum_{k=1}^K \phi(k; \omega) L^{k/m}. \quad (3)$$

In Formula (3), K represents the maximum lag period, and $L^{k/m}$ represents the lag operator:

$$L^{k/m} X_t = X_{t-k/m}, \quad k \in [1, K]. \quad (4)$$

There are many forms of the selection of the weight function, mainly including the following three forms:

(1) Almon Weight Function:

$$\phi(k, \omega) = \frac{\omega_1 k + \omega_2 k^2 + \dots, \omega_Q k^Q}{\sum_{k=1}^K (\omega_1 k + \omega_2 k^2 + \dots, \omega_Q k^Q)}. \quad (5)$$

In Formula (5), Q is the degree of freedom of the lag polynomial, and generally Q is less than K in order to reduce the estimated parameters to $K - Q$.

(2) Exponential Almon Weight Function

$$\phi(k, \omega) = \frac{\exp\{\omega_1 k + \omega_2 k^2 + \dots, \omega_Q k^Q\}}{\sum_{k=1}^K \exp\{\omega_1 k + \omega_2 k^2 + \dots, \omega_Q k^Q\}}. \quad (6)$$

When $Q = 2$, its general constraint condition is $\omega_1 \leq 300, \omega_2 < 0$.

(3) Beta Weight Function

$$\begin{aligned} \phi(k; \omega_1; \omega_2) &= \frac{f(k/K; \omega_1; \omega_2)}{\sum_{k=1}^K f(k/K; \omega_1; \omega_2)}, \frac{k}{K} = x, 0 < x \leq 1, \\ f(x; \omega_1; \omega_2) &= \frac{\Gamma(\omega_1 + \omega_2)}{\Gamma(\omega_1)\Gamma(\omega_2)} x^{\omega_1-1} (1-x)^{\omega_2-1}, \Gamma(\omega) = \int_0^\infty e^{-x} x^{\omega-1} dx. \end{aligned} \quad (7)$$

The above three weight functions all have their own advantages and disadvantages, but the beta weight function is more widely used, so the weight function used in the construction of the mixing model in the research is the beta weight function [13, 14].

3.2. GARCH-MIDAS Model. Since the volatility has the characteristic of “sharp peak and thick tail,” GARCH model can well describe the nature of volatility, so most literature on the stock market volatility use GARCH model [15, 16]. The yield Formula in the model is

$$r_{i,t} = \mu + \sqrt{\tau_t g_{i,t}} \varepsilon_{i,t}, \forall i = 1, 2, \dots, N_t, \quad (8)$$

In Formula (8), $r_{i,t}$ represents the logarithmic rate of return on the i th day of the t th month. μ is usually assumed to be constant and 0. $\tau_t, g_{i,t}$ are the long-term and short-term components of conditional variance, respectively. $\varepsilon_{i,t}$ is the random disturbance term in the Formula, and

$$\varepsilon_{i,t} | \Phi_{i-1,t} \sim N(0, 1). \quad (9)$$

That is, $\varepsilon_{i,t}$ obeys the standard normal distribution under the condition of $\Phi_{i-1,t}$. In Formula (9), $\Phi_{i-1,t}$ represents the historical information set, and N_t is the number of days in the t th month. The short-term component $g_{i,t}$ of volatility follows the GARCH(1,1) distribution, namely:

$$g_{i,t} = (1 - \alpha - \beta) + \alpha \frac{(r_{i-1,t} - \mu)^2}{\tau_t} + \beta g_{i-1,t}. \quad (10)$$

In Formula (10), α, β are parameters, $\alpha > 0, \beta > 0$, and $\alpha + \beta < 1$. τ_t represents the long-term component of volatility. The realized volatility RV_t is used to model the long-term component τ_t , which is expressed as follows:

$$\tau_t = m + \theta \sum_{k=1}^K \phi_k(\omega_1, \omega_2) RV_{t-k}. \quad (11)$$

In Formula (11), the realized volatility RV_t is

$$RV_t = \sum_{i=1}^{N_t} r_{i,t}^2. \quad (12)$$

In Formula (12), K represents the maximum lag order of the variable and $\phi_k(\omega_1, \omega_2)$ is a weight formula constructed based on Beta polynomial function. In order to avoid excessive parameters, parameter estimation of the model is simplified by referring to Engle (2008). Therefore, $\omega_1 = 1$ is assumed in the research and polynomial function with single weight is used, namely:

$$\phi_k(\omega_1, \omega_2) = \frac{f(k/K; \omega_1, \omega_2)}{\sum_k^K f(k/K; \omega_1, \omega_2)}. \quad (13)$$

In Formula (13),

$$f(x; \omega_1, \omega_2) = \frac{\Gamma(\omega_1 + \omega_2)}{\Gamma(\omega_1)\Gamma(\omega_2)} x^{\omega_1-1} (1-x)^{\omega_2-1}, \quad (14)$$

$$\Gamma(\omega) = \int_0^\infty e^{-x} x^{\omega-1} dx.$$

The above formulas together constitute the GARCH-MIDAS model of realized volatility, which is expressed as follows:

$$r_{i,t} = \mu + \sqrt{\tau_t g_{i,t}} \varepsilon_{i,t}, \quad (15)$$

$$g_{i,t} = (1 - \alpha - \beta) + \alpha \frac{(r_{i-1,t} - \mu)^2}{\tau_t} + \beta g_{i-1,t}.$$

In order to make more effective use of data, t is logarithmically processed to obtain:

$$\log \tau_t = m + \theta \sum_{k=1}^K \phi_k(\omega_1, \omega_2) RV_{t-k}. \quad (16)$$

The above formula is the logarithmic GARCH-MIDAS model.

3.3. Building a GJR-GARCH-MIDAS Model Based on Changed Knowledge

3.3.1. Volatility Decomposition Theory. Scientists around the world now generally believe that volatile markets lead to long-term weakness and short-term product defects. The GARCH-MIDAS model developed by Engle (2012) is one of the models conforming to the volatility decomposition theory. This model can be gradually developed from GARCH model [17, 18]. The traditional GARCH(1,1) model is shown as follows:

$$r_i = \mu + \sqrt{h_t} \cdot \varepsilon_t, \varepsilon_t \sim N(0, 1), \quad (17)$$

$$h_t = w + \alpha \cdot (r_t - \mu)^2 + \beta \cdot h_{t-1}. \quad (18)$$

In formulas (17) and (18), r_t is the daily return rate of the stock market, and μ is a constant term. Further, the theory based on volatility decomposition can be expressed as follows:

$$r_{i,t} = \mu + \sqrt{\tau_t \cdot g_{i,t}} \cdot \varepsilon_t, \varepsilon_t \sim N(0, 1). \quad (19)$$

As the above model needs to decompose volatility into long-term and short-term components, the long-term component is $g_{i,t}$, and the short-term component is τ_t . t represents the long-term range of weeks, months, or years, and i represents each day.

3.3.2. GJR-GARCH-MIDAS Model Construction. The GJR-GARCH-MIDAS model adopted in the research is based on the transformation of Formula (17). Further, the above

formula is sorted out, where the short-term component is in the following form:

$$g_{i,t} = \left(1 - \alpha - \beta - \frac{\gamma}{2}\right) + \frac{(\alpha + \gamma \cdot I_{i-1,t}) \cdot (r_{i-1,t} - \mu)^2}{\tau_t + \beta g_{i-1,t}}. \quad (20)$$

In Formula (20),

$$I_{i-1,t} = \begin{cases} 0 & \text{if } r_{i-1,t} \geq \mu, \\ 1 & \text{if } r_{i-1,t} < \mu. \end{cases} \quad (21)$$

In Formula (20), $I_{i-1,t}$ describes leverage effect, while γ represents the influence degree of leverage effect [19]. While knowledge of market volatility is rarely used as a long-term indicator, perceived weakness could mean:

$$RV_t = \sum_{i=1}^N r_{i,t}^2. \quad (22)$$

Thus, the long-term component of volatility can be expressed as follows:

$$\ln \tau_t = m + \theta \cdot \sum_k^K \psi_k(w_1, w_2) \cdot RV_{t-k}. \quad (23)$$

In Formula (23), ψ_k is the weight polynomial, and the beta weight function is adopted. K represents the total number of periods of past variable values to be summed up. θ represents the summation effect, reflecting the influence of past realized volatility on the long-term components of current volatility. m is a constant term.

3.4. Building GJR-GARCH-MIDAS Model Based on Macro Economy

3.4.1. Single-Factor Model. According to the volatility decomposition theory, the long-term component is described by a single macroeconomic variable, that is, X_{t-k} is used instead of RV_{t-k} , and the MIDAS term is defined in the following form:

$$\ln \tau_t = m + \theta \cdot \sum_k^K \psi_k(w_1, w_2) \cdot X_{t-k}. \quad (24)$$

In Formula (24), X_{t-k} represents the horizontal value of k period after a macroeconomic variable. The determination of K is generally confirmed according to experience and BIC and other criteria.

3.4.2. Two-Factor Model. The model only determines the impact of macroeconomic changes and does not take other factors into account. Therefore, the researchers decided to incorporate macroeconomic variables and understand stock market volatility in the model to develop a two-factor model [20] which is as follows:

$$\ln \tau_t = m + \theta_{RV} \cdot \sum_k^{K_{RV}} \psi_k(w_1, w_2) \cdot RV_{t-k} + \theta_X \cdot \sum_k^{K_X} \psi_k(w_1, w_2) \cdot X_{t-k}. \quad (25)$$

In Formula (25), K_{RV} is the lag period of realized volatility of the stock market, and K_X is the lag period of macroeconomic variables.

4. Empirical Analysis of Shanghai Composite Index

4.1. Variable Selection and Processing. The data were collected from January 2013 to December 2022 [21, 22]. The Shanghai Composite Index is that the daily trading data were obtained, and its logarithmic return rate was calculated. For the stability of model estimation, the logarithmic return rate was multiplied by 100 [23, 24]. Monthly data are collected for all macroeconomic indicators. However, since GDP is generally calculated quarterly or annually, the research adopts monthly industrial added value (IP) above designated scale as the proxy variable of monthly GDP according to the practice of previous researchers. All data can be obtained from China Tai'an database, RESSET database, China Economic Database, and Tushares data network.

The results of the different characteristics are shown in Table 1 below:

As can be seen from the above, the skewness and kurtosis of all the differences are not 0, and it can be seen for the first time that all the differences do not obey the normal distribution [25–30]. Among them, it can be seen that the yield difference of the Shanghai Composite Index is large, and its kurtosis is also large, indicating that the exchange rate is heavy and the exchange rate is significant close to the means [31–35]. Similarly, it can be seen that the kurtosis of the central parity of the exchange rate reaches 20.67, while the mean value is only 0.00 and the standard deviation is only 0.01. Therefore, it can be known that the value of this variable is very close to 0 with a small variation range.

Since all macroeconomic variables are time series data and are affected by the overall economic environment, the correlation among variables is inevitable. Now the correlation of the data of various macroeconomic variables is analyzed. The results of the analysis are shown in Figure 1.

Among them, CPI represents consumer price index, IP represents industrial added value, income represents financial income, outcome represents financial expenditure, consumption represents total retail sales of social consumer goods, ex_rate represents central parity of exchange rate, con_index represents consistent index, Rate_deposit represents the deposits of financial institutions.

The correlation between M2 and all kinds of deposits in financial institutions is the largest, reaching 0.83, which is easily explained economically. As M2 increases, when China lacks sufficient investment channels, people tend to deposit their funds in banks, so all kinds of deposits in financial institutions increase, and vice versa. Second, it can be seen that the consensus index generally has a strong correlation with other macrovariables. Therefore, it can be said that it can represent the macroeconomy as a whole to some extent. There is a strong correlation between CPI and the total retail sales of consumer goods, because CPI represents the consumer price index, and a moderate increase in the index means that the price of consumer goods rises, which

TABLE 1: Descriptive statistical results of macroeconomic variables.

	Mean	Standard deviation	Partial degrees	Kurtosis
Shanghai index log yield	0.03	1.63	-0.44	4.35
Industrial added value above designated size	0.12	0.05	0.21	-0.06
M2	0.16	0.04	1.13	2.55
Fiscal revenue	0.17	0.13	0.31	0.23
Fiscal spending	0.18	0.14	0.60	1.70
Total retail sales of consumer goods	0.14	0.05	0.48	0.27
Deposits in financial institutions	0.17	0.04	0.50	0.16
The exchange rate of RMB against US dollar	0.00	0.01	-1.93	20.67
Consumer price index	0.02	0.02	0.59	0.27
Consistent index	0.98	0.04	0.12	-1.31

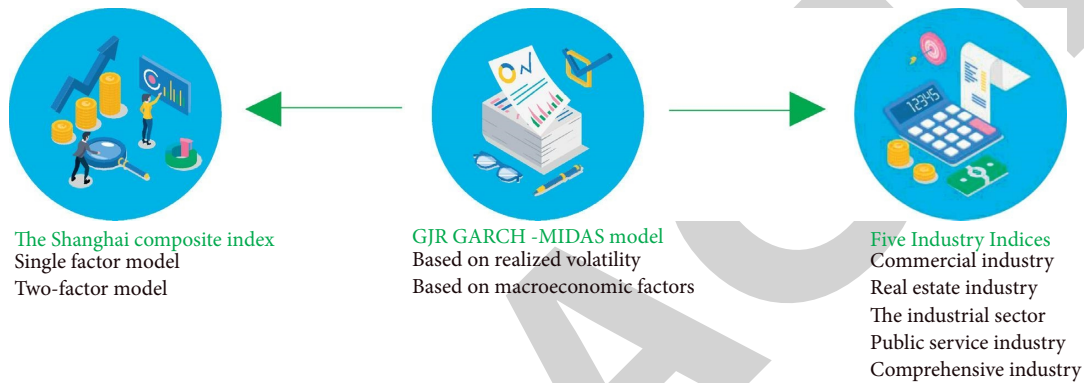


FIGURE 1: Analysis results.

inevitably leads to an increase in the total retail sales of consumer goods. Generally speaking, the correlation between various variables is not extremely strong. Therefore, it is meaningful to investigate the correlation between these variables and stock market volatility separately.

Before modeling and analyzing financial time series, it is usually required that the analyzed series have stationarity [36–42]. If the data is not stable, it indicates that the statistical law of time series is not fixed and will change with time. Therefore, data stationarity test is essential before modeling. ADF test is used to test the stationarity of each exponential logarithmic return rate. The ADF test results are shown in Table 2. As can be seen, the p -value for each parameter is equal to 0.01, so the negative hypothesis is rejected that the log return behind each indicator value is a stable point. Further analytical modeling can be done. Table 3 shows the Kolmogorov–Smirnov normal test results.

4.2. The Model Estimation Based on the Realized Volatility.

In the study, the infrequent frequency of product changes was first used to describe the MIDAS time difference from the GJR-GARCH-MIDAS model to the product model. Replicate log returns. From the definition of RV_t volatility knowledge, N is the time-varying frequency of the data, which is rarely volatility knowledge. Since the relationship between macroeconomic variables and stock market volatility is studied, macroeconomic variables are usually monthly data, so the known volatility can also be obtained as monthly data. So N is 22. Table 4 shows the model estimation

results of Shanghai Composite Index return based on realized volatility.

Through the parameter estimation, it can be seen that the realized volatility with a lag of 16 periods still has an impact on the long-term component of volatility. From the parameter estimation results, except for the parameter that is not significant, all other parameters are significant at the 1% level. From Table 4, $a+\beta+Y/2 < 1$, it can be seen that the estimated model is stable. In terms of the practical significance of the model parameters, the parameter μ represents the mean value of the rate of return, and the test result shows that the average value of the returned value is 0. The value is 0.0099, which is the aggregate effect of realized volatility, which means that realized volatility in the past can have a positive impact on the long-term component of current volatility, indicating that the theory of volatility component decomposition exists in the Shanghai Composite Index.

5. An Empirical Analysis of the Impact of Macroeconomic Factors on Stock Market Volatility

5.1. Data Preprocessing. In order to reflect the basic trend of the data itself more accurately, each series is firstly adjusted seasonally. Methodologically, the additive model in the X-11 seasonal adjustment method is used. The X-11 seasonal adjustment method is the standard adjustment method of the US Department of Commerce. In the additive model, the series can be decomposed into the sum of trend terms and seasonal terms. This method is a seasonal adjustment

TABLE 2: ADF test results of the logarithmic return of each Shanghai index.

Log rate of return	<i>p</i> value
Shanghai composite index	0.01
Business sector index	0.01
Real estate industry index	0.01
Industrial index	0.01
Utility industry index	0.01
Composite industry index	0.01

TABLE 3: Kolmogorov–Smirnov test results of logarithmic returns of each index.

Log rate of return	<i>D</i> value	<i>p</i> value
Shanghai composite index	0.0846	0.001
Business sector index	0.0749	0.001
Real estate industry index	0.0700	0.001
Industrial index	0.0800	0.001
Utility industry index	0.0844	0.001
Composite industry index	0.0804	0.001

TABLE 4: Model estimation results of Shanghai Composite Index returns based on realized volatility.

	Coefficient	Standard error	<i>p</i> value
μ	0.0134	0.0177	0.4475
α	0.0699***	0.0000	0.001
β	0.8931***	0.0000	0.001
θ_{RV}	0.0099***	0.0035	0.0051
γ	0.0374***	0.0024	0.001
m	0.3702	0.2571	0.1500
w_2	2.3822***	0.4044	0.001
BIC		16627.29	
LLH		−8284.00	

Note. *, **, *** indicate the significance at the 10%, 5%, and 1% levels, respectively.

method based on the moving average method and can adapt to the nature of various economic indicators. Table 5 shows the results of seasonal adjustment for monthly macroeconomic explanatory variables.

According to the seasonal adjustment report, 11 statistics (M1-M11) are given to judge the quality of the seasonal adjustment. These statistics take values between 0 and 3, but only the values less than 1 are acceptable (the less the better). Finally, by using the linear combination of these 11 statistics, a composite indicator (Q statistic) for evaluating the quality of seasonal adjustment is calculated, and the result whether to reject or accept is given. It can be seen from Table 5 that the seasonal statistical results of money supply and consumer price index are all rejected.

As can be seen from Figure 2, China's exchange rate has begun to stabilize. The main reason is that on July 21, 2013, China implemented an exchange rate system. In 2013, on the basis of the exchange rate reform in 2022, China proposed to adhere to the market supply and demand as the basis for adjustment with reference to a basket of currencies, so the Chinese exchange rate maintained a stable trend.

TABLE 5: The diagnostic results of seasonal adjustment.

Variable	Q statistic	Result
M1	1.56	Reject
CPI	1.14	Reject

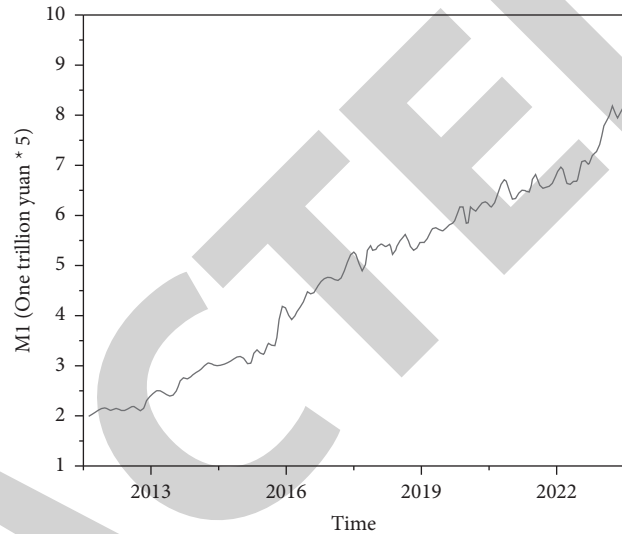


FIGURE 2: M1 level value after a unified order of magnitude.

5.2. Data Descriptive Statistics. In the research, descriptive statistical analysis on the macroeconomic explanatory variables and the explained variables of the Shanghai Composite Index is conducted, and indicators such as mean, standard deviation, variance, skewness, and kurtosis are selected. The calculation results are shown in Table 6. The sample interval of daily data is from August 1, 2011, to September 30, 2022, and the sample interval of monthly data is from August 2022 to September 2021. M1 means money supply, CPI means consumer price index, ER means USD/RMB exchange rate, and SCI means Shanghai Composite Index. All the above data for descriptive statistical analysis are sample raw data.

It can be seen from Table 6 that the standard deviation of money supply M1 is 95999.7638, indicating that the dispersion of money supply data is relatively large. The reason is that China's money supply M1 is mainly subject to the national macrocontrol. From 2011 to 2022, China's monetary policy has gone through a process from prudent to tight to lose to prudent, so its degree of dispersion is relatively large. The standard deviation of the Shanghai Composite Index SCI is 912.5329. From the statistical characteristics, it shows that the dispersion degree of China's Shanghai Composite Index is also relatively large, mainly due to the large fluctuation of the Chinese stock market in 2008 and 2016. The standard deviations of the consumer price index CPI and the USD/RMB exchange rate ER are 2.1511 and 0.6253, respectively, indicating that the data of the USD/CNY exchange rate ER is close to the average, and the data are more stable.

At the same time, it can also be seen from Table 6 that the kurtosis of ER's M1 exchange rate and USD/RMB exchange rate are both negative, −0.987 and −0.041, indicating that the

file is not much larger, and the tail is shorter than that of the well-distributed, similar to rectangular partitions. The kurtosis of the consumer price index (CPI) and the Shanghai Composite Index (SCI) were positive at 0.439 and 1.385, respectively. The observations of these two sample data are more concentrated and have longer tails than the normal distribution. The kurtosis of the consumer price index CPI is closest to 0, so the consumer price index CPI is closest to the normal distribution.

5.3. The Test Results of Single-Factor Improvement GARCH-MIDAS Model. First, the exogenous description effect of stock market volatility anomalies is studied from the perspective of phase effect and volatility effect. Commodity monthly returns and returns, including exchange rates for daily metering, price levels, and USD/CNY exchange rates are designed based on a GARCH-MIDAS mixed model of macroeconomic exogenous variables. Combining the magnitudes of the monthly macroeconomic exogenous variances into $[0, 10]$ yields the rate value, and the rate of change is obtained from the raw data of macroeconomic variables using the AR(p) model, residual sum of squares possible. As shown in Tables 7 and 8, the model estimation results based on the single-factor horizontal effect and the single-factor fluctuation effect are, respectively, shown.

According to the results in Tables 7 and 8, it can be seen that the BIC value and LLH value of each model are estimated at the same level by taking the single correction level mode and change mode as an example, and the game of all MAE and RMSE values is roughly the same equal. The error between the monthly realized volatility estimated by each model and the realized volatility calculated by using the original data is relatively small, so it can be considered that the effects of each model in the single-factor horizontal effect model and the single-factor volatility effect model are basically the same.

Table 9 presents the significance and direction of the coefficients of various macroeconomic variables. It can be seen that the coefficients of the level values of each variable in the single-factor model are in line with market experience. The coefficients of phase effect and volatility effect on the exchange rate of USD and RMB against RMB are also significant.

5.4. The Test Results of Multifactor Improved GARCH-MIDAS Model

5.4.1. The Two-Factor Horizontal Effect Affecting Stock Price Volatility. The significance of each variable coefficient under the two-factor horizontal effect. It can be seen from the results that each horizontal effect mixing model has only one variable coefficient that is significant, and the other variable coefficient is not significant. At the same time, the coefficient of the multifactor model under the horizontal effect of the money supply is significantly positive, which is the same as the estimated result of the single-factor horizontal-effect model. The coefficient of the multimodel in the horizontal ratio of the USD/RMB exchange rate is negative, similar to

that of the single model. The results of estimating the phase interference model are the same. It is not important to estimate the occurrence of multiple impact models based on the customer value proposition.

In real markets, it is important to simultaneously measure the impact of multiple macroeconomic variables on the stock market. At the same time, according to Tables 10 and 11, it can be seen that the estimated coefficients of the three two-factor horizontal effects GARCH-MIDAS are roughly in an important direction on the basis of the single-factor estimated coefficients. Component models, including estimated coefficients for horizontal models based on income and consumer value. Predictions from various GARCH-MIDAS models suggest that income levels have a positive impact on the transformation of China's commodity markets, which is similar to one of the benefits of estimating amounts., when the relationship between the value level of the CPI and the volatility of Chinese stock market prices is not significant. The main reason is that the impact of different macroeconomic variables on the market can cause one-to-one inconsistencies, which may differ from the results of individual tests.

For example, when estimating the value of a two-factor horizontal model, the effects of macroeconomic factors on market volatility are initially similar to those estimated for horizontal structure effects. The GARCH-MIDAS model has slightly different test results for the two horizontal values of USD/RMB exchange rate and income. It can be seen that when both the income and the cost of goods in the Chinese market are fully determined. In the case of the lateral effect, the lateral value of the currency is closely related to the Chinese stock market, as is the lateral value of the income when considering the USD/CNY exchange rate and total payment amount. Although it has a good relationship with the Chinese stock market.

5.4.2. Two-Factor Volatility Effect Affecting Stock Price Volatility. The significance of each variable coefficient under the two-factor fluctuation effect. From the results, it can be seen that only the two-factor model based on the fluctuation effect of the money supply and the consumer price index is not significant, and the other multifactor fluctuation models only have one variable is significant. At the same time, on the one hand, the estimated result of the variable coefficient of the multifactor fluctuation model of money supply is significantly positive, which is the same as the estimated result of the single-factor fluctuation effect model. The estimation results are the same, and both are significantly negative.

At the same time, according to Tables 12 and 13, it can be seen that the estimated coefficients of the three-factor, two-factor volatility GARCH-MIDAS are estimated in the same direction as the estimated coefficients of the separate model, in addition to standard volatility effects based on income and consumer value. The estimation results show that the fluctuation of money supply is not significant, and the fluctuation of money supply based on the fluctuation effect model of money supply and USD/RMB exchange rate is positively significant.

TABLE 6: Descriptive statistics.

Variable	Sample period	Mean	Standard deviation	Variance	Skewness	Kurtosis
M1	2011.08.01–2022.09.30	247200.7103	95999.7638	9216000000	0.106	−0.987
CPI	2011.08.01–2022.09.30	102.7659	2.1511	4.627	0.580	0.439
ER	2011.08.01–2022.09.30	6.7855	0.6253	0.391	0.897	−0.441
SCI	2011.08.01–2022.09.30	2706.1836	912.5329	832716.276	0.980	1.385

TABLE 7: Single-factor level effects.

Variable	M1L	CPI	ERL
M	0.0005* (1.3765)	0.0001 (0.1521)	0.0005* (1.4022)
A	0.0526*** (10.5549)	0.5575*** (8.9760)	0.0538*** (10.6083)
B	0.9411*** (137.2133)	0.3529*** (4.6973)	0.9413*** (142.0535)
M	0.0006** (2.1456)	0.0034*** (70.4076)	0.0003** (2.1229)
θ_l	0.0001* (1.6201)	−0.0004*** (−70.6836)	0.0108* (−1.4658)
ω_l	1.2325 (0.1653)	4.3098*** (10.3896)	1.0048** (1.8133)
g_0	0.1016 (0.9878)	0.0011 (0.0023)	0.1686 (1.0898)
BIC	−5.4798	−5.0909	−5.4793
LLH	−7248.3738	−6736.2355	−7247.7314
MAE	0.0023	0.0062	0.0022
RMSE	0.0035	0.0081	0.0034

Note. * is significant at 10% level; ** is significant at 5% level; *** is significant at 1% level.

TABLE 8: Single-factor fluctuation effect.

Variable	M1V	CPIV	ERV
M	0.0008* (1.5297)	0.0001 (0.3877)	0.0005* (1.3921)
A	0.7750*** (10.9102)	0.0526** (10.1796)	0.0533*** (10.4209)
B	0.2249*** (3.1662)	0.9437*** (141.716)	0.9422*** (143.0517)
M	5.8586*** (2.7296)	0.0004* (1.5068)	0.0004*** (1.9639)
θ_v	0.0001*** (2.6722)	−0.0001 (−0.3259)	−0.9664*** (−1.7606)
ω_v	1.0457*** (13.0019)	7.9103 (0.2899)	1.3265*** (3.4844)
g_0	0.0129 (0.6009)	0.5849 (1.0262)	0.1579 (1.0693)
BIC	−5.1196	−5.4583	−5.4816
LLH	−6154.2148	−6406.2665	−7250.7634
MAE	0.0066	0.0023	0.0022
RMSE	0.0077	0.0035	0.0033

Note. * is significant at 10% level; ** is significant at 5% level; *** is significant at 1% level.

TABLE 9: Significance of each macrovariable.

Effect	M1	CPI	ER
Horizontal effect	Significantly positive at the 10% level	Significantly negative at the 1% level	Significantly negative at the 10% level
Wave effect	Significantly positive at the 1% level	Not significant	Significantly negative at the 1% level

TABLE 10: Two-factor level effects.

Variable	M1+CPI	ER + M1	ER + CPI
M	0.0004* (1.3628)	0.0005* (1.3938)	0.0005* (1.3933)
A	0.0520*** (10.4582)	0.0516*** (10.4491)	0.0538*** (10.5955)
B	0.9425*** (139.1835)	0.9427*** (139.6579)	0.9410*** (140.7851)
M	0.0013 (0.4208)	0.0007** (2.0865)	0.0006 (0.1869)
θ_l^1	0.0001* (1.4755)	0.0017 (0.5678)	-0.0103* (-1.4668)
θ_l^1	-0.0001 (-0.2154)	0.0001** (1.7625)	-0.0001 (-0.0743)
ω_l^1	1.0032 (0.1510)	9.929 (0.0946)	1.0771** (1.8479)
ω_l^2	1.0071 (0.0421)	1.0029 (0.1844)	5.0243 (0.0222)
g_0	0.1032 (0.9517)	0.0867 (0.9940)	0.1767 (1.0792)
BIC	-5.4739	-5.4742	-5.4733
LLH	-7248.52	-7248.8531	-7247.6557
MAE	0.0023	0.0023	0.0022
RMSE	0.0035	0.0037	0.0033

Note. * is significant at 10% level; ** is significant at 5% level; *** is significant at 1% level.

TABLE 11: Coefficient significance of two-factor level values.

Variable	M1+CPI	ER + M1	ER + CPI
θ_l^1	Significantly positive at the 10% level	Not significant	Significantly negative at the 10% level
θ_l^2	Not significant	Significantly positive at the 5% level	Not significant

TABLE 12: Two-factor volatility effect.

Variable	M1 + CPI	ER + M1	ER + CPI
μ	0.0005* (1.4101)	0.0007* (1.5737)	0.0005* (1.3998)
α	0.1023*** (9.2659)	0.1535*** (8.7191)	0.0533*** (10.3449)
β	0.8976*** (81.2374)	0.8464*** (48.0567)	0.9430*** (144.8464)
m	0.1215 (1.2350)	0.2707*** (2.4730)	0.0004* (1.6072)
θ_y^1	-0.0001 (-1.0984)	5.0009 (0.0119)	-1.1112* (-1.5044)
θ_y^2	-0.0181 (-0.7499)	0.0001*** (2.3657)	0.0001 (-0.9133)
ω_y^1	1.1918*** (3.6566)	1.0001 (0.0057)	1.3065*** (3.5808)
ω_y^2	1.0001 (0.7556)	1.1127*** (4.6032)	1.0015 (0.8239)
g_0	0.0005 (0.6213)	0.0002 (0.5154)	0.1357 (1.0140)
BIC	-5.4553	-5.4296	-5.4765
LLH	-7224.0285	-7190.118	-7251.9256
MAE	0.0021	0.0020	0.0022
RMSE	0.0030	0.0028	0.0033

Note. * is significant at 10% level; ** is significant at 5% level; *** is significant at 1% level.

For example, when estimating the results of the above two-factor volatility effect model, the impact of macroeconomic factor volatility on stock market price volatility is actually similar to that estimated by a variant of the model. It can be seen from the calculation that in the Chinese commodity market, when the exchange rate between the two sources of income and consumers is determined, the exchange rate of currency and consumer goods will not interfere with the exchange of Chinese commodities., while comprehensively considering the USD/CNY exchange rate and the earnings exchange rate, the earnings exchange rate has a positive impact on the Chinese market, when the USD/CNY exchange rate has little impact on the Chinese market. Chinese stock markets are volatile.

5.4.3. Three-Factor Mixed Effect Affecting Stock Price Volatility. In the estimation of the three-factor model, the representative mixture model, horizontal model, and fluctuation model are selected. The estimated results are shown in Table 14. The BIC and LLH values for each model are at the same level, and the MAE and RMSE values for the estimates are equal, so it can determine the benefit for each individual. The three-factor model is consistent.

In the estimated results of the three-factor mixed model selected as a representative, Table 15 shows the significance

TABLE 13: Coefficient significance of two-factor volatility.

Variable	M1+CPI	ER + M1	ER + CPI
θ_y^1	Not significant	Not significant	Significantly negative at the 10% level
θ_y^2	Not significant	Significantly positive at the 1% level	Not significant

Note. * is significant at 10% level; ** is significant at 5% level; *** is significant at 1% level.

TABLE 14: Three-factor mixture.

Variable	ERV + M1L + CPIL (three-factor mixture)	ERL + M1L + CPIL (three-factor level)	ERV + M1V + CPIV (three-factor fluctuation)
μ	0.0004* (1.3591)	0.0005* (1.5801)	0.0004 (0.9837)
α	0.0498*** (10.2851)	0.0518*** (8.9983)	0.5688*** (9.4800)
β	0.9445*** (144.5195)	0.9419*** (110.5251)	0.4311*** (7.1803)
m	0.0002 (0.0785)	0.0007** (1.6587)	-0.0739 (-0.4316)
θ^1	-0.5755** (-1.8597)	-0.0251* (-1.5454)	-4.9995 (-0.0061)
θ^2	-0.0001* (-1.2887)	-0.0001* (-1.2997)	0.0001 (0.6980)
θ^3	0.0001 (0.1137)	0.0001 (0.0324)	1.0401 (0.8253)
ω^1	1.5402*** (2.5768)	1.0758* (1.4662)	9.9993 (0.0043)
ω^2	9.5854 (0.0382)	1.0101 (0.1634)	1.0005 (0.9365)
ω^3	9.6721 (0.0109)	4.5075 (0.0108)	2.4398*** (2.7191)
g_0	0.1692 (1.0022)	0.0895 (0.9288)	-0.0001 (-0.0056)
BIC	-5.4703	-5.4894	-5.1914
LLH	-7251.6159	-6452.6558	-6312.7576
MAE	0.0022	0.0027	0.0019
RMSE	0.0034	0.0045	0.0024

Note. * is significant at 10% level; ** is significant at 5% level; *** is significant at 1% level; L is level, V is fluctuation.

TABLE 15: The significance of each variable coefficient under the three-factor mixed model.

Variable	ERV + M1L + CPIL (three-factor mixture)	ERL + M1L + CPIL (three-factor level)	ERV + M1V + CPIV (three-factor fluctuation)
θ^1	(5%) significantly negative	(10%) significantly negative	Not significant
θ^2	(10%) significantly negative	(10%) significantly negative	Not significant
θ^3	Not significant	Not significant	Not significant

of each variable coefficient under the effect of each three-factor mixed (level + fluctuation) effect. The three-factor models of volatility, money supply volatility, and consumer price index volatility are not significant, and the other two three-factor mixed models have two significant coefficients. Meanwhile, the USD/CNY exchange rate and lateral value coefficients are negative, the same as the estimates from the separate models, while the lateral rib coefficients are worth the money. Delivery is negative and only affects the estimated probability of the sample.

To sum up, compared with the single-factor model and the three-factor model, the estimation results of the three-

factor model are not significant. This is because the multifactor model has more estimated parameters than the model that introduces a single macrofactor. There may be problems such as overparameterization that make some coefficients no longer significant.

6. Conclusions

Although the improved GARCH-MIDAS model used in the research has overcome the problem of the inconsistent frequency of macroeconomic variables and stock market data, in fact, the improved GARCH-MIDAS model can also

introduce other factors. In the selection of macroeconomic explanatory variables, the calculation and selection are carried out from the perspective of macroeconomic factors. Subsequently, macroeconomic changes are estimated from two perspectives: phase effects and phase shifts. Second, estimates of single GARCH-MIDAS model improvements and estimates of multiple GARCH-MIDAS model modifications are presented. Combined with China's real market conditions and similar theoretical analysis, the estimated results of each model are tested in detail. Through the model test, it is found that the H value of the volatility effect model of the three factors is 0.0307, the H value of the horizontal effect model is 0.0220, and the result of the horizontal effect model is the closest to 1%. The quantitative evaluation prediction results are relatively accurate.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

A Product Modeling Design Decision Model Based on PGA Genetic Algorithm

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A Pareto-based genetic algorithm (PGA) product design decision model is proposed in this work to improve the efficiency of product design decisions and avoid the instability of individual decision differences. Based on the product modeling design decision constraint space, decision variables, and other factors, the model utilizes the PGA optimization algorithm to make an objective decision on a design scheme. Using the analytic hierarchy process, the design expectations, objectives, variables, and schemes are constructed into a hierarchical structure. The design decision problems are then mapped to a mathematical model, and a simulation of the design scheme decision process is performed. Finally, the feasibility of the proposed model is analyzed and verified by evaluating the design decisions of a brand electric scooter product to guide designers in making innovative design decisions.

1. Introduction

Product modeling design integrates various factors, including art, technology, and engineering [1]. Product modeling characteristics can convey a brand's cultural concept and are the most direct carrier of a product's brand image [2]. The product modeling design process involves iteration and intersection [3] and the collision and integration of reason and emotion [4]. The design scheme evaluation process is also a multitask, multiobjective decision weighing method. In the process of product scheme design, decisions are a typical multiattribute, multiobjective comprehensive decision problem influenced by the diversity of design criteria and the ambiguity of evaluation [5].

Currently, in the field of product modeling design research, research on product modeling design decisions is mainly focused on the following three areas: (1) experimental evaluation: by collecting physiological and psychological data from the evaluators on the product design scheme, a scheme preference is optimized. For example, Lin et al. [6] determined the visual effects of different camouflage design

schemes through eye-movement experiments analysis. Guo et al. [7] constructed an accurate user perception measurement method via EEG experiments, analyzed the inner mechanism of product morphology and user preference and used the results as an indicator of product design. (2) Mathematical evaluation: the mathematical evaluation method is based on the establishment of an indicator and the construction of an evaluation algorithm, which is a quantitative method. Commonly-used evaluation algorithms include the analytic hierarchy process [8], neural network [9], Genetic Algorithm [10], and deep learning [11]. For example, Shieh and Yeh [9] used a neural network to build a system to predict design changes to the external form of running shoes and consumer emotion and to study how design factors influenced the consumers' emotional responses. (3) Online evaluation: this method is a recently-developed network information evaluation technique, which uses data mining technology to obtain, cluster, and analyze online user data. Related research methods include big data [12], natural language processing [13], and text mining [14]. For example, Lai et al. [15] analyzed big data generated in a

complex product design process using a deep neural network, predicted the design variables, and built a data-driven product design decision method. In the field of mathematical evaluation methods, combined with the Pareto solution set to improve the traditional genetic algorithm, the PGA algorithm will effectively improve the algorithm convergence speed and speed up the operation process [16]. Therefore, this paper is based on the PGA algorithm, proposes a product modeling design decision-making model, and researches the multiobjective decision-making method of product modeling design.

2. Theory

2.1. PGA Genetic Algorithm. Genetic algorithms are based on the bio-mimic optimization algorithm proposed by John Holland in 1975, which was inspired by natural selection [17]. The algorithm is based on the theory of biological evolution and chromosomal genetic variation and is characterized by large-scale global search capability, parallelism, simplicity, and strong robustness. Figure 1 shows the pseudocode of the classical genetic algorithm [18].

Proposed by Pareto, the Pareto solution set was initially used for multiobjective optimization in the field of economics [19]. The Pareto solution set is defined as follows: if $u' \in U$ (U is the feasible domain of multiobjective optimization) and there is no other feasible point $u \in U$ such that $f_q(u) \leq f_q(u')$, $q = 1, 2, \dots, n$ (n is the number of objectives) holds, then u' is said to be a noninferior solution of multiobjective optimization. For multiobjective optimization, the Pareto optimized solution is a solution set instead of one single solution, and it is denoted as the Pareto optimized solution set.

Multiobjective optimization is a design concept adopted to optimize of the overall performance of a design object according to multiple design objectives [20]. The Pareto-based genetic algorithm (PGA) is developed based on the standard genetic algorithm, in which the efficiency of the algorithm and the distribution status of the Pareto solution set are improved by introducing techniques such as floating-point coding, the hierarchical penalty function, and a Pareto solution set filter, it can effectively avoid problems such as local optimum and premature convergence and improve its global searchability and computational efficiency.

In the specific genetic operation, the operator is selected using a roulette wheel, and the crossover probability p_c and the variation probability p_m of the genetic operator are dynamically adjusted according to the fitness value in the evolutionary process.

$$\begin{aligned} \% p_c &= \begin{cases} k_1 \frac{f_{\max} - f_{big}}{f_{\max} - f_{ave}} & f_{big} \geq f_{ave} \\ k_2 & f_{big} < f_{ave} \end{cases}, \\ p_m &= \begin{cases} k_3 \frac{f_{\max} - f}{f_{\max} - f_{ave}} & f \geq f_{ave} \\ k_4 & f < f_{ave} \end{cases}, \end{aligned} \quad (1)$$

where f is the individual fitness value, f_{big} is the larger fitness value among individuals, f_{\max} is the maximum fitness value in the current population, and f_{ave} is the average fitness value in the current population, $0 \leq k_i \leq 1$ ($i = 1, 2, 3, 4$).

In order to make the population evolve in a benign direction, it is necessary to introduce a shared penalty function, which imposes a penalty on the individuals that are clustered into small pieces in the population so that their fitness value is reduced. The reduced individual fitness value is

$$\begin{aligned} F(K)|_{share} &= \frac{F(K)}{\sum_{i=1}^M f_{share}(K, Z_i)}, \\ f_{share}(K, Q) &= \begin{cases} 0, & \sigma(K, Q) \geq \sigma_{share} \\ \frac{1 - \sigma(K, Q)}{\sigma_{share}}, & \sigma(K, Q) < \sigma_{share} \end{cases}, \end{aligned} \quad (2)$$

where M is the group size, K is any individual, Z_i is an individual different from K , $F(K)$ is the fitness value before and after imposing the shared function, $\sigma(K, Q)$ is the Euclidean distance between individuals, σ_{share} is the distance parameter, and $f_{share}(K, Q)$ is the shared function of K and Q .

2.2. Description of Product Modeling Design Decision Space. Product modeling design involves a product's brand gene, function, ergonomics, commercial marketing, processing technology, and other factors [21]. For example, the modeling design of an automobile product can be divided into the front, side, and rear modeling, interior design, etc. Front modeling includes the design of the engine hood, air-inlet grille, air intake, headlights, and fog lights, while side modeling includes the side profile, waistline, side windows, front to rear overhang ratio, and overall vehicle length to height ratio design. Modeling design varies significantly across different car brands. Therefore, product modeling design has multiobjective, multitask properties [22]. Table 1 shows the factors of product modeling design.

In product design, different design goals will produce completely different design schemes, and the fusion of various design tasks will further increase the complexity of the evaluation in styling design schemes. Therefore, by limiting the multiobjective decision space of modeling design, unnecessary iteration and output of design schemes can be avoided, shorten the design cycle, and improve design efficiency.

3. PGA-Based Product Modeling Design Decision Model

3.1. Model Description. During product design, the design scheme will go through multiple rounds of project analysis and selection in the process of locating an optimized solution to the design problem. The PGA-based product modeling design decision model works to describe and hierarchize the design decision objectives until a Pareto optimized solution is selected [23]. The design

Input:

Population Size, n

Maximum number of iterations, MAX

Output:

Global best solution, Y_{bt}

Begin

Generate initial population of n chromosomes Y_i ($i=1,2,\dots,n$)

Set iteration counter $t=0$

Compute the fitness value of each chromosomes

while ($t<MAX$)

Select a pair of chromosomes from initial population based on fitness

Apply crossover operation on selected pair with crossover probability

Apply mutation on the off spring with mutation probability

Replace old population with newly generated population

Increment the current iteration t by 1.

end while

return the bestsolution, Y_{bt}

End

FIGURE 1: Classical genetic algorithm (GA).

TABLE 1: Multiobjective factors of product modeling design.

Factor	Content
Brand	Brand characteristics and brand gene are the first factors that must be considered and satisfied in product modeling design. A brand's image and connotation will drive the style of product modeling design. The designer's main responsibility is to convey the product's brand connotations and culture through product modeling design so as to accurately and consistently stimulate user cognition
Function	The function is the core service provided by the product itself, which will determine the direction and orientation of product modeling design to a certain extent. The orientation of the product function has an important impact on product modeling design
Business	Product modeling design will eventually reach consumers through commercial marketing, where the ultimate purpose of production is sales for profit. Product business positioning has a significant influence on product modeling design and is also an important constraint factor
Technology	Different processing requirements, materials, and production processes will directly affect the final shape of the product modeling design
Material	The use of different materials involves factors, such as product brand positioning, function consideration, and commercial marketing, and the properties of the materials themselves directly affect the final shape of the product design
Human-machine	Product modeling design ultimately serves humans. Thus, the form, function, usage, and scenario of the product must be compatible with human posture and conform to the fixed range of values and movement of the human body. The stability, safety, comfort, and other human-machine factors of the final use of a product are also important constraints of product modeling design
Others	In the face of sustainable development, product design also needs to consider factors such as environmental protection and life cycle. Changing social, cultural, and fashion trends and consumption habits are also important constraint factors

decision model includes a design decision function, variables, constraints, and a design evaluation model [24].

The product modeling design multi-objective optimization design decision function $F(X)$, design decision problem description $f_n(x)$, and design variable x constitute the design constraint space model. In the product design process, the design assignment is analyzed and interpreted as design decision constraints and expectations for product modeling design, and the specific tasks are described as particular design problems, design variables, and optimized scheme parameters, forming the design decision space. The

designer and their team then generate a design scheme in the design decision space. Table 2 shows the product modeling design constraint model.

Figure 2 shows the overall model structure. The process is described as follows:

- (1) Initialize the product design decision space, set the group size, randomly assign the design scheme initial position, and assign the initial velocity to 0.
- (2) In the design process, the target is located according to the objective function and design constraints. The

TABLE 2: Product modeling design constraint factors.

$f_n(x)$	x
$f_1(x)$ brand gene	Brand design characteristics, style, language, and other design genes
$f_2(x)$ function parameters	The product's main function, positioning, use, parameters, etc
$f_3(x)$ business factors	Product positioning, manufacturing cost, price, sales expectation, marketing mode, etc
$f_4(x)$ technology factors	Manufacturing and assembly process, forming method, process flow, process difficulty, etc
$f_5(x)$ material factors	Material properties, technology, prices, ratios, etc
$f_6(x)$ Human-machine relationship	Safety, comfort, stability, ease of use, human-computer interaction, etc
$f_7(x)$ emotional semantics	For example, modern, retro, simple, technology, humanities, gender, etc
$f_n(x)$ other factors	Fashion trends, consumption habits, aesthetic culture, technological innovation, product replacement, etc

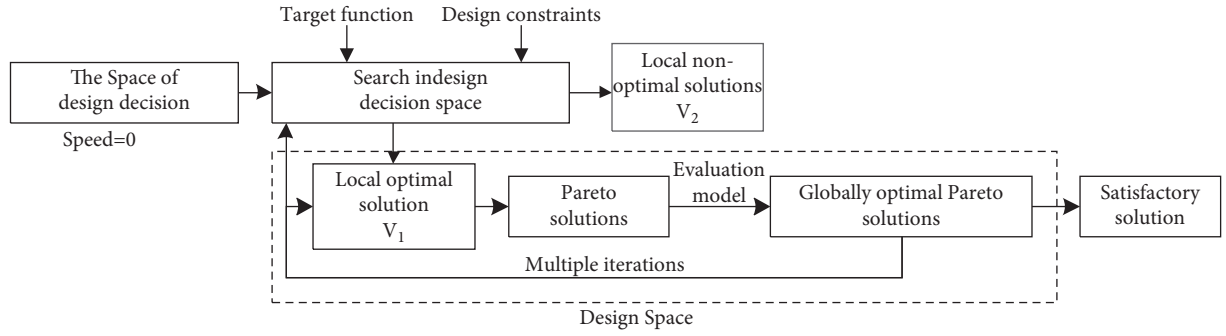


FIGURE 2: Overall model algorithm mechanism.

design decision space is searched, the locally optimized solution is stored in the population pool V_1 , and the nonoptimal solution is stored in the population pool V_2 .

- (3) After multiple searches, the selected optimized solutions are formed into a Pareto solution set, and an optimized design scheme library is constructed.
- (4) In the Pareto solution set, based on the design evaluation model, the global optimized Pareto solution is selected, and the population pool V_1 is updated. The design team will then refine the design based on the optimized design scheme and update the design decision constraint space.
- (5) Using population V_1 as the initial population and the global optimized Pareto solution as the starting point, multiple iterations are performed in the design space until the output is satisfactory.
- (6) The Pareto solution is output, the final scheme is selected, and the operation is ended.

3.2. Decision Hierarchy in Product Modeling Design. Design evaluation is the main basis for product design decisions [25], and the design often undergoes multiple rounds of scheme selection. Thus, the design decision space is constantly converging in the design decision process, and design evaluation is the main basis for Pareto global optimized solution selection [26]. In the design evaluation process, the diversity of the design scheme and evaluation

factors lead to complexity in design evaluation. In order to reduce the computational complexity of the system and make the comprehensive evaluation more reasonable, the analytic hierarchy process is used for expert weighting and to make the complex evaluation factors hierarchical [27]. The design expectations, objectives, variables, and scheme are built into a hierarchical structure, as shown in Figure 3.

When constructing the judgment matrix, experts employ the design decision constraints and expectations as the basis for judgment and finally derive the weight coefficient by comparing the design decision objectives and variables. The judgment scale is 1: equally important; 3: slightly important; 5: important; 7: much more important; 9: absolutely important. The judgment matrix O is expressed as follows:

$$O = \begin{bmatrix} o_{11} & o_{12} & \cdots & o_{1n} \\ o_{21} & o_{22} & \cdots & o_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ o_{n1} & o_{n2} & \cdots & o_{nn} \end{bmatrix}. \quad (3)$$

In the judgment matrix, the importance ratio of objects i and j is a_{ij} , $o_{ij} > 0$, $o_{ji} = 1/o_{ij}$, $o_{ii} = 1$. In the hierarchical structure, B_m and C_q are transitive. Thus, the judgment matrix is a consistency matrix, so the judgment matrix $O = (o_{ij})_{m \times m}$. Meanwhile, using the row vector averaging method for hierarchical sorting, the weight vector W_i is obtained after normalizing the n column vectors:

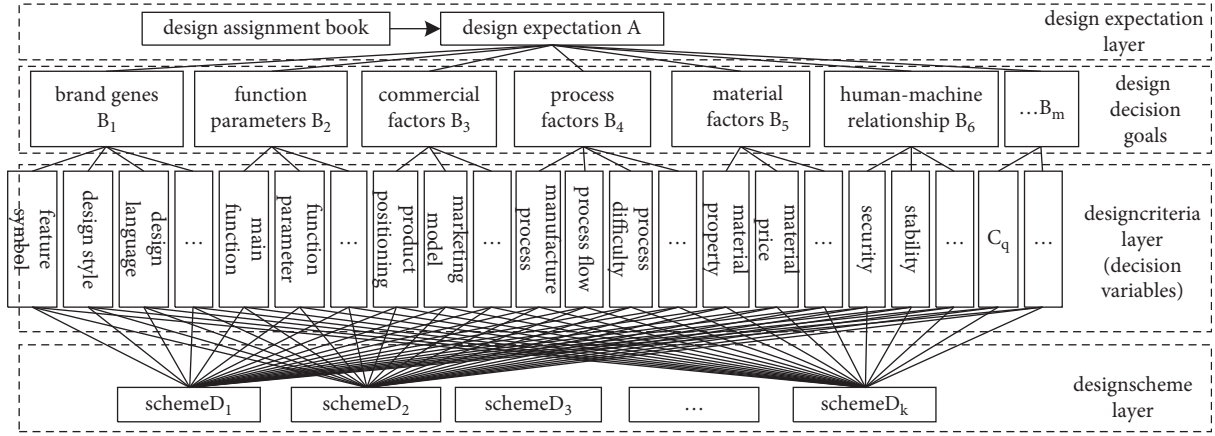


FIGURE 3: Product modeling design hierarchical evaluation model.

$$W_i = \frac{1}{n} \sum_{j=1}^n \frac{o_{ij}}{\sum_{i=1}^n o_{ij}}, i, j = 1, 2, \dots, n. \quad (4)$$

In the consistency index test of the weight vector, calculate the consistency vector V_i ,

$$V_i = \frac{\sum_{j=1}^n W_j o_{ij}}{W_i}, i, j = 1, 2, \dots, n. \quad (5)$$

The consistency index formula is as follows:

$$C.I. = \frac{\lambda - n}{n - 1}. \quad (6)$$

It can be seen from (5) that,

$$\lambda = \frac{1}{n} \sum_{i=1}^n V_i, i = 1, 2, \dots, n. \quad (7)$$

The $C.I.$ value can be obtained by substituting (7) into (6), calculate the concordance ratio $C.R.$, the formula is as follows:

$$C.R. = \frac{C.I.}{R.I.} \quad (8)$$

The $R.I.$ can be obtained by looking up the table, and the $C.R.$ can be calculated. When $C.R. < 0.1$, it means that the judgment has a better consistency. Here, W_i is the weight vector of a set of elements to an element in the upper level. Finally, the weight vector of each element can be obtained, and the weights of the elements at the bottom of the target are weighted. The total ranking weights can be synthesized from the top down under a single criterion. If $W^{(k-1)} = (w_1^{(k-1)}, w_2^{(k-1)}, \dots, w_{n(k-1)}^{(k-1)})^T$ denotes the ranking weight vector of the $nk-1$ th element on the $k-1$ th layer with respect to the total target, and $P_j^{(k)} = (P_{1j}^{(k)}, P_{2j}^{(k)}, \dots, P_{n(k)}^{(k)})^T$ denotes the ranking weight vector of the nk -th element on the k -th layer with respect to the j -th element on the $k-1$ th layer as the criterion, then the total ranking $W^{(k)}$ of the elements on the k -th layer with respect to the total target is as follows:

$$W^{(k)} = (w_1^{(k)}, w_2^{(k)}, \dots, w_n^{(k)}) = P^{(k)} \cdot W^{(k-1)}. \quad (9)$$

4. Case Study

The feasibility of the PGA product modeling design decision model is verified by using a fashionable electric scooter as an example. The project assignment requires this electric scooter modeling design to be stylish, simple, and popular as design objectives.

4.1. Modeling Design Decision Space Constraints. As shown in Table 3, $F(X)$ is the goal of the entire design project, corresponding to the goal expectation A. Each subfunction $f(x)$ is a subobjective function under the corresponding decision constraint, corresponding to the decision goal layer B, and the specific constraint index is the C layer.

4.2. Realization of Target Scheme Design Decision. In the design process, the design group size was a team of five persons. The designers performed the scheme design in the framework of a clear design decision constraint and finally carried out scheme evaluation with the design scheme side view. This design scheme is shown in Figure 4, where D_0 is the design scheme reference model, and the first round of the design scheme population includes D_1, D_2, D_3, D_4 , and D_5 .

In the design process, according to the design objective and decision constraints, the optimized scheme was searched in the decision space, the local optimized solution was stored in the population pool U_1 , and the local non-optimal solution was stored in the population pool U_2 . Table 4 lists the design scheme population in the first round.

The experts compared the importance of the objective function and design variables of D_1, D_3 , and D_4 , with respect to the design constraints and design expectations, scored them, and constructed a judgment matrix. Table 5 shows the weights of indexes in A-B.

The experts then scored the C layer, constructed a judgment matrix, and calculated the B-C weights using MATLAB. The weights are shown in Table 6.

TABLE 3: Description of product design constraint model.

Design problem description $f_n(x)$		Design variable x
$F(X)$	Brand gene $f_1(x)-B_1$	Chassis: C_1 ; color: C_2
	Function parameter $f_2(x)-B_2$	Motor driven: C_3 ; rear drive: C_4
	Business factor $f_3(x)-B_3$	Mid-range model: C_5 ; daily transportation: C_6
	Technology factor $f_4(x)-B_4$	Module welding: C_7 ; bolt fixing: C_8 ; blow molding: C_9
	Material factor $f_5(x)-B_5$	Stainless steel: C_{10} ; plastic: C_{11}
	Human-machine relationship $f_6(x)-B_6$	Safe: C_{12} ; stable: C_{13}
	Emotional semantics $f_7(x)-B_7$	Modern: C_{14} ; fashion: C_{15} ; dynamic: C_{16}
	Other factors $f_n(x)-B_8$	Low cost: C_{17} ; simple shell: C_{18}



FIGURE 4: Design schemes in the first round.

TABLE 4: Design scheme population in the first round.

D_1	U_1 D_3	D_4	U_2 D_2	D_5
Conforms to design constraints, overall modeling simplicity, fashion	Conforms to design constraints, overall modeling simplicity, popularity	Conforms to design constraints, overall modeling simplicity, fashion	Modeling slightly complex, body structure is not simple enough	Modeling proportion is large, the design is not stylish and simple

TABLE 5: A-B weights.

$W(A-B)$	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8
A	0.15	0.22	0.13	0.14	0.20	0.16	0.14	0.22

TABLE 6: B-C weights.

$W(B-C)$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
B_1	0.31	0.30							
B_2			0.41	0.28					
B_3					0.61	0.34			
B_4							0.36	0.21	0.33
$W(B-C)$	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
B_5	0.32	0.41							
B_6			0.43	0.46					
B_7					0.65	0.41	0.32		
B_8								0.65	0.33

The D layer was then scored, a judgment matrix was constructed, and the C - D weights were calculated by MATLAB. The weights are shown in Table 7.

The final weight of layer D to layer A was obtained as $W_{sumD1} = 0.2834$, $W_{sumD3} = 0.3921$, and $W_{sumD4} = 0.3127$, where $C.R. = 0.0082 < 0.1$, which passed the consistency test. In

TABLE 7: C-D weights.

W (C-D)	D_1	D_3	D_4
C_1	0.32	0.31	0.32
C_2	0.33	0.32	0.32
C_3	0.21	0.47	0.33
C_4	0.20	0.42	0.32
C_5	0.34	0.46	0.22
C_6	0.24	0.46	0.25
C_7	0.30	0.35	0.31
C_8	0.31	0.30	0.27
C_9	0.33	0.26	0.41
C_{10}	0.33	0.34	0.25
C_{11}	0.30	0.30	0.31
C_{12}	0.32	0.32	0.31
C_{13}	0.19	0.38	0.34
C_{14}	0.21	0.40	0.22
C_{15}	0.27	0.44	0.29
C_{16}	0.28	0.32	0.36
C_{17}	0.33	0.30	0.31
C_{18}	0.31	0.31	0.32

TABLE 8: C-P weights.

W (C-P)	P_1	P_2	P_3	P_4	P_5
C_1	0.14	0.21	0.14	0.25	0.23
C_2	0.13	0.22	0.17	0.24	0.22
C_3	0.15	0.17	0.19	0.25	0.22
C_4	0.16	0.18	0.21	0.22	0.20
C_5	0.17	0.15	0.18	0.23	0.21
C_6	0.16	0.15	0.22	0.24	0.22
C_7	0.11	0.15	0.21	0.18	0.31
C_8	0.21	0.15	0.20	0.21	0.20
C_9	0.17	0.18	0.19	0.21	0.22
C_{10}	0.21	0.20	0.18	0.19	0.20
C_{11}	0.15	0.22	0.18	0.21	0.24
C_{12}	0.21	0.18	0.16	0.21	0.24
C_{13}	0.23	0.16	0.18	0.25	0.21
C_{14}	0.18	0.17	0.18	0.28	0.17
C_{15}	0.21	0.14	0.21	0.22	0.19
C_{16}	0.22	0.18	0.21	0.20	0.17
C_{17}	0.23	0.21	0.17	0.20	0.17
C_{18}	0.21	0.17	0.22	0.18	0.18

the Pareto solution set, the global optimized Pareto solutions D_3 and D_4 were selected according to the design evaluation model, and the population pool U_1 (D_3 , D_4) was updated.

4.3. Realization and Analysis of Final Scheme Decision.

Using the population V_1 as the initial population and the global optimized Pareto solution (D_3 , D_4) as the design starting point, the designers completed five design schemes in the updated design decision space. The design schemes P_1 , P_2 , P_3 , P_4 , and P_5 were selected after five iterations, a judgment matrix was constructed, and the weight list of criterion layer C for the five schemes was obtained (see Table 8).

Finally, $W_{sumP1} = 0.2931$, $W_{sumP2} = 0.2061$, $W_{sumP3} = 0.1945$, $W_{sumP4} = 0.2341$, and $W_{sumP5} = 0.2621$ were obtained, where $C.R. = 0.035482 < 0.1$. After the consistency test, the scheme P_1 was obtained as the final scheme. The

overall design of scheme P_1 is simple and elegant, the color of P_1 is mainly gray, the shape design and color matching meet the expected design goals, and the design decision is effective.

5. Discussion

To verify the validity and decision satisfaction of the PGA design decision model, the design entrusting party and four experts participated in six rounds of design scheme decision processes. The design scheme selected by the PGA-based decision model and the scheme selected by experts were scored according to the satisfaction of the design entrusting party, with a full score of 10 points. As shown in Figure 5, the client satisfaction trend of the four experts and the PGA design decision model gradually increased as the design progress deepened. After six rounds of scheme evaluation, the client satisfaction with the PGA-based design scheme

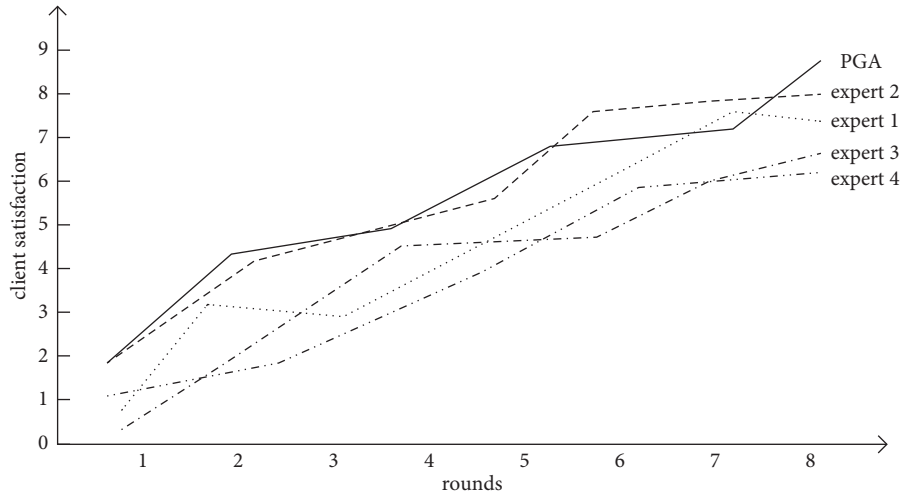


FIGURE 5: PGA-based design decision model vs. expert decision satisfaction.

TABLE 9: The comparison of design evaluation satisfaction.

Method	Average satisfaction (%)	Average recall (%)
GA	63.5 ± 4.1	51
DNN	57.8 ± 4.6	63
PGA	71.6 ± 5.3	64

decision model was higher, and the decision results of the four experts were highly compatible with the PGA decision model. Meanwhile, during the PGA-based design decision model experiment, the design decision evaluations were more stable, the decision time was shorter, and the decision efficiency was higher after six rounds.

The intelligent decision-making system is more rational and efficient than traditional manual decision-making. By comparison, it is found that the design decision model based on PGA can quickly optimize the design scheme without losing satisfaction, and it can be used as a rapid auxiliary evaluation tool for product design schemes.

To further verify the validity of the PGA design decision model, based on the original data set, the classical GA [18] algorithm and the traditional DNN [28] deep learning algorithm were compared respectively (see Table 9), and the average decision satisfaction of the PGA design decision model is higher than the other algorithms. The PGA design decision model performed stably in 6 rounds of the design decision, and the design decision time was greatly shortened compared with the manual decision.

6. Conclusions

As product modeling design decisions are characterized as multitask, multiobjective, and dynamic, the conventional expert evaluation method has low efficiency and stability in the decision-making process. This article proposed a PGA-based product design decision model and basic concepts based on the essential characteristics of design decision-making. During design, the design decision task index was decomposed, and the design expectation was transformed

into the design decision constraint space using the analytic hierarchy process. By iterating the design evaluation process, the design scheme population was updated and a Pareto solution set satisfying the design expectation was obtained. A case study of electric scooter design decisions was then employed to verify the validity of the decision model. The experimental results showed that the PGA-based decision model had a high degree of fit with the conventional expert evaluation method, the decision stability and efficiency were greatly improved, and the design decision satisfaction was high. Future studies will further improve the PGA algorithm, improve the PGA-based design decision model, combine deep learning and big data theory, improve the accuracy of the design decisions, and build a product modeling design decision software system.

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 there are no conflicts of interest regarding the publication of this paper.

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Research Article

Optimal Allocation of Human Resources Recommendation Based on Improved Particle Swarm Optimization Algorithm

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People are the most dynamic factor of productivity, and human resource allocation is both the starting point and the end point of human resource management. In modern enterprises, human resource optimization is the scientific and rational allocation of human resources within the enterprise through certain means and methods. The basic concept of particle swarm optimization (PSO) originates from the study of bird predation. It is an evolutionary computation technique based on the swarm intelligence method, which is similar to genetic algorithms and is a population-based optimization tool. This paper is inspired by the ant colony algorithm and introduces the ant colony pheromone and variation algorithm model into the PSO algorithm for further optimization. The application of this improved particle swarm optimization algorithm to the optimal allocation of human resources recommendations is demonstrated by a real case study.

1. Introduction

From the point of view of business economics, human resource allocation refers to the total amount of labor actually invested and occupied by each department within an enterprise under the combined effect of multiple factors [1]. In any society, social activities must be allocated in proportion to the prevailing production conditions. According to this economic principle, labor activities can also be classified according to the nature of the work of the employees in an enterprise: (1) craft labor, i.e., labor activities that directly change the object of labor; (2) auxiliary labor, i.e., labor activities performed to ensure the normal performance of craft labor; (3) technical and managerial labor, i.e., labor engaged in product design, research and development, organization, operation, statistics, measurement, inspection, information, and other (3) technical and managerial labor, i.e., activities that are mainly mental labor. The above three types of labor of different nature lay the foundation for the development of production and operation activities of enterprises. Therefore, the improvement of the efficiency of human resources allocation should be optimized from multiple angles and factors, which is not only reflected in the

space and time of human resources but also in the quantity and quality structure of talents, and the relationship between various types of talents in the enterprise should be handled properly and adjusted within a reasonable range, so as to finally realize the scientific layout of the enterprise talent structure [2].

Human resource optimization is through the recruitment, appointment, assessment, deployment of personnel, and other continuous optimization and improvement, to carry out a reasonable allocation of employees and positions and to achieve the purpose of the best use of people. In the final analysis, human resource optimization is to place the right people in the right positions to maximize the value of human resources [3].

Human resource allocation is the efficient integration of physical resources and human resources by using some of people's own abilities, such as physical strength, intelligence, and skills, to create greater value. Efficient human resource allocation is the core factor for enterprises to maintain a strong vitality, which not only makes the internal human resource structure more scientific and optimal but also is an important embodiment of the best use of human talent, human potential is brought into play, and the business

objectives of the enterprise can be achieved [4]. The following is a brief description of the importance of the optimal allocation of human resources from four aspects [5]. (1) In the work of human resources management, human resources optimization is the core element of which, talent is the root of the enterprise, is the soul of enterprise development. How to retain existing talents and attract foreign talents, so that people can make the most of their talents and responsibilities, this is, the development of enterprises must pay attention to the subject, through the optimal allocation of human resources, and constantly improve the economic efficiency of enterprises and constantly improve the level of production and operation of enterprises. Times are changing, technology is advancing, the development of enterprises should also be viewed with a dynamic vision of development, and constantly optimize the allocation of human resources to ensure the efficient operation of enterprises and long-term development. (2) The optimal allocation of human resources can not only ensure the realization of organizational goals but also an important way to motivate and inspire employees, while mobilizing the enthusiasm of the staff, the economic benefits of the enterprise has been improved, the staff's self-worth has also been reflected, the staff's motivation, the economic benefits of the enterprise to a higher level. (3) The optimal allocation of human resources is involved in the entire production and operation of the enterprise, always throughout the beginning and end of human resources management work, to improve the efficiency of the enterprise organization, and to ensure a high degree of staff and job matching. Enterprise human resources configuration is the necessary content of the development of human resources themselves, will also have a certain impact on other economic resources of the enterprise, and low human resources configuration will directly affect the business development of the enterprise. On the contrary, enterprises have a higher efficiency of human resources allocation, the work of human resources management can be carried out in an orderly and healthy manner, and the work of the enterprise will be more efficient. (4) The optimal allocation of human resources can create a good atmosphere for the work of the enterprise and constantly improve the core competitiveness of the enterprise. In the development of enterprises, talent is the first productive force and a necessary factor to improve the development ability of enterprises, so human resources are optimally configured to help enterprises improve their competitiveness. Through assessment and selection, talents are given suitable jobs, which not only can stimulate their enthusiasm and maximize their ability but also can create a positive working atmosphere, and the future development of the enterprise will be better and better.

In modern enterprises, human resource optimization is to allocate human resources in a scientific and rational way through certain means and methods, so that they can be used rationally to the maximum extent and improve the efficiency of the enterprise. Its core elements include the organization, the design of the staff structure, and the training of internal staff, etc. Its main tasks include recruitment, reward system development and implementation, training, and

compensation, etc. In general, there are three common approaches to HR optimization: competency-based, dynamic adjustment, and strengths-based. Using these three approaches, HR optimization controls the core system of modern enterprise management and has an irreplaceable position and value in the development of the enterprise [6]. At the present stage, with the continuous progress of society, the market competition environment of enterprises is becoming more and more intense, and modern enterprise management theories are constantly sublimated [7]. Scientific human resource allocation can effectively reduce the management costs of enterprises, fully mobilize the enthusiasm and creativity of employees, and help enterprises improve their management efficiency and create greater market profitability.

Optimization of the organizational structure of the enterprise, that is, the enterprise with its own business situation, the rational allocation of resources and arrangements [8]. The unreasonable and unscientific organizational structure of the enterprise will directly affect the production and operation results of the enterprise in order to play the role of the least allocation of resources, and the enterprise operation results are not very satisfactory [9]. In the case of enterprises operating in the linear-functional model, for example, the organizational model lacks mechanisms related to the training of talents, and therefore lacks the talents, processes, and corresponding organizational structures to support projects, which leads to the phenomenon that the efficiency of projects that management is concerned about is high, while the efficiency of projects that are not concerned about is reduced, and when operating in multiple projects, the linear-functional model will directly affect the achievement of strategic business goals of the enterprise. The organizational performance will be greatly reduced [10]. In addition, the organizational structure of the enterprise is unreasonable, the internal resources of the enterprise are not effectively used, the resources are idle, the personnel are at a loss, and once the external environment changes, they cannot make timely responses, the coordination between various departments is poor, and the employees are negligent, which in the long run is not conducive to the realization of strategic business objectives [11].

Any organization is a system, a specific position needs to be configured what kind of people, according to the overall optimum of the system to design, rather than just choose the best employees in the same position. This means that in the selection of personnel, there should be a good identification, selection process, selected with the appropriate skills, knowledge and experience, but also to achieve the needs of the organizational system optimization. However, in the actual operation of staffing, due to the lack of scientific and feasible methods, often fail to achieve the desired results. For this reason. By exploring and analyzing the optimal allocation of human resources, a mathematical model of optimal allocation of human resources is established, which better realizes the need for system optimization in optimal allocation of human resources.

In fact, in the enterprise human resource management configuration, it is often encountered that some jobs are

unoccupied, while some employees have no positions. Since the conditions of each employee are different, the efficiency of completing the task is also different. The purpose of optimal allocation is to make the enterprise achieve the best overall efficiency with the least consumption of total resources as much as possible. To put it simply, each employee in the enterprise has a position, each position is occupied, each employee can be competent in their own position, and the enterprise consumes the least amount of resources. Especially in large enterprises, it is difficult to achieve the optimal effect of artificial allocation in the case of more employees and positions. It was found that this problem can be converted into a problem of maximum and optimal matching of dichotomous graphs, and then the Hungarian algorithm can be used to solve the best result, and the solution process can be easily implemented on the computer [12]. In this way, companies can use information management systems to solve the problem of optimal human resource allocation well within a very short period of time [13].

Particle swarm optimization (PSO) was proposed by Kennedy and Eberhart in 1995 [14, 15]. It is a population-based evolutionary algorithm that simulates the behavior of a flock of birds flying for food and makes the flock optimal through collective collaboration among birds. The advantages of PSO are the simplicity of the algorithm, easy implementation, fast convergence, and not many parameters to be adjusted. This algorithm has been widely used in function optimization, neural network training, pattern classification, fuzzy system control, and other applications [16, 17]. Based on the characteristics of the mathematical model for optimal allocation of human resources, an improved particle swarm optimization algorithm is designed to solve this problem by embedding the idea of genetic algorithm into the particle swarm optimization algorithm, and the numerical simulation results show the effectiveness of the algorithm [18].

2. General Application of Particle Swarm Algorithm

The basic concept of particle swarm optimization (PSO) originates from the study of bird flock predation behavior. It is an evolutionary computation technique based on the Swarm Intelligence approach. PSO is similar to genetic algorithms and is a population-based optimization tool. The system is initialized as a set of random solutions and the optimal values are searched by iterations [19]. But instead of crossover and variation operations used by genetic algorithms, the particles (potential solutions) are searched in the solution space following the optimal one. Compared to genetic algorithms, PSO has the advantage of being simple and easy to implement while having a deep intelligent background, which is suitable for both scientific research and especially for engineering applications [20]. Therefore, once PSO was proposed, it immediately attracted a lot of attention from scholars in the field of evolutionary computation and other fields [21], and a large number of research results appeared in just a few years, forming a research hotspot [22].

Imagine a scenario in which a flock of birds is searching for food at random. There is only one piece of food in the area. None of the birds know where the food is. But they know how far their current location is from the food. So what is the optimal strategy to find the food. PSO takes inspiration from this model and uses it to solve optimization problems [23]. All particles have an adaptation value determined by the function being optimized, and each particle has a velocity that determines the direction and distance they fly. The particles then follow the current optimal particle and search the solution space [24]. The PSO is initialized as a group of random particles (random solutions), and the optimal solution is found by iteration [25]. In each iteration, the particles update themselves by tracking two “extreme values” [26]. The first one is the optimal solution found by the particle itself, and this solution is called the individual extreme value. The other extreme value is the optimal solution currently found by the whole population, and this extreme value is the global extreme value. Alternatively, instead of using the whole population, only some of them can be used as neighbors of the particle, then the extreme value among all neighbors is the local extreme value [27]. Let PSO be initialized as a group of random particles (random solutions), and in each iteration, the particles update themselves by tracking two “extremes.”

The first one is the best solution found by the particle itself, which is called the individual extremum (denoted by p_{best}), another extremum in the global version of PSO is the best solution found by the whole population so far, which is called the global extremum (denoted by g_{best}), while the local version of PSO does not use the whole population but a part of it as the neighbors of the particle, and the best solution among all the neighbors is the local extremum (denoted by l_{best}). The steps of the traditional particle swarm algorithm are as follows: 1 Initialization: the position X of the initial search point and its velocity V are usually generated randomly within the allowed range. The particle number of this optimal value is recorded and set to the current position of this optimal particle. If it is better than the current individual extreme value of the particle, it will be set as the position of the particle and the individual extreme value will be updated. If the best individual polar value of all particles is better than the current global polar value, it is set to the position of the particle, the serial number of the particle is recorded, and the global polar value is updated. 3. Update of particles: the velocity and position of each particle are updated using the above formula. 4 Check if the end condition is met. If the current iteration number reaches the predefined maximum number (or reaches the minimum error requirement), then stop the iteration and output the optimal solution, otherwise go to step 2. See Figure 1.

In realistic human resource optimization, the selection and configuration needs to be based on the specifics of the organizational structure and the measurement focus of the job's competency requirements for the staff. It is usually necessary to consider the ratings of candidates on the multiple competency elements required for the position and the weight distribution of each competency element in different positions.

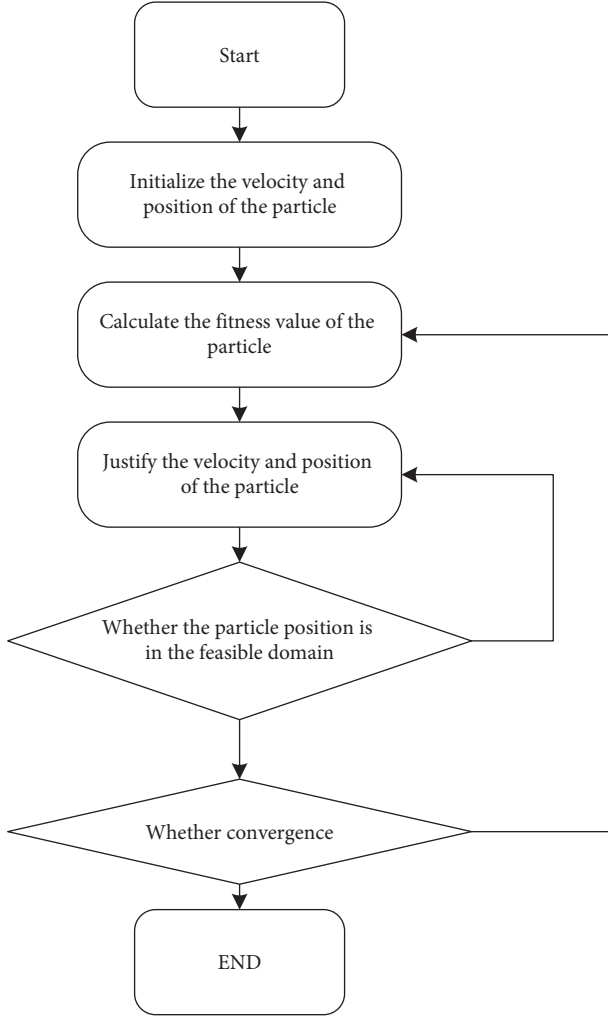


FIGURE 1: Algorithmic flow of the basic particle swarm algorithm.

The basis of information particle swarm technology is the network analysis method, which is time based and expresses the engineering planning and engineering control process as a whole, so that people can intuitively understand the intrinsic connection of each subsystem and enhance the organization of work, and its tool is the network plan diagram. The network plan diagram is represented by the set of nodes N and arrows A , which could written as $G(N, A)$. It organically forms the work, events, and lines into a whole, effectively reflecting the whole picture of the task. The preparation of network plan generally includes four steps of information compilation, task decomposition, work breakdown preparation, and network diagram drawing. After drawing the network plan diagram, it can clearly express the progress between the tasks in the project and their interrelationship, and on this basis, the analysis and optimization of the network plan can be carried out.

The establishment of the HR optimization model is the premise of the information particle analysis method. Based on the demand of human resource optimization, we established the following basic PSO parameter model based on the relationship between supply and demand and resource relationship as the premise, as shown below:

There are three general indicators for judging the degree of resource balance, namely, the coefficient of unevenness, K , the extreme deviation, ΔQ , and the mean square deviation, σ^2 . These are shown in equations (1)–(3).

$$K = \frac{Q_{\max}}{Q_m}. \quad (1)$$

In this case, Q_{\max} and Q_m represent the maximum and average values of resource requirements per unit time, respectively. It can be seen that the smaller the inhomogeneity coefficient K is, the better the balance of resource requirements is.

$$\Delta Q = \max(|Q_i - Q_m|), \quad (2)$$

where Q_i denotes the resource requirement at the i th time period. It can be seen that the smaller the extreme difference ΔQ is, the better the balance of resource requirements is.

$$\sigma^2 = \frac{1}{T} \sum_{i=1}^T (Q_i - Q_m)^2, \quad (3)$$

where T is the duration of the network plan. It can be seen that the smaller the mean square deviation σ^2 , the better the balance of resource requirements.

In this paper, we use the mean squared deviation σ^2 to judge the balance of resource requirements, i.e., the dispersion of resource consumption per unit time from the horizontal line $y = Q_m$ to measure the merit of a scheduling solution. The ideal situation is that the resource dynamic curve converges to a rectangular distribution, i.e., a rectangle with Q_m as the height and a specified duration T as the length. The model for human resource balance optimization is shown in

$$\min E = \frac{1}{T} \int_0^T [R(t) - R_m]^2 dt \quad (4)$$

$$= \frac{1}{T} \int_0^T R^2(t) dt - R_m^2,$$

$$R(t) = \sum_{(i,j)} R_{i,j}(t) \quad (i, j) \in W, \quad (5)$$

$$R_{i,j}(t) = \begin{cases} R_{i,j}^0, & t_A(i, j) \leq t \leq t_A(i, j) + d(i, j), \\ 0, & \text{Else.} \end{cases} \quad (6)$$

$$t_A(k, i) + d(k, i) \leq t_A(i, j) \quad (k, i) \in F(i, j), \quad (7)$$

$$t_{ES}(i, j) \leq t_A(i, j) \leq t_{LS}(i, j). \quad (8)$$

In equation (4)–(8), $\min E$ is the minimum energy consumption; T is the total duration of the task, which is a fixed value; $R(t)$ is the sum of resource consumption of all jobs at time unit time t ; R_m is the average of resource intensity distribution of current network plan; $R_{i,j}(t)$ is the resource intensity of job (i, j) at time t ; $t_{ES}(i, j)$ is the earliest start time of job (i, j) ; $t_{LS}(i, j)$ is the latest start time of job (i, j) ; $t_A(i, j)$ is the actual start time of job (i, j) ; $d(i, j)$ is the

duration of job (i, j) ; and $F(i, j)$ is the set of all the immediately preceding jobs of job (i, j) .

The essence of the resource equilibrium problem is to use the total time difference and the free time difference to rearrange the start time of each job to stagger the peak and trough periods of resource utilization so that the mean squared difference of resource requirements is minimized. Therefore, the essence of the model is to seek the optimal combination of the actual start times of all the jobs in the task, so that the objective function is minimized.

3. Specific Improved Particle Swarm Optimization Algorithm

The ideal human resource arrangement is to keep the demand for coverage resources constant for each time period. However, due to the unevenness of the operation process, there are often peaks and valleys in the demand for security resources per unit of time. Modern enterprises have more human resources project processes, and if the project plan is not arranged properly, the phenomenon of large ups and downs in the use of human resources can occur. In the peak period of resource use, the maximum human resources demand in certain periods will exceed the limit of human resources in that period, resulting in the work not being carried out normally, and also increasing the load of the security system, affecting the quality of security; in the trough period of resource use, there will be problems such as human resources not being fully utilized, thus affecting the coordinated management of technical security. Therefore, under the regulations of the task duration, some work in the network plan can be reasonably adjusted to make the resources used in a balanced way, so as to reduce the fluctuation of the demand of human resources in the process of use, reduce the difficulty of scheduling management, and improve the utilization rate of resources, which is the optimization problem of "fixed resource balance of duration," referred to as the resource balance optimization problem.

As can be seen from the mathematical model of human resource equilibrium, the activities are subject to logical relationship constraints and time relationship constraints, and the actual start time of the activity is not only limited to the earliest start time and the latest start time range but also influenced by the state of all immediately preceding activities of the activity, which makes the available total time difference subject to certain restrictions.

This paper integrates the characteristics of highly hidden constraints in the engineering network plan resource balance optimization problem and proposes a dynamic time-difference-based resource balance optimization method: adding this logical constraint relationship directly to the determination of the time difference range of the activity, considering that the total time difference of the activity is not fixed in a certain range when the activity is constrained by logical and temporal relationship constraints, but with the determination of the actual start time of the immediately preceding activities in the process of engineering. The actual start time of the activity is determined and changes dynamically [28]. Based on this idea, when applying the

particle swarm algorithm to the solution, the algorithm is improved accordingly to the particle swarm initialization stage and the evolutionary postprocessing process, which makes the calculation process avoid the generation of nonfeasible solutions. The specific improvement methods are as follows:

When there is no tight front activity, actual starting time t_A could be in a flexible set, as shown in equation (5).

$$t_A(i, j) \in [t_{ES}(i, j), t_{LS}(i, j)]. \quad (9)$$

When there are immediately preceding activities, let the set of immediately preceding activities of activity be $\text{Pre}\{a_1, a_2, \dots, a_k\}$, k be the number of immediately preceding activities of activity (i, j) , the upper bound of the time difference of activity (i, j) remains $t_{LS}(i, j)$, and the lower bound of the time difference becomes t , and shown in equation (6):

$$t = \max\{t_A(i, j) + D_i | l = 1, 2, \dots, k, t_{ES}(i, j)\}, \quad (10)$$

where D_i is the duration of immediately preceding activity l of job (i, j) . Therefore, the actual starting time for the job (i, j) becomes $t_A(i, j) \in [t, t_{LS}(i, j)]$.

In this way, the actual start time of the subsequent activity must be determined after the actual start time of the immediately preceding activity is determined, and the total range of time differences available for each activity is always in flux. It ensures that the activities satisfy both the logical relationship constraints and the temporal relationship constraints, while avoiding the generation of nonfeasible solutions and ensuring the reasonableness of the results.

According to the resource balance optimization principle, the feasible solution space of the target problem can be assumed as an N -dimensional search space of particles, and N represents the number of activities in this problem. All feasible solutions of the objective problem are like discrete points scattered in the space, and the particle corresponds to the scheme, and the coordinates of each dimension of the particle correspond to the actual start time of each activity in the scheme. The particle gradually arrives at the position that is at the best fitness value, which is the best arrangement scheme for the activity, by constantly evolving and changing its position [29].

Considering that the total time difference of the activities is dynamic, thus, when performing the initialization of the particle swarm, it cannot be generated randomly on specific range as in the original algorithm, and adjustments must be made [30]. To determine whether there is an activity immediately preceding the activity corresponding to a dimension of each particle, find the spatial coordinates of the particle with the largest actual completion time among all immediately preceding activities of that activity [31].

Since the particle population position is not fixed and the spatial coordinates of each particle keep changing, this change makes the particles may be within the feasible space or may jump out of the feasible space and become nonfeasible solutions. Therefore, after each evolution, improvements have to be made to the basic particle swarm algorithm so that the particles can always be within the feasible solution space after each movement. That is, to

determine whether there is an activity immediately preceding the activity corresponding to a certain dimension of each particle and to find the maximum actual completion time among all immediately preceding activities of that activity.

Through the particle swarm initialization process and particle swarm evolution postprocessing, it is ensured that the position of each particle is always in the feasible solution space and the generated solution always satisfies the target problem, avoiding the generation of nonfeasible solutions. Based on the above analysis, this paper presents an information particle swarm algorithm design based on optimal resource allocation.

3.1. Structure and Encoding of Individual Particles. The resource allocation problem is the process of adjusting the start time of each job under the time sequence constraint using the free time difference, so as to obtain a variety of different scheduling schemes and find the one with the smallest mean squared difference of resources among the many schemes. Adjusting the free time difference of the jobs is to delay the start time of the jobs, thus the particle individual can be designed as follows: a particle corresponds to a set of job sequences, and the value of the particle represents the start time of each job within the job sequence.

The start time range is calculated.

The model constraint, equation (7), shows that the existence of the time difference allows the work start time to fluctuate within a certain range. Since the network plan is constantly adjusted in the process of solving the model, the start time range of the job is also changing, so to determine the start time of a job, we must find out the start time range of the job. Figure 2 shows the flow chart for calculating the start time range of the work immediately before the work after the start time of the work is determined.

3.2. Initial Population Generation. The determination of the start time of one job will affect the start time range of other jobs, so when generating different particle swarms to form the initial population, if the start time is determined for each job in its corresponding time range according to the corresponding job order of the particle swarm itself, it will lead to a fixed priority, thus the probability of getting the same total time difference for the jobs in the next order is greatly reduced and the population lacks diversity. In this paper, before generating each particle population, a non-critical job order is randomly generated, and then its start time is randomly determined from its corresponding time range in turn, and after each job's start time is obtained, the start time ranges of other jobs are redetermined. In this way, the priority of each job is theoretically the same, ensuring a wide diversity of populations. The flow is shown in Figure 3. In this way, a particle population corresponds to a feasible solution in equation (4), and the initial population composed of a certain number of particle populations corresponds to a subset of the model solution space.

3.3. Evaluation Function. The rules of the evaluation function make the adaptation value of the individual with smaller mean variance of resource usage larger, and as the particle swarm evolves, the algorithm eventually finds the resource plan with the smallest variance. Since equation (4) seeks to minimize the objective function, the original objective function is to be converted into an fitness value function to ensure that suitable individuals have large fitness values. This can be achieved by the following conversion process.

$$f(x) = \frac{\sigma_{\max}^2 - \sigma^2(x)}{\sigma_{\max}^2 - \sigma_{\min}^2}. \quad (11)$$

In (5), x denotes a particle of the contemporary population; $f(x)$ denotes the fitness of particle x ; σ_{\max}^2 and σ_{\min}^2 denote the maximum and minimum values of the contemporary objective function, i.e., the mean variance of resource use; and $\sigma^2(x)$ denotes the mean variance of resource use corresponding to particle x .

3.4. Convergence Conditions. Convergence is an important issue in particle swarm algorithms, which can indicate whether the feasible solution found by such an algorithm is optimal or whether the currently found solution satisfies the accuracy requirement. Here we give a definition of convergence for a particle swarm optimization algorithm [13]. Let the position of a particle in the swarm at time t be $x(t)$ and P be an arbitrary position in the entire search space, then the particle converges as in (8).

$$\lim_{t \rightarrow \infty} x(t) = P. \quad (12)$$

This definition suggests that the convergence of a swarm algorithm means that a particle in the swarm eventually stays at a fixed position in the search space. After analyzing the trajectories of the particles, we also find that for all particles in the swarm, they will eventually converge to the position of the global optimal particle.

By the definition, it is clear that the historical best fitness value $gBest$ of a particle swarm is a function of the iterative information t . As t varies, $gBest(t)$ constantly changes and tends to a fixed value as $t \rightarrow \infty$, which is shown in (9):

$$\lim_{t \rightarrow \infty} [gBest(t+1) - gBest(t)] = 0. \quad (13)$$

Theoretically, the optimization search process of an algorithm is the process of continuously preserving the historical best fitness values, which has been proved theoretically to be globally convergent, but it takes a considerable amount of time under the current computational power and conditions, which is one of the urgent problems that various intelligent bionic-like algorithms need to solve at present. In practice, an alternative strategy is usually adopted, i.e., preserving the current optimal individual values. In this way, the global optimal solution can be found with probability 1 for all the specified evolutionary generations, which is also the approximate convergence strategy

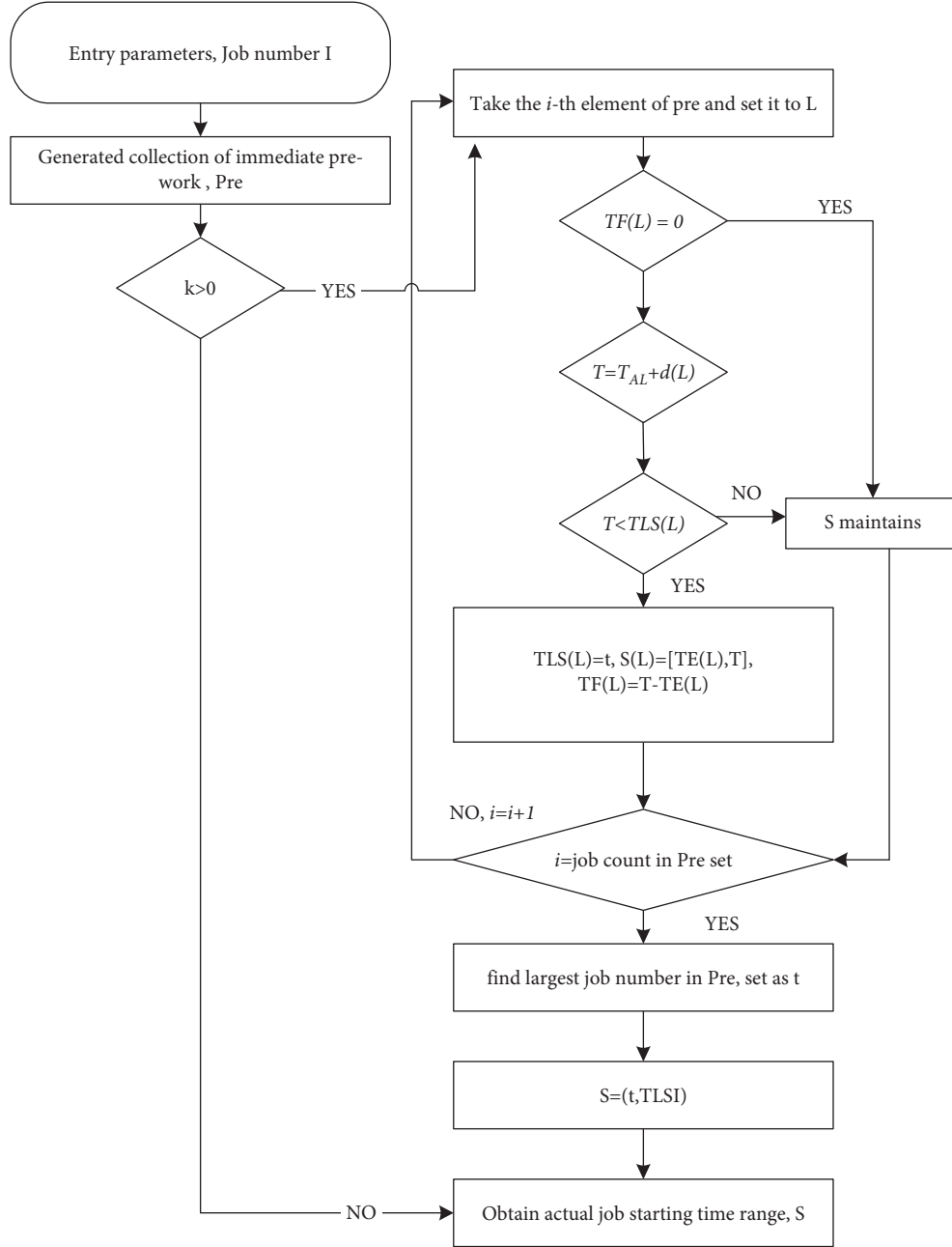


FIGURE 2: Flow chart for start-up time range regulations.

currently adopted by many intelligent affine algorithms. This is done by setting a maximum evolutionary generation G before the program runs, such that the program automatically terminates after running G generations and takes the currently found optimal solution as the global optimal solution.

3.5. Algorithm Flow. The flow of PSO is shown in Figure 4, where pBest is the individual extreme value.

In the ant colony algorithm, the pheromone concentration on the ant's route is analyzed, and the one with higher pheromone concentration is selected as the forward direction according to a certain probability, so as to achieve the goal of finding the optimal solution of the problem. If the global optimal solution of the swarm is close to the local optimal solution

during the whole evolution process, the particle may fall into the local optimal and cannot continue to search further in the solution space. Inspired by the ant colony algorithm to introduce the pheromone model for PSO, a local search in the neighborhood of the current local optimal solution (p_i) of each particle generates k points pp_i , shown in (10) and (11), and record k points generated by local search in the neighborhood of the current local optimal solution of the i th particle.

$$pp_i(j) \in \{pp_i(1), pp_i(2), \dots, pp_i(k)\}, \quad (14)$$

$$pp_i(j) = p_i + rd_i, \quad (15)$$

where r is the step size and d_i is the direction.

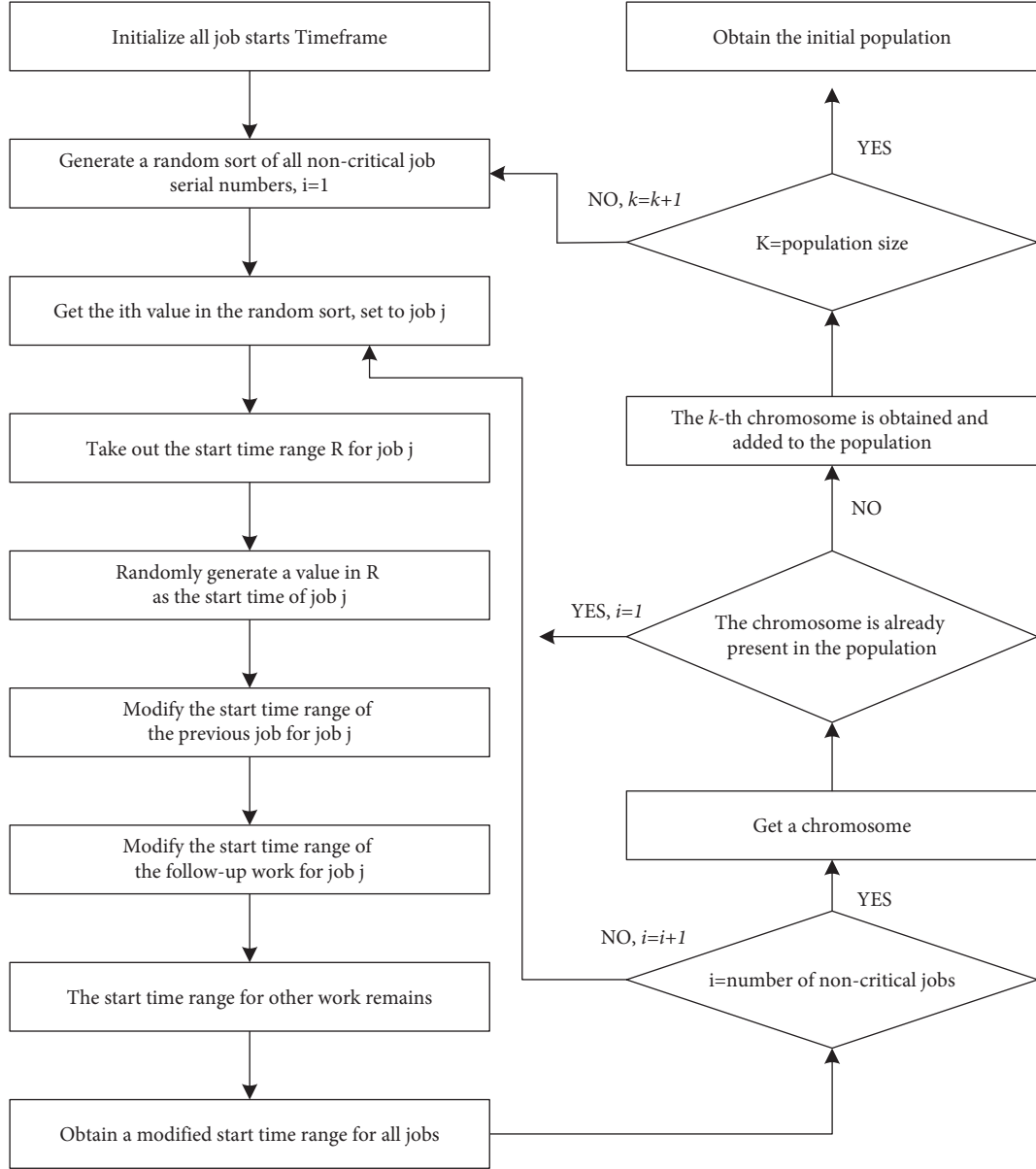


FIGURE 3: Initial population generation flow chart.

Let the current locally optimal solution p_i of the i th particle be $pp_i(k+1)$. Establish the corresponding probability selection in the PP sequence. In this paper, we construct the probability of each current locally optimal solution for selecting the points in the PP sequence as (12).

$$p_i(j) = \begin{cases} \max f(pp_i(j)), & q \gg q_0, \\ \frac{f(pp_i(j))}{\sum_{i=1}^{k+1} f(pp_i(j))}, & q < q_0. \end{cases} \quad (16)$$

Here q_0 is a given parameter ($0 \leq q_0 \leq 1$) and the function $f(x)$ is the fitness of the point x , as shown in (7) above.

From the selection probability, it is known that the point with higher fitness in the PP sequence is more likely to be selected as gBest in (9). The PP sequence and the selection

probability are obtained by embedding the neighborhood search mechanism, which introduces a mechanism similar to the pheromone in the ant colony algorithm in the PSO algorithm, and selects the appropriate locally optimized solution as the evolutionary direction in the extended PP sequence according to a certain strategy. The PP sequence is obtained through the neighborhood search mechanism, which provides multiple choices of particle swarm evolutionary directions and increases the diversity of differences among particles, thus improving the ability of the particle swarm algorithm to avoid local optima.

Further, in order to retain the advantage of fast convergence of the basic particle swarm algorithm, an optimization strategy based on the clustering degree is designed, and the clustering degree of particles is characterized by the variance of the particle fitness function, as shown in (13):

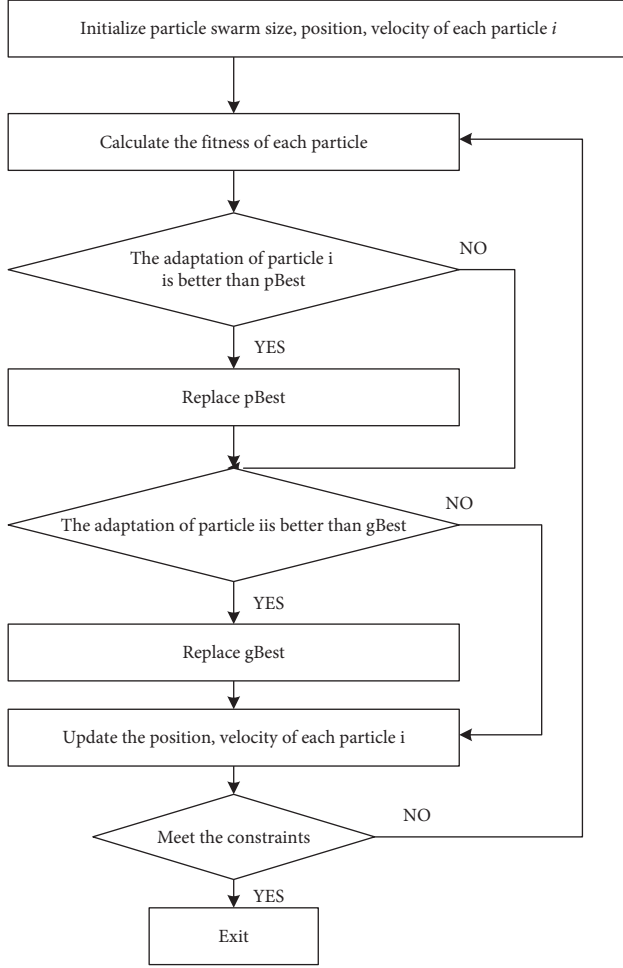


FIGURE 4: Improved information particle swarm algorithm. Reoptimization is based on ant colony idea and variation idea.

$$\sigma^2 = \sum_{i=1}^m \left(\frac{f(i) - F_{ave}}{F} \right)^2, \quad (17)$$

where F is the adjusting factor, detailed operation shown in (14). The main role of this factor is to limit the size range of σ^2 . F_{ave} is the mathematic average of the adjusting factor, F .

$$F = \begin{cases} \max_{1 \leq i \leq m} \{f(i) - F_{ave}\}, & \max_{1 \leq i \leq m} \{f(i) - F_{ave}\} > 1, \\ 1, & \max_{1 \leq i \leq m} \{f(i) - F_{ave}\} \leq 1. \end{cases} \quad (18)$$

When the particle distribution is scattered, the whole swarm has a strong search ability and the obtained σ^2 value is large, and only the highest fitness point in the PP sequence needs to be selected during iteration to ensure the convergence speed; while the σ^2 value gradually becomes small to indicate that the swarm starts to converge, and the selection range of the PP sequence is gradually expanded to increase the diversity of particles. The segmentation function, equation (19), is designed to determine the range of k .

$$k = \begin{cases} 0, & \sigma^3 > \sigma_1, \\ Kv, & \sigma < \sigma_2. \end{cases} \quad (19)$$

TABLE 1: Algorithmic test of the standard formula for the average optimal adaptation value.

	PSO	AMPSO
Function 1, equation (22) number of iterations		
500	4539.0211	468.5385
1000	6434.2409	201.6000
1500	1702.5929	78.5833
2000	850.4407	17.4000
Function 2, equation (23) number of iterations		
400	27.9011	13.5385
800	21.7812	6.2500
1000	19.2118	3.5714

Also the variational strategy is applied to the global optimal solution when the clustering of particles $\sigma^2 < 1$, shown in (16) and (17):

$$pBest = pBest + N(0, \sigma_d), \quad (20)$$

$$\sigma_d = \exp(\tau N(0, 1)), \quad (21)$$

where $N(0, 1)$ denotes a random normal distribution with mean 0 variance 1 and τ is the step parameter. In this way, when the particle aggregation degree $\sigma^2 < 1$, the particle may occur prematurely and the aggregation phenomenon, which is perturbed to the current optimal position of the particle, can be avoided. Based on the above discussion, the improved PSO based on ant colony algorithm idea and mutating strategy (AMPSP) is proposed.

At this point, the problem of optimizing the resource allocation of the optimized information particle swarm algorithm has been solved. However, since the numerical modeling still requires the evolution and comparison of formulas, we introduce the validation model here. In this paper, classical functions are used to test the performance of AMPSO, conventional PSO algorithms. Generalized Rosenbrock's function and Generalized Rastrigin's function are used, respectively. In the algorithm running test, the number of particles is 30, $c1 = c2 = 1.7$, $k = 10$, and the inertia weights are linear decreasing strategy. The algorithms were run 50 times for each function, and the results were averaged over the optimal adaptation values, which are compared in Table 1.

$$f_1(x) = \sum_{i=1}^{10} [100(x_{i+1} - x_i)^2 + (x_i - 1)^2], \quad x_i \in [-100, 100], \quad (22)$$

$$f_2(x) = \sum_{i=1}^{10} (x_i^2 - 10 \cos(2\pi x_i) + 10), \quad x_i \in [-10, 10]. \quad (23)$$

By analyzing the advantages and disadvantages of the particle swarm optimization algorithm and introducing the ant colony algorithm model and variation strategy, the problem of premature convergence of the particle swarm optimization algorithm is improved. The algorithm has shown strong adaptability, robustness, and high efficiency

TABLE 2: Parameters of the jobs.

Job name	Preimmediate work	Working days	Resource required/people	Earliest starting time	Latest starting time
A		2	6	1	1
B		4	3	1	4
C		5	5	1	6
D	A	4	4	3	3
E	A	3	7	3	10
F	B	7	4	5	8
G	C/D	6	5	7	7
H	C/D	4	3	7	11
I	E/G	2	5	13	13

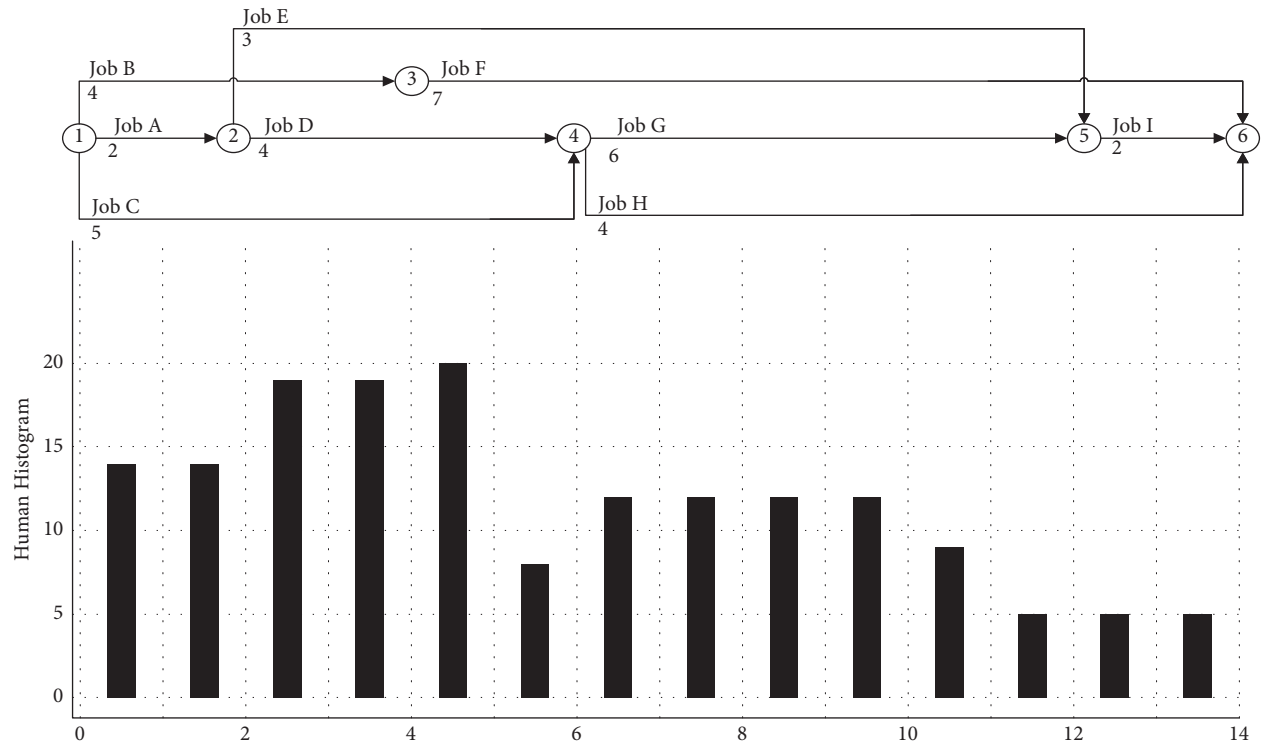


FIGURE 5: Preoptimization work network diagram and HR histogram.

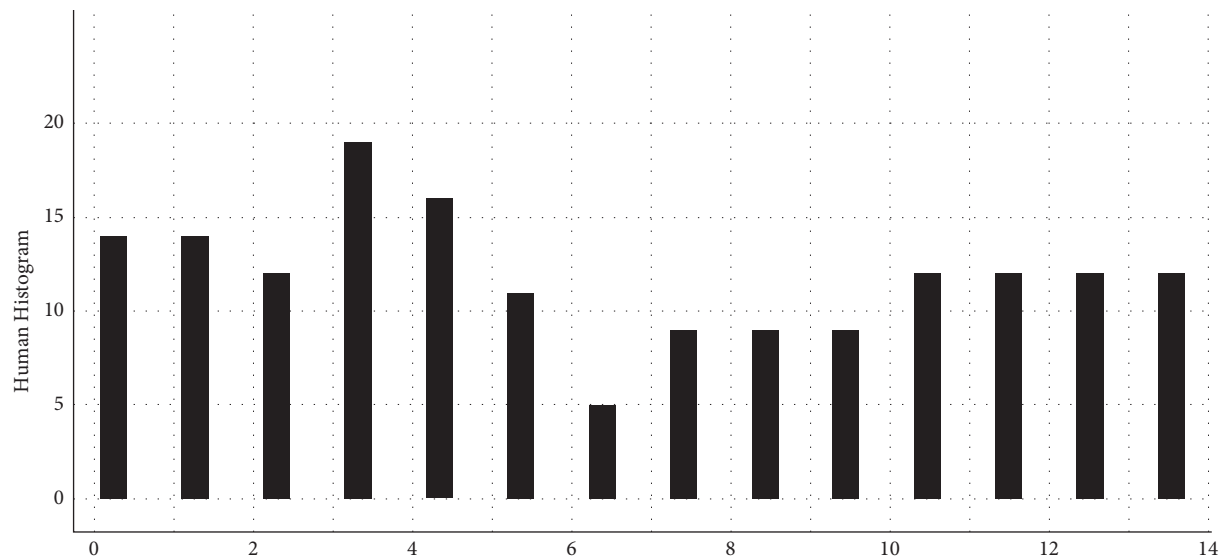


FIGURE 6: Histogram of HR after optimization of the traditional particle swarm model.

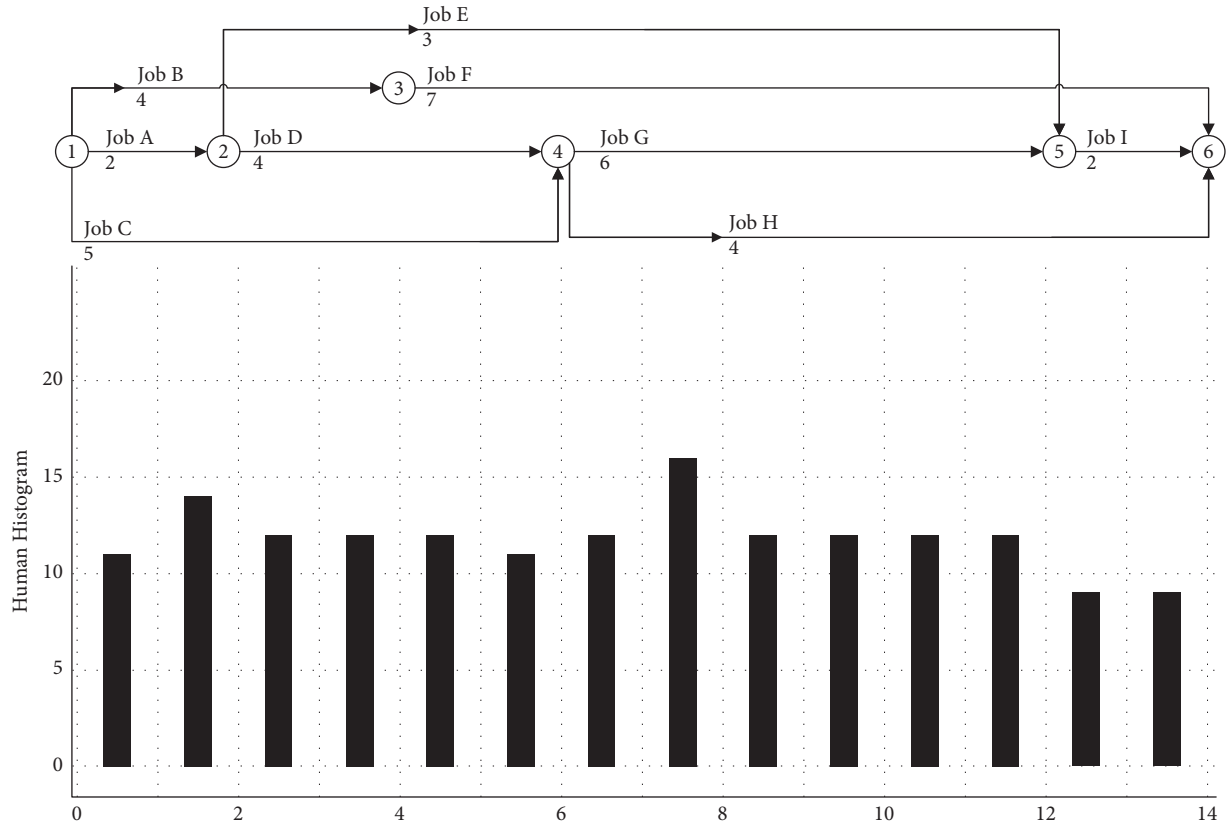


FIGURE 7: Optimized work network diagram and HR histogram.

TABLE 3: Starting time of each job after optimized by AMPSO.

Job	Working days
A	1
B	2
C	1
D	3
E	6
F	8
G	7
H	9
I	13

for complex test function optimization problems, and the experiments show that the algorithm improvement is feasible.

4. Case Study

Suppose an engineering design project consists of 9 tasks with the process parameters shown in Table 2. The network plan diagram and resource distribution histogram of the tasks are shown in Figure 5. The total duration is 14 d and the critical line is A-D-G-I. As seen from the figure, the human resources are very unevenly distributed. The highest value reaches 20 people/d, while the lowest value is only 5 people/d, and the mean square deviation is 24.41, with very large ups and downs. Therefore, it is necessary to optimize the resource allocation for this task.

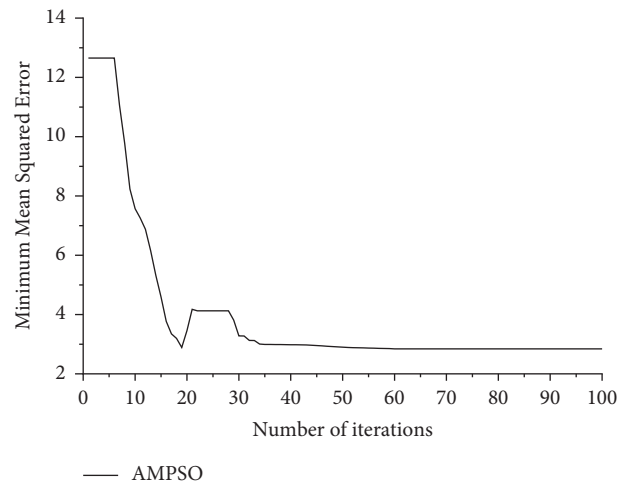


FIGURE 8: Schematic diagram of the iterative convergence result of the AMPSO algorithm.

In accordance with the design of the start time flow chart, the start time of each job in this task was calculated to obtain the process parameter table shown in Table 2. Among them, the earliest/late start time is between 1 and 14 because the total duration is 14 d.

As described in part 3, the histogram of resources of the optimized solution is shown in Figure 6, and the mean squared deviation of the optimized solution is 10.70, using the traditional

TABLE 4: Comparison of the three schemes.

Scheme	σ^2	Minimum human resource	Maximum human resource
Original	24.41	5	20
Regular PSO	10.70	5	19
AMPSO	2.84	9	16

particle swarm algorithm for resource balancing optimization of the algorithm.

In order to verify the effective convergence of this AMPSO information model, this algorithm is performed in this paper. The parameters of the particle swarm algorithm are set as follows: the initial population of particle swarm is taken as 20, the length of individual particles is taken as 9 according to the task requirements, where each one represents the start time of $A-I$ jobs; the earliest and latest start times of each job in the particles are shown in Table 1; the acceleration constants $c1$ and $c2$ are taken as 1.2 and 0.8, respectively; the inertia weight coefficient ω is taken as 0.9; and the evolutionary generation is 100.

The network diagram and resource histogram of the optimized AMPSO information particle swarm model are shown in Figure 7, and the start-up schedule is shown in Table 3. The change of the minimum resource usage mean squared deviation per generation of the particle swarm algorithm is shown in Figure 8, and comparison of the three schemes is shown in Table 4.

It can be seen that in the ordinary PSO optimization scheme, the mean variance of resource requirements is 10.70, which is 56.2% less than the initial scheme. In this paper, the average variance of resource requirement in the information AMPSO optimization scheme is 2.84, which is 88.4% less than the initial scheme and 73.4% less than the conventional PSO optimization scheme, and the range of resource usage is also greatly reduced to avoid the phenomenon of large fluctuations in resource usage. Obviously, the method in this paper has better optimization effect.

5. Discussion

In order to improve the efficiency of human resources utilization in business operation, this paper studies the optimal allocation of human resources in enterprise-level projects. The current evaluation model of resource balancing optimization problem is analyzed, the optimization method based on dynamic time difference is introduced, the resource balancing optimization method based on particle swarm algorithm is proposed, and the improved particle swarm algorithm AMPSO with ant colony idea and variation idea is proposed. Algorithm thus verifies the feasibility and effectiveness of the human resource optimization allocation method in the enterprise-level project.

The premise of sustainable, healthy, and stable development of the enterprise is the scientific and reasonable human resource allocation work, only the optimal allocation of human resources, employees can be motivated to work, personal value advantages can be maximized, and the development of the enterprise will be more stable and rapid. Therefore, the development of enterprises must pay

attention to the optimization of human resources allocation, combined with the business objectives of enterprises at different stages, analyze some of the current problems in the allocation of human resources, and constantly optimize and adjust and actively improve the human resources allocation structure of enterprises, laying a solid human resources foundation for the development of enterprises, in order to achieve leapfrog development of enterprises.

Data Availability

The data set can be accessed upon request to the author.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Comparative Analysis of the Influence of Mobile Intelligent Terminal on Human Cardiopulmonary Function in Anaerobic and Aerobic Exercise Training

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In order to understand the impact of mobile smart terminals on human cardiopulmonary function in anaerobic and aerobic exercise training, we study the effects of moderate-intensity aerobic exercise and anaerobic exercise on improving human physical fitness, shape, etc. Measurement and analysis of body composition and cardiorespiratory fitness in humans during moderate-intensity aerobic and anaerobic exercise studies. The characteristics of diversified, emerging, and humanized mobile intelligent terminals have attracted the attention of college students. Mobile smart terminals have brought a lot of convenience to college students' aerobic and anaerobic fitness. The results showed that people who participated in aerobic exercise and anaerobic exercise were more fit, and their BMI, WHR, and body fat rate were significantly better than those who did not participate in aerobic exercise and anaerobic exercise; at the same time, the lung capacity of people who participated in exercise was significantly higher. Stroke volume, maximum oxygen uptake, ejection fraction, etc., were significantly improved, and myocardial contractility was significantly improved, all better than those who did not participate in the exercise. Therefore, aerobic and anaerobic exercise can help improve a person's body composition and improve cardiopulmonary function. Therefore, how to give full play to the value of mobile smart terminals in aerobic and anaerobic fitness has become a hot research topic.

1. Introduction

The Telecommunications Research Institute of the Ministry of Industry and Information Technology of the People's Republic of China released the "Mobile Terminal White Paper" in 2012, pointing out that since 2007, intelligence has caused "genetic mutation" of mobile terminals [1, 2], changing the role of mobile terminals [3] as a mobile network. Traditional positioning of the tip: since 2007, mobile smart terminals [4–6] represented by Apple's iPhone have gradually replaced traditional mobile terminals [7] and gradually entered a new era of mobile smart terminals. Therefore, the mobile intelligent terminal has undergone a transformative development [8]. Mobile intelligent terminals have gradually become new media, e-commerce, and

information service platforms, the most important link between Internet resources, mobile network resources, and environmental interaction resources. Its operating system and processor have reached a strategic level in the entire ICT industry point. The core of mobile intelligent terminals is to provide application services. The biggest feature is entertainment and practicality. With the continuous development of science and technology and Internet technology, its influence has been far greater than that of radio, television, and the Internet, becoming the fourth largest in history. It is a terminal product with wide coverage, rapid popularization, and huge influence.

After decades of gradual development [9], mobile terminal technology has entered the era of intelligent terminals. In 2013, the sales volume of mobile smart terminals exceeded

that of Internet machines. Under this trend, the related industry structure based on various terminal operating systems has gradually stabilized. Under the background of the rapid development of mobile intelligent terminal technology [10, 11], the use of smartphones, wearable devices, and other mobile terminals for aerobic and anaerobic fitness is more and more popular among college students [12, 13]. Smartphone applications featuring sensitive operation, high brightness, fast Internet access, and long-lasting power are the most popular and widely used. The university stage is an important period for establishing the outlook on life and values and also an important period for forming the habit of physical exercise and the outlook on lifelong sports. Times are changing, society is developing, and the aerobic and anaerobic fitness methods of college students are constantly being updated. Aerobic and anaerobic fitness are facing the challenge of change. In the face of college students who like innovation, fashion, challenges, and following trends, traditional aerobic and anaerobic fitness methods can no longer fully meet their fitness needs.

The cardiopulmonary function generally refers to the physiological process of delivering oxygen and nutrients to the body through the oxygen transport system, through the blood circulation promoted by lung respiration and cardiac activity, so as to meet the needs of various human life activities and energy metabolism. The whole process involves the function of the heart to make and pump blood, the ability of the lungs to take up oxygen and exchange gas, the efficiency of the blood circulatory system to carry oxygen to various parts of the body, and the function of the muscles to use this oxygen. The cardiopulmonary function represents the aerobic work capacity or aerobic metabolism capacity of the human body. Good cardiopulmonary function is the basis for the development of various functions and qualities of the human body. Its quality is directly related to the strength of the human metabolic function and the recovery of the body after exercise. The speed of the function: a large number of studies in sports medicine at home and abroad have proved that the level of human cardiopulmonary function is closely related to health status and exercise capacity. Therefore, the level of cardiopulmonary function is an important indicator to reflect the level of physical fitness of the body. Therefore, detecting and evaluating the cardiopulmonary function of human exercise is an important method to reflect human health. At present, the commonly used dynamic test methods for the assessment of cardiopulmonary function are as follows: Ledunov combined functional test, Harvard step test, bicycle exercise test, and movable platform (treadmill) exercise test. These types of exercise tests mainly focus on the cardiac functional status, and overall cardiopulmonary function was assessed indirectly by estimating VO_{2max} , without direct measurement of changes in gas metabolism.

The State Council's notice on the "National Fitness Program (2011-2015)" clearly pointed out that "National fitness [14, 15] is closely related to people's physical health and life happiness, and is an important symbol of comprehensive national strength and social civilization progress. It is an important part of the construction of socialist

spiritual civilization and an important part of building a well-off society in an all-round way." The outline of the "National Fitness Plan" pointed out that "physical exercise" [16] is the key means to achieving national fitness, and it is the key to improving the quality of the people. Among the many factors, affecting physique is the most positive, effective, obvious, simple, and easy-to-follow and important means. Physical exercise can improve the physical fitness of the people, and it can also bring economic benefits to the society, form a healthy and civilized lifestyle, and also play an important role in cultivating good moral quality. At present, the implementation of the outline of the "Comprehensive Fitness Program" is positive covering all parts of the country, the key to the development of national fitness [17, 18], and the benefits of fitness lies in people's awareness of participating in fitness. As the hope of the motherland and high-level talents in the 21st century, on the one hand, one must have profound knowledge, and on the other hand, they must have a strong physique, in order to better serve the motherland, serve the society, and serve the general public. Colleges and universities at all levels must fully advocate the physical education policies promulgated by the state, paying attention to the school's physical education work, paying close attention to the physical and mental health and physical health of college students, and cultivating college students' lifelong sports outlook. Regular participation in physical exercise not only has a positive impact on college students' physical health [19], physical fitness, and sports skills but also can improve and develop college students' intelligence, cultivate their sentiments, hone their will, etc., and also help to cultivate college students' lifelong sports awareness. In addition, in the comprehensive development of college students' morality, intelligence, physical beauty, labor, implementation of the national fitness plan, and accelerating the formation of a harmonious society. It will have a certain degree of positive impact. Therefore, this paper uses mobile smart terminals as a medium to study the fitness status of aerobic and anaerobic fitness. The diversified, emerging, and humanized characteristics of mobile smart terminals have an impact on college students' aerobic and anaerobic fitness. Aerobic fitness has the role of guiding, promoting, and supervising. By studying the application of aerobic and anaerobic fitness of mobile smart terminals and putting forward corresponding development countermeasures according to actual problems, people can be guided to exercise correctly and form good aerobic fitness. With anaerobic fitness awareness and correct aerobic and anaerobic fitness behaviors, a certain foundation is laid for the improvement of people's physical fitness and health status.

With the popularization of smartphones and the increasing attention to healthy life [20, 21], other personal health and exercise monitoring devices and mobile phone applications based on sensor behavior recognition are also emerging one after another. For example, the human motion data are collected by the three-axis accelerometer embedded in the smartphone and uploaded to the server for processing and identification. Users can view the motion behaviors identified by the software within a certain period through the Web, including walking, running, and lying down. The

TABLE 1: Sensors on smartphones.

Designation	Description
Triaxial accelerometer	Measure the acceleration of a device in three dimensions, including gravity
Gyroscope	Measure the rotation angle of the equipment about the x , y , and z axes
Light sensor	Detect the intensity of ambient light
Range sensor	The nearest neighbor degree of the detection object relative to the mobile phone screen is generally within 10 cm
Magnetic field sensor	Detect magnetic field changes in the surrounding environment
Fingerprint sensor	Collect user fingerprint information
Temperature sensor	It can detect the temperature change of the phone's chip and battery, as well as the ambient temperature
Air pressure sensor	Measure the total pressure of a gas in the environment
Ultraviolet sensor	Monitor the UV index in the environment

experimental data show that its recognition accuracy can reach 82%–95%; the early domestic cooing movement can monitor the duration of different movements of the user, track the movement route through the GPS function [22, 23], and calculate the exercise distance, speed, number of steps, and energy consumption; as a wearable health monitoring device, the Xiaomi Mi Band can not only check the amount of exercise in real-time through the mobile app but also count the steps of walking and running, as well as the user's health monitoring. Sleep status and quality are monitored and analyzed.

2. Related Technologies

With the increasingly powerful functions of smartphones, sensors have also become the nerve endings of smartphones, which can obtain information about the surrounding environment and users in a timely and accurate manner and also provide a platform for smartphone-based human motion recognition technology. At present, sensor-based human behavior recognition mainly adopts the method of statistical pattern recognition. This chapter will focus on the acquisition of common sensors and sensor data on android smartphones, as well as the theoretical basis and processing flow required for human motion recognition.

2.1. Smartphone Sensors. Today's smartphones not only have the increasingly powerful computing power and convenient human-computer interaction but also add a variety of sensors. Mainstream smartphones are generally equipped with a three-axis accelerometer, gyroscope, fingerprint recognition sensor, light sensor, and distance. There are many different types of sensors. Table 1 gives a brief introduction to the current sensors on smartphones. These sensors can detect signals such as light, temperature, and magnetic fields in the environment, as well as various user operations and motion states. For example, a smartphone can automatically adjust the brightness of the screen by recognizing the intensity of the outside light through the light sensor. When the user is talking, the distance sensor will turn off the screen when the phone is close to the ear, and the user can easily unlock the screen through the fingerprint sensor. Thanks to the built-in sensors of the smart hand, the user's operations are more convenient.

In the research of sensor-based human motion recognition, the most commonly used acceleration sensor is the

acceleration sensor generally used in smartphones. The unit of data is m/s^2 , which includes the influence of the current gravity. When the mobile phone is in a stationary state, the resultant acceleration on the three axes is equal to the gravitational acceleration, and the current posture of the mobile phone can be estimated by the components of the gravitational acceleration on the three axes. Another motion-related sensor in a smartphone is a linear acceleration sensor, which measures the acceleration of the phone in three-dimensional space after excluding the current gravity. It is a synthetic sensor. The difference between the acceleration sensor and the linear acceleration sensor is only whether the output measurement value includes gravity data, and whether the spatial coordinate system used by the two is the same.

An accelerometer is a kind of inertial sensor, which is usually composed of a measurement circuit, sensitive element, and conversion element. Among them, the capacitive sensor is based on the principle of capacitance. Under the action of acceleration, the movable elastic diaphragm electrode will be displaced, so that the capacitance between the electrodes changes accordingly, and the acceleration value is obtained through the peripheral measurement circuit. With the advantages of high sensitivity, high precision, small size, and low power consumption, it is widely used in mobile phone mobile devices and car airbags. And when the accelerometer is stressed, the force on the piezoelectric element changes at the same time. When the vibration frequency of the object is far less than the natural frequency of the accelerometer, the change in the force on the piezoelectric element is proportional to the acceleration of the measured object; piezo resistance. The structure of the type sensor is similar to that of the piezoelectric type. The resistance value of the diffusion resistor changes with the magnitude of the acceleration, and the current acceleration value is detected according to the change in the output voltage. Due to its small size and low power consumption, it is used in equipment vibration monitoring, test instruments, automobile crash experiments, and other fields; servo accelerometers are closed loop test systems with dynamic feedback, so they have high anti-interference performance, high measurement accuracy, and large dynamic range, so they can be used in inertial navigation, inertial guidance systems. It is widely used in fields such as high-precision vibration measurement.

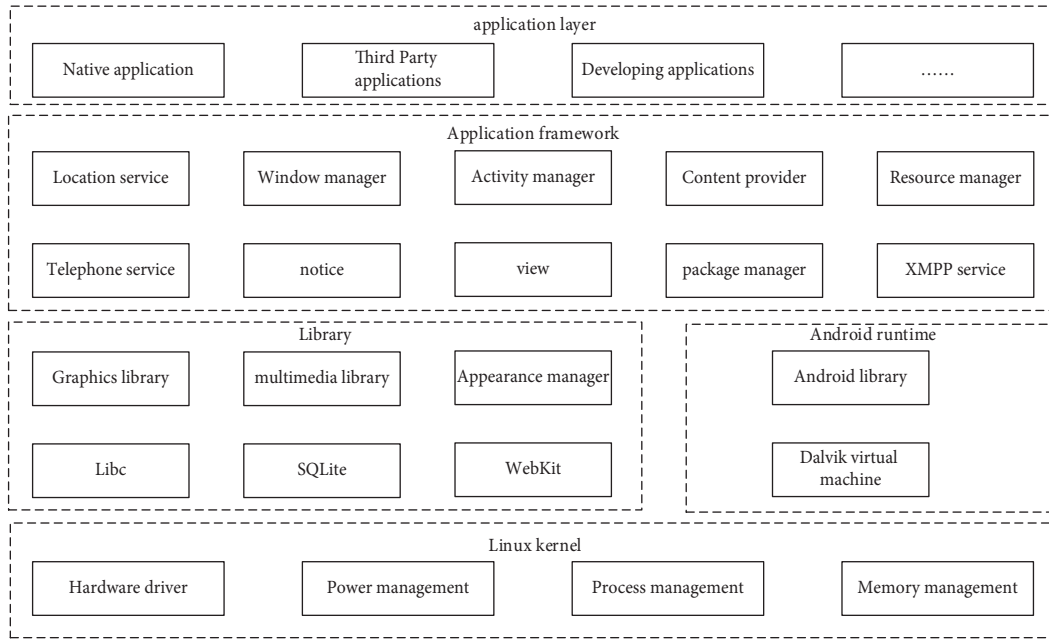


FIGURE 1: Android system architecture diagram.

The smartphone used in this experiment is Samsung GT-I9508, Android 4.3 version operating system, the built-in three-axis accelerometer model is STMicroelectronics SK330 three-axis accelerometer, the maximum range is 19.6 m/s^2 , and the resolution is 0.00059 m/s^2 . Considering the system power consumption and computational complexity, the human motion recognition research in this paper only uses the three-axis acceleration sensor on the Android smartphone, so the experimental scheme mainly collects acceleration sensor signals closely related to human motion.

2.2. Android Platform Data Acquisition

2.2.1. Android Platform Overview. The Android operating system is an operating platform based on the Linux kernel, and the source code is open. The Android parallel environment provides developers with a large number of API libraries to access system programs. The Android system adopts a layered architecture. Its structural system is shown in Figure 1. From the highest layer to the lowest layer, it is the application layer, the application framework, the system runtime library, and the Linux kernel. The functions of each layer are briefly introduced as follows:

- (1) **Application layer:** Android application layer is composed of all applications running on Android devices, such as calling programs, SMS text messaging programs, browsers, contact management, etc., as well as various third-party applications. All applications can call the classes and services provided in the application framework.
- (2) **Application framework:** the development of Android applications is realized through the interaction between the program framework and the bottom layer.

The application architecture simplifies the reuse of components. Developers can use the API framework of the core application or follow the framework principles and expand on the development of new applications.

- (3) **System runtime library:** this layer includes the function library and Android operating environment. The function library has various C/C++ libraries, which are provided to different components of the Android system. The commonly used libraries are the media function library, appearance management function library, OpenGL Graphics library, SQLite database, SGL, etc. Android runtime environment includes core function library and Dalvik virtual machine. The core library has most of the functions of the Java programming language core library. The virtual machine can support multiple virtual systems simultaneously and efficiently run.
- (4) **Linux kernel:** Android uses Linux 2.6 as the core of the entire operating system. The main system services provided by Linux include power management, process management, security management, memory management, network protocols, and driver models.

2.2.2. Sensor Data Collection. At present, smartphones based on the Android platform are equipped with acceleration sensors. At the same time, due to the open-source characteristics of the Android platform, it is very convenient to collect and store acceleration sensor data by writing data acquisition programs. So, the acquisition of sensor signals under the Android smartphone platform is the first step of this research. At the same time, the accuracy of the original

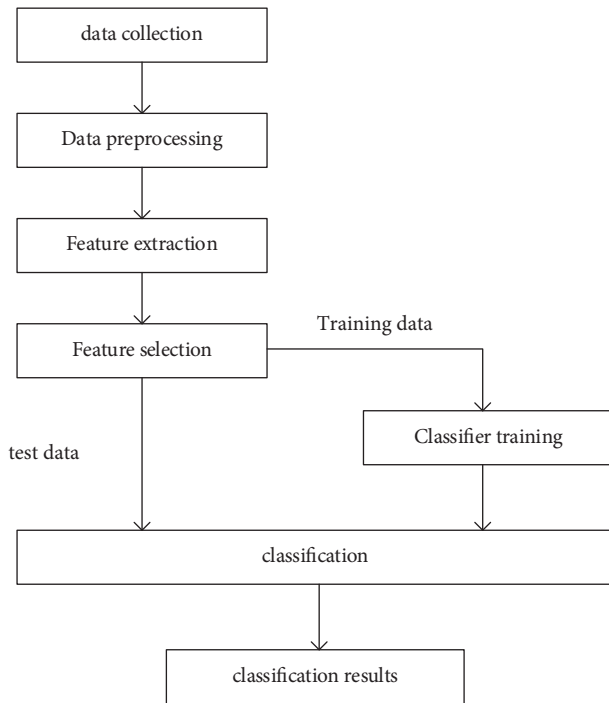


FIGURE 2: Basic process of human motion recognition.

data also directly affects the subsequent classifier training and the accuracy of user motion recognition. It affects the training of subsequent classifiers and the accuracy of user motion recognition. To obtain the data of the acceleration sensor of the smartphone, it is necessary to write the corresponding Android system application program. The data acquisition program written in the experiment in this paper is in the Eclipse development environment, using the Java language to obtain and store the user's motion acceleration data through the application program. At the same time, the raw data collected by the acceleration sensor is obtained through the sensor API interface provided by Android. The sensor API interface is located in the Android hardware package, and the sensor data are obtained mainly through the monitoring mechanism.

2.3. Human Motion Recognition Process. A human motion recognition system based on an acceleration sensor usually includes motion data collection and preprocessing, feature extraction, feature selection, and classification and recognition, and its general processing framework is shown in Figure 2:

- (1) Data collection and preprocessing: since the sequence of the raw data signal collected by the sensor is very long and contains various noises, it is necessary to perform preprocessing such as windowing, denoising, filtering, etc., on the raw signal data. Among them, windowing is to divide the original signal into fixed time segments to facilitate subsequent feature extraction, while denoising and filtering are to eliminate the influence of noise in the original data to make the signal smoother, and at the

same time, it can filter out the gravitational acceleration component. This can affect the prominence of human motion acceleration.

- (2) Feature extraction: the preprocessed acceleration data are still a time-based signal sequence, and the motion state cannot be directly identified by the classification algorithm. Therefore, it is necessary to obtain the information reflecting the differences between different motion types through feature extraction, so that the classification and identification can be carried out quickly and effectively. Feature extraction is used to obtain feature vectors describing human motion behavior, which are used as the input of the classification model for model training.
- (3) Feature selection: the original signal is converted into a set of feature vectors representing different movements of the user through feature extraction, and then a specific feature selection algorithm is used to perform subsequent processing on the extracted feature vectors. The feature selection process can remove redundant features and improve the recognition rate of system classification.
- (4) Classifier training: the core of motion recognition is the training process of the classifier. The training set usually used is the feature set that has marked the motion category, the classification algorithm is supervised to learn the feature information of different categories, and the classification model is generated after a large number of sample training.
- (5) Classification and identification: in the recognition stage, the trained classification model can predict the corresponding motion behavior for the input unknown category data, that is, the recognition result is obtained.

3. Research Methods

3.1. Documentation Method. Through the library, we have consulted a large number of related books on lung function and the effect of aerobic exercise on lung function in recent years, as well as the full-text database of Chinese journals, the full-text database of Chinese excellent doctoral and master's dissertations, and the full-text database of Chinese journals in CNKI. The literature data searched from the full-text database of important conferences and the full-text database of important Chinese newspapers are summarized, its theoretical essence is summarized, and some useful contents are cited, which provides a theoretical basis for writing the paper.

3.2. Experimental Method

3.2.1. Experimental Subjects. The research object of this paper is a total of 60 middle-aged people in Xi'an City, Shaanxi Province. Subject requirements: physical health, no major diseases such as cerebrovascular, no genetic history, not taking any drugs that affect the experimental results

TABLE 2: Basic information of subjects ($\bar{x} \pm s$).

Group	Average age (y)	Average height (cm)	Average weight (kg)
Jogging ($n = 30$)	52.11 ± 4.82	170.11 ± 5.05	71.10 ± 8.58
Spinning ($n = 30$)	51.91 ± 4.82	170.30 ± 5.10	72.30 ± 10.38

during the test period, voluntarily participating in a 4-month exercise intervention, and actively cooperating to complete all tests.

Table 2 reflects the basic information of 60 people who exercised irregularly in Xi'an. The 60 middle-aged men who exercised irregularly were divided into two groups on average. Among them, 30 participated in the exercise intervention of fitness running, and the other 30 participated in the exercise. Spinning exercise intervention: through the comparative analysis of the data of the two groups of subjects, it is concluded that the significance level is $P > 0.05$, and there is no significant difference. Regular exercise intervention can be carried out in this group.

3.2.2. Test Indicators and Precautions

(1) *Test Indicators FVC*. Forced vital capacity refers to the amount of air that can be exhaled after a maximum inhalation and exhale as quickly as possible:

FEV1: the maximum exhalation is performed after the maximum deep inhalation. The volume of the exhaled air volume in the first second of the maximum exhalation is the forced expiratory volume in one second, which is called the one-second volume.

FEV1%: FEV1/FVC ratio.

FEF25-75% (L/s): the expiratory interruption flow rate, that is, the average flow rate in the interval of 25%–75% of the vital capacity when the expiratory volume is forced to exhale.

FEF25% (L/s): the instantaneous flow rate in the pre-breathing period, that is, the maximum expiratory flow rate at 75% of the vital capacity.

FEF50% (L/s): the instantaneous flow rate in the midbreathing period, that is, the maximum expiratory flow rate at 50% of the vital capacity.

FEF75% (L/s): the instantaneous flow rate in the late stage of breathing, that is, the maximum expiratory flow rate at 25% of the vital capacity.

(2) *Indicator Test Frequency*. One week before the exercise intervention, the relevant indicators were tested, and one week after the exercise intervention, a total of 2 tests were conducted.

(3) *Precautions*. The subjects took the standing position and clamped the nose with a nose clip to ensure that the bilateral nostrils were not leaking. The mouthpiece is fully inserted into the mouth (make sure no gas leaks out of the mouth). After starting a few natural breaths in a calm state, slowly inhale as much air as you can, and then exhale all the air as

quickly as possible (as you exhale, try to bend over as much as possible to help the air out of the lungs as much as possible), followed by deep inhalation as soon as possible. Repeat the spirometer three times to automatically select the best result, and take the best test result for recording:

- (1) Use a 3-liter volume syringe for calibration
- (2) The mouthpiece is a disposable consumable and should be compatible with the pulmonary function tester
- (3) Professionals are responsible for explaining and telling the subjects how to breathe before the test
- (4) The test results are printed on thermal paper, and the subject number and name are marked on the thermal paper

3.3. *Data Processing*. This research uses the relevant knowledge of mathematical statistics and uses SPSS17.0 statistical software and Microsoft Excel 2003 software to carry out statistics and analysis of the data obtained in the experiment. All data are expressed as mean \pm standard deviation ($\bar{x} \pm s$), and the comparison between related experimental data was performed by paired-sample T test for statistical analysis, with a significance level of $P < 0.05$ and $P < 0.01$ as a very significant difference standard.

4. Experiments

The effects of aerobic and anaerobic exercise on cardiopulmonary function were studied by means of a literature review and expert interviews. It is concluded that aerobic exercise can improve cardiopulmonary function. After group training for the experimental group and the control group, the cardiopulmonary function of the experimental group after eight weeks of aerobic exercise training can be significantly improved, which is comparable to the anaerobic training of the control group. In comparison, the two may be relatively close to the changes in the indicators.

Before the experiment, the cardiopulmonary function indicators of the research subjects were measured in advance, and the resting heart rate, maximum vital capacity, and step test index of the three groups (A, B, and C) were statistically sorted. As well as the experimental subjects in the normal observation group, the conditions are similar and have small differences, and the independent sample T test is used to illustrate the situation.

Table 3 shows the results of resting heart rate, maximum vital capacity, and latter-order experimental index of students in experimental (group A) and control (group B) groups.

Note: there is a significant difference when $P < 0.05$, and there is no significant difference when $P > 0.05$.

TABLE 3: Results of resting heart rate.

	Resting heart rate (times/min) $\bar{x} \pm s$	Vital capacity (ML) $\bar{x} \pm s$	Step test index $\bar{x} \pm s$
Experimental group (A)	87 ± 5.049	2854.67 ± 745.54	45.83 ± 1.756
Experimental group (B)	86.58 ± 4.212	2853.33 ± 810.62	45.47 ± 2.676
X	0.42	1.34	0.36
T	0.221	0.004	0.422
P	0.835	0.997	0.708

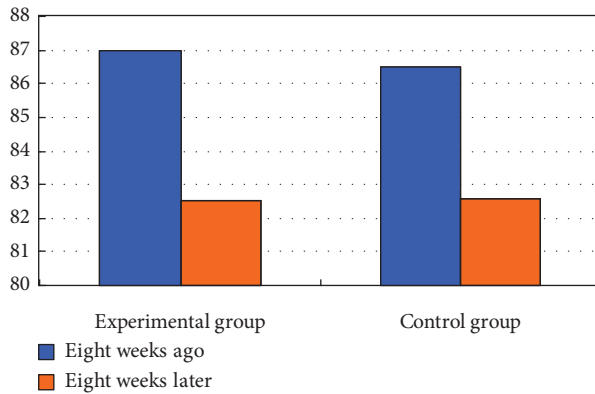


FIGURE 3: Changes in resting heart rate before and after eight weeks in the experimental group and the control group.

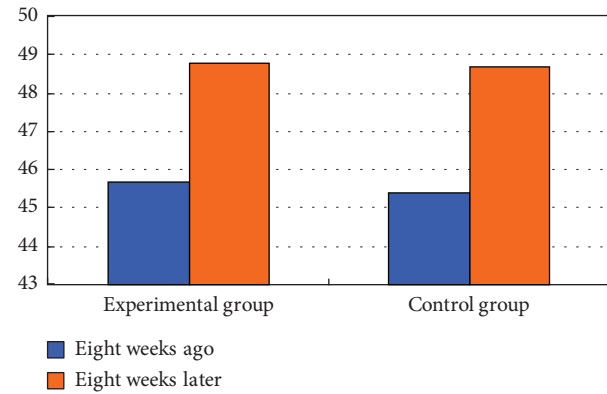


FIGURE 5: Changes in the step test index before and after eight weeks in the experimental group and the control group.

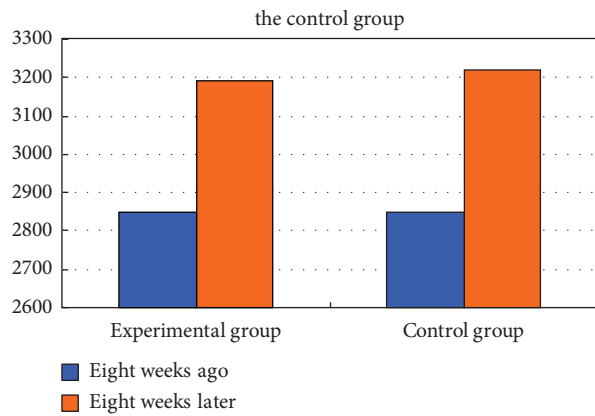


FIGURE 4: Changes in the maximum vital capacity of the experimental group and the control group before and after eight weeks.

Through the sample test of their resting heart rate, maximum vital capacity, and step test index of the experimental group and the control group, it can be concluded that the resting heart rate P values of the experimental group and the control group were 0.835, respectively, and the P value was greater than 0.05, indicating that there was no significant difference in the resting heart rate of the players in the experimental group and the control group. There is no significant difference in the aspects.

The maximum vital capacity P value of the experimental group and the control group was 0.997, and the P value was greater than 0.05, indicating that there was no significant difference in the maximum vital capacity between the experimental group and the control group.

The P value of the step test index between the experimental group and the control group was 0.708, and the P value was greater than 0.05, indicating that there was no significant difference in the step test index between the experimental group and the control group.

To sum up, the cardiopulmonary function of the experimental group and the control group was basically at the same level, and there was no significant difference. Figures 3 and 4 are the changes in resting heart rate before and after eight weeks in the experimental group and the control group and the changes in the maximum vital capacity of the experimental group and the control group before and after eight weeks.

Although there was no significant difference in improving lung function between the two exercise intervention methods; as far as the subjects themselves are concerned, during the gas transport process, the utilization rate of oxygen in the body has been improved, and from the changes before and after the intervention, fitness the impact of running on pulmonary function indicators is greater than that of spinning. Therefore, it can be seen that, under the same intervention time and the same exercise load intervention, the pulmonary function-related indicators are more likely to produce positive changes when fitness running is selected. And, Figure 5 is the changes in the step test index before and after eight weeks in the experimental group and the control group.

5. Conclusion

Healthy and scientific aerobic exercise [24, 25] is extremely beneficial to improving the cardiopulmonary function of young people. At present, there is relatively little research on real-time monitoring and evaluation of fitness exercise using

scientific methods and means of exercise physiology at home and abroad. Therefore, using the cardiopulmonary function exercise test to find the appropriate load for aerobic and anaerobic exercise through dynamic monitoring of physiological and biochemical indicators during aerobic exercise and anaerobic exercise can make the research results more practical. Therefore, we perform dynamic detection on these two kinds of motion, hoping to contribute to the research in this area.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

From “Social Integration” to “Class Integration”: Applying Durkheim’s Sociological Thought to Hidden Dropout of Junior Middle School Students

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At present, China’s academic circles have made some research results on the hidden dropout of junior middle school students, but they have not formed a relatively mature theory. Based on Durkheim’s “social integration” theory, this paper studies hidden dropout from the perspective of class sociology and puts forward the influencing mechanism of “class integration” of junior middle school students’ hidden dropout behavior. By class observation, this paper obtains the hidden dropout theoretical model of the interaction between individuals and class organization.

1. Introduction

With the continuous and powerful implementation of the policy of controlling the dropout to ensure compulsory education, the phenomenon of students’ dropping out of school has almost disappeared in various regions in China. However, the phenomenon of “hidden dropout,” such as teenagers’ weariness and unwillingness in study, remains common. Hidden dropout, when first introduced, refers to the situation of leaving school early without deprivation of the status as a student; subsequently, researchers have also included phenomena such as “being bodily but not mentally present,” “being bodily present with a lack of love,” “being bodily present with a lack of power” [1], and “being present in the school education scene, but wandering away from class and classroom all day long” [2] in the research of hidden dropout. At present, China’s academic circles mainly focus on junior middle school students in rural areas in the research of hidden dropout, and have made some achievements from the phenomenon description of hidden dropout to an analysis of causes, hazards, integration strategies, and other aspects. Nevertheless, there is a lack of effective theory integration in the research, which relies more on theories than on practice.

2. Durkheim’s “Social Integration” Theory

Durkheim, in his research on suicide, first proposed the concept of “social integration.” Based on the concept, social integration refers to a process in which social individuals form the collective consciousness based on social division of labor to maintain social order. He refers to “social integration” in a broad sense, namely, the process in which an individual establishes and maintains close relationships with others or communities. The term “social” here includes various social connections, such as friends, relatives, and colleagues [3]. Social integration reflects the integration level and cohesion of a society. Durkheim drew the following conclusion in his *On Suicide* [4]: better social integration levels can reduce the suicide rate; both religion and family are, in essence, a communal life, and what really matters is how cohesive the community is and how involved individuals are in the community. Figure 1 shows Durkheim’s view of two social forces.

Durkheim’s *On Suicide* is a classic of sociology. Different from the traditional perspective of individual psychology, Durkheim, from a sociological group perspective, established the theory of analyzing suicide by the causality of a social fact, and expounded the relationship between the

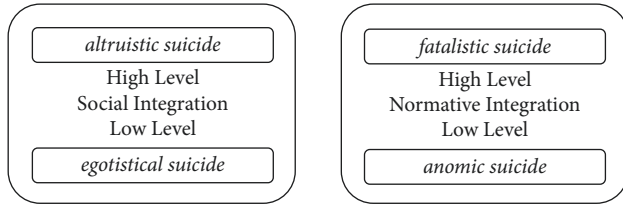


FIGURE 1: Durkheim's view of two social forces (social integration and normative integration).

society and individuals, considering that suicide occurs when the connection between individuals and a social group or the society is impaired or alienated. Durkheim pointed out that the suicide rate in a society is regular, and each suicide, no matter how different the stories behind them, is related to the solidarity and cohesion of the society. There are two social forces behind suicide, namely, social integration and normative integration. In the case of too low or high social integration, egoistic or altruistic suicide occurs; in the case of insufficient or excessive social normative integration, anomic or fatalistic suicide occurs. Both integrations act together on the suicidal tendency and behavior in a society, and their moderate and balanced state restrains the suicidal tendency and stabilizes the suicide rate.

3. From "Social Integration" to "School Integration"

In the 20th century, Western sociological circles began to apply the social integration theory to the adaptation issue of immigrants, and later developed two rival theoretical factions, assimilation and pluralism [5]. The applicability of the Western immigrant integration theory in China (which mainly applies to the research of social integration in rural areas with migrant population) has been confirmed by some empirical studies [6]. School integration, as an important part of social integration of migrant children, began to be studied by China's academic circles (mainly sociology).

In this paper, however, the "school integration" continues the broad meaning of the primitive notion of Durkheim's "social integration," and is studied in larger groups, in addition to migrant children. The "school integration" here refers to a process and state in which all students participate in school life normally and live in harmony with natural, social, and cultural environments of the school. ZHOU [7] divided school integration by operationalization into seven dimensions, i.e., satisfaction evaluation, collective identity, relations between students and teachers, relations between classmates, academic performance, code of conduct, and interpersonal conflict. School integration reflects the integration and cohesion of a school.

In higher education, the development of dropout theories is profoundly related to Durkheim's "social integration" theory. In American higher education, the paradigm of the dropout behavior has undergone the transition from the individual psychological paradigm of "blaming the victim" to the sociological paradigm of "serving disadvantaged students" with interactions between individuals and environments. As early as the 1960s, college students' dropout

behavior became the focus of American higher education research, and researchers mainly analyzed the motives for staying at school, learning capacity, willingness of employment, and other aspects of dropouts from the psychological paradigm, believing that the dropout behavior is an individual behavior, and the dropout phenomenon is caused by the failure of individuals rather than those at the school. This is the view of "blaming the victim" [8]. Since the 1970s, this view has changed, and a college dropout theory based on Durkheim's "social integration" theory has been gradually formed, which clarifies the relations between individuals' dropout behavior and the college environment, and theoretically describes the reasons for dropout by sociological paradigm; that is, the integration between college students and the school is insufficient.

3.1. First-Generation Dropout Model: From "Social Integration" to "College Integration". William Spady (1970) first applied Durkheim's "social integration" theory to dropout in the *Dropouts from Higher Education: An Interdisciplinary Review and Synthesis*. Spady argued that there was somewhat a lack of "conceptual clarity, methodological rigor, complexity of design, breadth, clear theoretical basis" and other aspects in most of the studies on college dropout at that time [9]. He argued that we must try a method with "a more interdisciplinary-based, theoretical synthesis." Durkheim's "social integration" theory provides a fruitful theoretical tool to summarize most of the existing studies, and focuses these studies on the interaction between students' personality (namely, disposition, interests, attitudes, and skills) and the college environment forces (such as influence, expectation, and requirements). By combining Durkheim's "social integration" theory with dropout studies, Spady tried to establish a more dropout process-focused sociological model, namely, the first-generation longitudinal dropout theoretical model of interaction between individuals and environments. According to the model, the decision to leave a specific social system is the result of a complex social process, as shown in Figure 2. The factors of norm consistency and friendship support are parallel to moral consciousness (normative integration) and collective belongingness (social integration), two factors that Durkheim used to explain the high integration of individuals and the society in common life. Spady also asserted that if there is a lack of sufficient "norm consistency" and "friendship support" between students and the school, students will break their connection with the school system and produce the dropout behavior [10].

3.2. Second-Generation Dropout Model: From "Social Integration" to "Student Integration". Vincent Tinto (1975) pointed out, in the *Dropout from Higher Education: A Theoretical Synthesis of Recent Research*, the ignorance of the responsibility and role of institutions in keeping students complete their studies in early research on dropout [11]. To build a dropout theoretical framework, he, by citing Durkheim's "social integration" theory and revising on the basis of Spady's, formed the second-generation longitudinal dropout theoretical model, as shown in Figure 3. The model

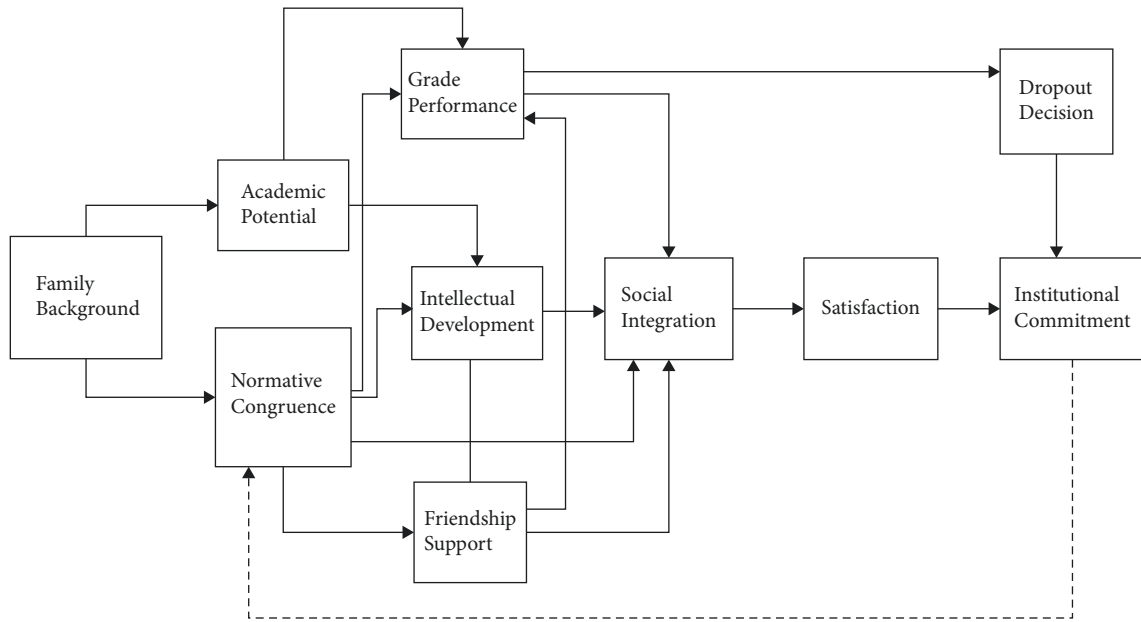


FIGURE 2: Spady's longitudinal dropout theoretical model (1970).

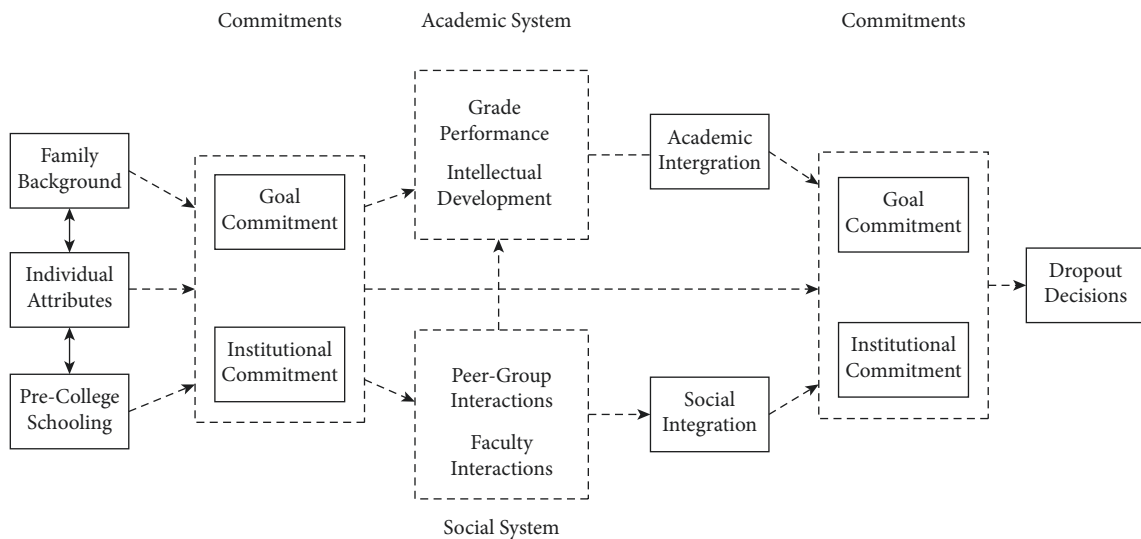


FIGURE 3: Vincent Tinto's longitudinal dropout theoretical model (1975).

analyses the interaction between students and the environment (college) in more detail, believing that there are two subsystems (academic system and social system) in the school system, of which the academic system represents students' academic performance, intellectual development, school achievement, and other comprehensive performance, and the social system represents students' relations with peers, relations with teachers, social behaviors, and other comprehensive performance in the school [12]. According to Durkheim's description on how individuals integrate in the society, Vincent Tinto defined two types of integration: academic integration and social integration. In Vincent Tinto's dropout model, the college dropout process can be regarded as a longitudinal process of interaction between individuals and colleges in academic and social systems,

during which what a student has experienced in these systems (measured by academic integration and social integration) constantly changes his goal commitment and institution commitment, and eventually leads to perseverance or dropout. Vincent Tinto found that dropout is attributed to the failure to effectively realize "academic integration" and "social integration" between students and colleges [13].

Nowadays, Vincent Tinto has become a prestigious expert on college dropout in the United States [14], whose research results have had great influence on dropout research in the past four decades. Vincent Tinto's longitudinal dropout theoretical model contains several key factors, which have been recognized as a prominent focus of student dropout research. For instance, inspired by Durkheim's

“social integration,” he proposed the “student integration” (academic integration and social integration), which led to a large number of subsequent studies on student integration (Bamber and Tett 2001; Berger and Milem 1999; Mannan 2007; McQueen 2009; Pascarella and Terenzini 1979a, 1983; Severiens and Schmidt 2008). In addition, Vincent Tinto analogized college students leaving school with Durkheim’s egoistic suicide, which also greatly influenced the research on student dropout [15].

3.3. Summary: Sociological Explanation of Suicide and Dropout Behaviors. In the above dropout models, dropout can be analogous to suicide, and the school environment to the society. Both dropout and suicide behaviors can be construed as individuals’ divorcement from the society due to their inability to integrate into the group [16]. People escape from the society by giving up their lives, and teenagers escape from the school by giving up their studies. We can say that suicide and dropout are consistent in inadequate integration between individuals and organizations, and there is a mandatory social fact at work behind an individual behavior. Table 1 shows the analogy of influencing mechanisms of suicide and dropout.

4. From “Social Integration” to “Class Integration”

Compared with college students, junior middle school students have their communal life in the class, and spend most of their school life in the class. The class is the basic organization unit of the school, where the class teacher, students, and subject teachers constitute a close and united collective life, with class norms and rules that must be followed, and fixed curriculum activities and hours made. The more powerful the class organization is, the more dependent the students’ life and study are in the class. As the basic form of education activities, the class is the main object and field of research of educational sociology.

The problem of junior middle school students’ hidden dropout can be solved in a more targeted way by further focusing the school environment of junior middle school students on the classroom environment and studying the problem from the perspective of class sociology.

Durkheim thought that suicide is an individual phenomenon in terms of its results, and yet its causes are essentially a social one; the degree of social integration (social integration and normative integration) influences the suicide behavior. The class integration influencing mechanism of junior middle school students’ hidden dropout behavior is proposed by analogy with the social integration influencing mechanism of the suicide behavior proposed by Durkheim [16].

Despite family, social, students, and other related reasons for junior middle school students’ hidden dropout behavior, there are differences in hidden dropout behaviors and rates in different classes. Take, for example, 14 classes of Grade 2017 in S Middle School in L City. Every two classes are a pair of parallel classes, in which the major subject

teachers (Chinese, Math, and English) are the same. However, differences in hidden dropout rates become more obvious over time in two parallel classes with basically the same subject teachers and students’ admission levels, such as Class 2 and Class 9, Class 4 and Class 11, Class 5 and Class 12, and Class 7 and Class 14, as shown in Table 2. Comparison of parallel classes suggests that the class teacher’s style and management influence the class culture and thus students’ sense of belonging and integration into the class, and the hidden dropout rate can be explained from the perspective of class integration.

In Table 2, there are two semesters in an academic year. With mid-term and final examinations in a semester as the statistical time nodes, there are 4 statistical time nodes in an academic year and totally 12 statistical time nodes in the three years of junior middle school. For coding and analysis, the 12 examinations in the three years are marked as 1, 2, 3, ..., 12.

Based on the concept of Durkheim’s “social integration,” the class integration in this study refers to the process of adaption and integration of junior middle school students into their classes. The class integration is an interaction process, mainly including two aspects from the perspective of interaction subjects: the class teacher’s acceptance of junior middle school students with poor academic performance or discipline, and the degree of junior middle school students’ acceptance and adaptation to the learning requirements of their classes and the junior middle school, including their adaptation to class life, recognition and acceptance of class culture, situation and willingness to make friends with classmates, self-efficacy, and recognition of the value of junior middle school curriculum. This study shows that students may have hidden dropout behaviors in the case of insufficient class integration.

From the perspective of the class teacher, class integration can adjust students’ cohesion through class culture. Class culture can be broken down into the two basic factors of class solidarity and class norms, corresponding to “social integration” and “normative integration.” Class solidarity reflects the connection and combination between members and the class, which is essentially a cohesion and can provide support for class members. Class norms are, in essence, an external control force, which limits and adjusts class members’ desire and behaviors, helps students transform their desires into achievable goals, and defines the ways to achieve the goals. Class solidarity and class norms together affect a class’s hidden dropout tendency, and their balance can restrain the hidden dropout to a certain extent, where the hidden dropout rate will be at a low and stable level if they are in a moderate and stable state. Table 3 shows the decomposition of class integration force.

5. Excellent Cases of “Class Integration”

Through ethnographical observation, interviews with teachers, list of students taking an examination, results analysis, and other methods, it is found that Class 8 of Grade 2017 in S Middle School in L City, led by Teacher W, has maintained a zero hidden dropout rate for five consecutive

TABLE 1: Analogy of influencing mechanisms of suicide and dropout.

Analogy between suicide and dropout	Research unit (group perspective)	Influencing mechanism	Two factors for integration of individuals and organizations	
Durkheim explained the suicide behavior	Society	Social integration	Moral consciousness, code of conduct (normative integration)	Collective belongingness (social integration)
Spady explained the college dropout	College	College integration	Norm consistency	Friendship support
Tinto explained the college dropout	College	Student integration	Academic integration	Social integration
This paper explained the hidden dropout of junior middle school students	Class	Class integration	Class norms	Class solidarity

TABLE 2: Hidden dropout rates of 14 classes of grade 2017 in previous tests (unit: percentage point).

	Statistical point	1	2	3	4	5	6	7	8	9	10	11	12
Parallel class	Class 1	0	0	0.00	0.00	1.96	3.92	5.77	7.69	7.69	7.69	7.69	7.69
	Class 8	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	7.14
Parallel class	Class 2	0	0	0.00	0.00	4.08	4.08	4.00	4.00	4.00	4.00	6.00	18.00
	Class 9	0	0	0.00	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27	2.27
Parallel class	Class 3	0	0	2.00	2.00	6.12	6.12	8.16	8.16	12.24	12.24	12.24	12.24
	Class 10	0	0	0.00	0.00	4.55	4.55	4.65	4.65	6.98	6.98	13.95	16.28
Parallel class	Class 4	0	0	0.00	0.00	2.00	2.00	2.00	4.00	6.00	5.88	7.84	7.84
	Class 11	0	0	4.44	4.44	8.89	8.89	11.11	13.33	15.56	15.91	18.18	18.18
Parallel class	Class 5	0	2	2.00	2.00	6.00	6.00	6.00	8.00	16.00	15.69	17.65	17.65
	Class 12	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.82	11.36
Parallel class	Class 6	2	4	3.92	3.92	5.77	5.77	5.77	7.69	11.54	11.32	11.32	11.32
	Class 13	0	0	0.00	2.27	2.33	4.65	4.65	4.65	6.98	9.30	9.30	13.95
Parallel class	Class 7	0	0	0.00	2.00	2.00	2.00	4.00	4.00	4.00	4.00	4.00	6.00
	Class 14	0	0	0.00	0.00	2.13	8.51	12.77	14.89	19.15	18.37	18.37	18.00

TABLE 3: Decomposition of class integration force.

Class solidarity (cohesion)	Collective belongingness: class emotion, teacher-student communication, and friendship support	
	Learning traction: learning interest, learning motivation, and discipline emotion	
Class norms (external control force)	Disciplinary norms: daily code of conduct, class rules and regulations, moral standards, and evaluation credits	
	Learning norms: regular rules of class, writing norms, assignment requirements, and performance standards	

years [1]. Teacher W, who is good at summarizing and reflecting on education, has released more than 400 original stories on education in his or her WeChat Official Account “Story of Grassroots Gardeners” [2]. Teacher W has been committed to the development of class culture and is able to consciously organize class activities to improve students’ collective belongingness and learning motivation to make them feel loved and be well-disciplined so that the class solidarity and class norms are in a moderate and stable state. Teacher W also pays close attention to the changes in students’ status, and intervenes in those with a tendency toward dropout.

5.1. Colorful Class Activities. Class activities can enhance the class cohesion and the mutual understanding of teachers and students and friendship between students, and are also a rare education opportunity. Teacher W attaches great importance to the organization, implementation, and

summarization of class activities, especially extracurricular activities, which require teachers to motivate the parent committee and keep activities safe and educational. The extracurricular activities of Teacher W’s class are so colorful that students have had many precious memories.

When first taking over Class 8 in September 2017, Teacher W said to students: “You must study willingly. I’m not here to force you study, because I paid a heavy price for forcing students to study. Some students in Grade 2014, who were forced to study, were admitted to an ideal senior middle school, but they were not doing very well in their school. What should I do while I’m not forcing you? I will focus more on the construction of the class. How can we build a fighting and cohesive group? Class activities. I will organize colorful class activities each semester. I look forward to your excellent performance.”

In the first semester of the seventh grade, class activities have been held four times by Class 8 of Grade 2017, including military training, hands-on inquiry-based learning

activities of *Seek the Source of Yi River in Yimeng*, broadcast exercise competition, and campus tour in target senior middle schools. Students thoroughly enjoy class activities based on those held. “To build a cohesive class with colorful class activities” is Teacher W’s concept for class team building. Particularly, Teacher W is proud of making so-called “poor students” gain valuable confidence in class activities.

5.2. Discipline Development and Cooperative Management. Students’ habits are developed in the seventh grade. If it fails, more efforts will be needed to ensure good class operation in the eighth and ninth grades. If a good learning and living habit is formed, students in the class will benefit from this atmosphere and the class teacher will spend more time and energy in leading students’ study and ideological and cultural construction.

In the first month of school, what Teacher W mainly does in the class meeting course is to discuss and set class rules with students. The problems in being late, morning reading willingly, failing to finish homework, school uniforms, snacks, self-study courses, midday rest, and class recess discipline have been basically controlled after the first month of school.

The class teacher’s education and guidance are essential, but Teacher W does far more than these. First, Teacher W attaches importance to students’ self-education, since only those who can educate themselves are able to overcome difficulties in the future. Second, Teacher W pays attention to peer education, while relations between students and teachers are less influential than peer relations in the school. Third, Teacher W lays stress on parents’ involvement, such as allowing parents to give lectures in the class, a move benefiting parents, students, and teachers. Fourth, the class teacher strengthens communication and cooperation with subject teachers to form the resultant force of school education, which helps timely discover and properly resolve problems in the class.

5.3. Means of Education with Reasonable Rewards and Punishments. In student education and management, two powerful measures used by educators and managers are rewards and punishments, which are two sides of means of education.

Rewards used by Teacher W include material rewards (such as preparing some delicious food for students with good grades or great progress after the examination to remember the glory of students) and mental rewards (such as public praise and awarding the certificate).

Punishments used by Teacher W include common criticism, criticism in a circulated notice, written self-criticism, written guarantee, standing, public apology, contacting parents, and push-up. The corresponding disciplinary measures are also discussed while class rules are made. Teacher W believes that the disciplinary measures should be reasonable and acceptable to students; educational punishments are not imposed arbitrarily, and punishment sheets may be used.

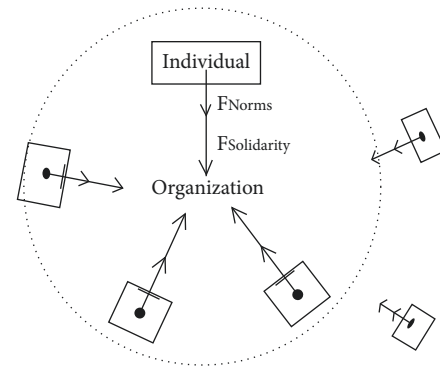


FIGURE 4: Hidden dropout theoretical model of interaction between individual students and class organization.

5.4. Tolerance and Acceptance of “Poor Students”. We have learned that Teacher W is a master, who graduated from a normal university directly under the Ministry of Education. As a new teacher full of dreams of education, Teacher W can tolerate and respect “poor students.” When speaking of Teacher W’s tolerance of “poor students,” a math teacher in the same class said, “It’s lucky for ‘poor students’ to have such a caring class teacher as Teacher W. In a class with more ‘poor students’, these students will form a group and find a sense of belonging and joy in their own way. It is also a happy thing to have their own partners in the school. However, in a class with more good learners and several bad ones, the latter will feel lonely and hardly find their sense of existence. With no common interests with other students, they may not talk to others and find no peers, and may finally give up before finishing the three years of study in junior middle school.”

6. Conclusion

Based on Durkheim’s “social integration” theory, this study proposes the “class integration” influencing mechanism of junior middle school students’ hidden dropout behavior from the perspective of class sociology. From the perspective of class integration, the hidden dropout is essentially caused by the failure of students to properly integrate into class life. The internal factors influencing the urban junior middle school students’ hidden dropout mainly include students’ personality and cohesion of class life.

6.1. Influence Factors of Hidden Dropout Rate in a Class. The cohesion of class life is mainly reflected in class culture by observation and analysis of real classes. Class culture can be divided into class solidarity and class norms. Students are attracted by class solidarity and suppressed by class norms, thus resulting in the cohesion. Influenced by the cohesion of class culture, students have their activities in a range allowed by the class organization. Benign class culture, the internal force that restrains students’ hidden dropout behavior and keeps the balance of students’ learning environment, tends to maintain the class’s hidden dropout rate at a steadily low level. In the case of inadequate ability to adjust class culture, a class’s hidden dropout rate will rise at key transition points such as changes in the grade and study phase.

6.2. Students Prone to Dropping Out in the Class Structure. For a class, the hidden dropout rate is low when class solidarity and class norms are at a steadily moderate level. For students in the class, central students are less likely to drop out, while marginal students have a stronger tendency to drop out. In a class with more students, the class cohesion plays a less disciplinary role in marginal students. This suggests that marginal students in a class of a larger size are prone to dropping out in the class structure.

Class culture is divided into core values and practical activities, of which students' academic performances and disciplinary behaviors are observable practical activities. Teaching is the central work of a school and a center of class culture. Therefore, study is the core of a class's practical activities. The integration of students' personality and school collective life mainly reflected the matching of students' personality and class culture, while such matching is reflected in students' contribution in promoting the study of the class. A student with poor academic performance or disciplinary behavior will drag down the learning speed and level of the class. Thus, such students are likely to be excluded and gradually marginalized in the class. According to the theory of structuration of Anthony Giddens, a British sociologist, the structuration process has the two natures of action and structure, of which the social structure defines people's social activities, and people's social activities produce and regenerate a new social structure. Similarly, the formation of the class's "central and marginal" structure also has dual natures. On the one hand, the marginal position of a student decides the degree of the tendency of dropout and the student's hidden dropout action; on the other hand, the student's action affects his or her position in the class. That is, practical activities in the class also produce and regenerate a new class structure.

6.3. Hidden Dropout Theoretical Model of Interaction between Individual Students and Class Organization. According to the cohesion of the class and students' position in the class, the hidden dropout theoretical model of interaction between students and the class organization is obtained in the study, as shown in Figure 4.

This study shows that students' "positive personality" and "negative personality" are a pair of neutral concepts. From the perspective of the consistency in students' personality and the direction of school culture, "negative personality" refers to a personality contrary to the direction of mainstream values of the current education. Under certain conditions, positive personality and negative personality can be mutually transformed. For example, hair coloring is prohibited in the code of conduct for primary and secondary school students, and thus, this behavior is a negative personality in primary and secondary schools; however, in the work focusing on arts and fashion, this behavior is a positive personality. We can see that "positive personality" and "negative personality" are divided mainly according to the degree of matching with the current organizational culture. For the same personality, its strengths in one organization or scenario may become its weaknesses in another organization or scenario.

Proper class culture can reduce the hidden dropout rate. However, it should be noted that students' hidden dropout behaviors cannot be completely eliminated in a cohesive class, which is because students' hidden dropout behaviors are also related to students' "negative personality" from the perspective of individual dropouts. When the attribute value of a student's "negative personality" exceeds a certain mean range, the greater the deviation of the attribute value is, the more antisocial the student is, and the farther the student is from the center of the group; when a student is in the marginal position, the class is less cohesive to the student. The class teacher can accept more students with "negative personality" by inclusive class culture.

Data Availability

The dataset used to support this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

The Correlation between Monetary Policy and Housing Price Change Based on a VAR Model

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In early 2020, the global economy was severely hit by the COVID-19 pandemic. Governments, including China, have adopted expansionary fiscal policies to stimulate demand and quantitative easing to increase the money supply to boost the economy by lowering lending rates. This paper starts from the influence of monetary policy on housing price mechanism, tries to explore the monetary policy on interest rate and money supply, finally establishes the VAR model, empirically analyzes the effectiveness of the impact of monetary policy on housing price changes, and makes a policy suggestion to demonstrate the necessity of consideration when stimulating the economy, to avoid housing price rise too fast, which affects the people's livelihood, and to have a negative impact on social sustainable development.

1. Introduction

Since the abolition of the housing welfare distribution system in 1998, the housing transaction market has shown a rapid upward trend [1]. Specifically, the total amount of real estate investment surges year by year, the supply and demand of the real estate market are booming, and the real estate prices have repeatedly reached new highs [2]. Since 2004, housing prices have basically increased by about 18% year on year, and even housing prices have increased by 25% in 2009. Since 2010, with a series of favorable policies and economic stimulus policies loosening the property market, the real estate industry has shown a rapid recovery and shown a relatively obvious polarization state. The first- and second-tier cities led by North, Shanghai, Guangzhou, and Shenzhen have begun to flourish, repeatedly reaching new highs. Even though China has begun to introduce a variety of housing price control policies since 2003, the housing price is still in the dilemma of being higher and higher. The high housing prices will lead to the redistribution of social resources, involving a series of issues such as financial stability, economic development, and social equity [3, 4]. At present, the high housing price in some economically developed areas has exceeded the consumption level of many residents,

and even produced a large number of “mortgage slaves”. It can be seen that the rising speed of housing price rates is not only an economic issue, but also a livelihood issue closely related to every people [5].

2. Empirical Analysis

2.1. Variable Selection and Interpretation. This paper is based on analyzing the macroeconomic data for 44 periods between the fourth quarter of 1999 and the fourth quarter of 2010 [6]. Considering the availability of data, the variables selected the five-year nominal loan interest rate (X_1), M2 (X_2) of broad money demand, and real estate sales price index (Y) after eliminating the impact of seasonal changes, and were processed logarithmically [7, 8]. Table 1 is the list of variables affecting real estate prices. All the data came from the National Research Network, China Economic Network database, and the website of the National Bureau of Statistics.

2.2. Empirical Inspection and Data Analysis

2.2.1. ADF Stationarity Test. Stationarity means that the target time series is generated by a random process; that is, each value is derived from a random probability

TABLE 1: List of variables affecting real estate prices.

Variable symbol	Variable name	Variable interpretation
LNy	Real estate prices	The logarithm of the China property sales price index
LNx1	Lending rate	Logarithm of the 5-year loan benchmark interest rate
LNx2	Money supply	Generalized money supply M2

Source: summarized above.

TABLE 2: Results of the ADF test.

Variable	ADF	Critical value1%	Critical value5%	Critical value10%	P Value	Conclusion
LNy	-4.9039	-4.1705	-3.5107	-3.1855	0.0013	Stationary
LNx1	-2.8334	-4.1657	-3.5085	-3.1842	0.1932	Nonstationary
LNx2	-1.6698	-4.1809	-3.5155	-3.1882	0.7478	Nonstationary
D (LNx1)	-7.0784	-4.1705	-3.5107	-3.1855	0.0010	Stationary
D (LNx2)	-2.7197	-3.5885	-2.9297	-2.6030	0.0788	Stationary

Data source: Eviews 10 software calculation.

distribution. Neither the mean nor the variance varies with the time t , and the covariance between the values is only related to the time t . Before establishing the VAR model, the stationarity test [9] is required, and the time series can only be estimated using the OLS method; however, if the non-stationary time series is used, then the problem of pseudoregression is likely [10] because the Dickey-Fuller test assumed that time series is generated by first-order autoregression (AR) process with random error of white noise; however, in the actual test, time series may be generated by higher order autoregression process or the random error term is not white noise, and since the OLS method still shows the random error autocorrelation problem, the DF test is invalid. The author uses the ADF method for the stationarity test of three variables; the test equation is as follows [11].

Model 1 (equations with the trend terms and the intercept terms):

$$\Delta X_t = \alpha + \beta t + \delta X_{t-1} + \sum_{i=1}^m \beta_i \Delta X_{t-i} + \varepsilon_t. \quad (1)$$

Model 2 (the equation for which no trend term has an intercept term):

$$\Delta X_t = \alpha + \delta X_{t-1} + \sum_{i=1}^m \beta_i \Delta X_{t-i} + \varepsilon_t. \quad (2)$$

Model 3 (the equation for the intercept term without a trend term) [12]:

$$\Delta X_t = \delta X_{t-1} + \sum_{i=1}^m \beta_i \Delta X_{t-i} + \varepsilon_t, \quad (3)$$

where α is the drift term, and βt is the trend term. The null hypothesis $H_0: \delta = 0$ and the alternative hypothesis $H_1: \delta < 0$ are tested step by step from models 1 to 3. If the test rejected the null hypothesis, the sequence does not have a unit root and is a stationary sequence. If the null hypothesis cannot be rejected, the sequence is considered to have at least one unit root and is a nonstationary sequence, so differential processing is required to ensure its stationarity [13]. The intercept and trend terms are also determined in the equation

according to the minimum information criterion (AIC) [14]. Table 2 shows the results of the ADF test.

The test results show that the ADF value of the variable LNy is less than 5% critical value, the P value is less than 0.05, and the log of the house price index is a stable sequence [15]. At the significance level of 10%, the raw data of interest rate (LNx1) and money supply (LNx2) are not significant, indicating that the two variables correspond to the nonstable sequence, indicating that these data have a unit root. Regarding the loan interest rate and money supply log of the first-order difference processing, it is found that D (LNx1) ADF value is significantly less than 5% critical value, so the log of the interest rate index LNx1 is a first-order single sequence; however, for the generalized money supply M2, the test equation with intercept term form of P value < 0.1 (further check the equation δ) estimate result is negative and P value = 0.0096 is significantly less than 0.05, so there is a enough reason to think that the difference of money supply index D (LNx2) is stable and that LNx2 is also first-order single sequence [16].

2.2.2. Integration Test. The classical regression model is based on the assumption that all variables are stable data. For nonstationary data, the classical regression model cannot be used, but if there are long-term stable relations between variables, the method of classical regression model can be used. The logical significance of the cointegration test is as follows [17]: there is a long-term change law of multiple nonstable sequences; if there exists (d, d) order cointegration, their sequence is under a linear combination of long-term and equilibrium stable proportional relationship, namely, that variables will not produce false regression results; and even if there is a variable after a period of time interference from the equilibrium point, the equilibrium mechanism will also cause the next adjustment regression near the equilibrium point [18]. Two variables selected in this paper are first-order single integration sequence, and there may be a cointegration relationship, which needs to be tested. Here, the more commonly used Johansen's method for the cointegration test are selected [17–19].

TABLE 3: Optimal lag-period test results.

Lag	LogL	LR	FPE	AIC	SC	HQ
1	290.2633	NA	1.09e-10	-14.4237	-14.0398	-14.2860
2	307.9213	29.8827	7.06e-11	-14.8677	-14.0999	-14.5922
3	326.4486	28.5035*	4.41e-11*	-15.3563*	-14.2046*	-14.9431*
4	331.1505	6.5102	5.70e-11	-15.1359	-13.6003	-14.5849
5	336.3393	6.3862	7.38e-11	-14.9404	-13.0209	-14.2517
6	345.7963	10.1845	7.98e-11	-14.9639	-12.6605	-14.1374
7	356.9153	10.2636	8.36e-11	-15.0725	-12.3852	-14.1084
8	367.4198	8.0804	9.76e-11	-15.1497	-12.0785	-14.0478

Data source: Eviews 10 software calculation.

TABLE 4: Johansen's coconsolidation test results.

Examination table (trace test)				
Hypothetical cointegration relationship	Characteristic value	Trace test	Critical value 5%	P Value
None *	0.4150	39.4807	29.7970	0.0028
At most 1	0.2328	15.3494	15.4947	0.0526
At most 2	0.0733	3.4258	3.84147	0.0642
Examination table (maximum characteristic root statistic)				
Hypothetical cointegration relationship	Characteristic value	Trace test	Critical value 5%	P value
None *	0.4150	24.1313	21.1316	0.0183
At most 1	0.2328	11.9236	14.2646	0.1135
At most 2	0.0733	3.4258	3.8414	0.0642

* represents a rejection of the null hypothesis at the 5% level. Data source: Eviews 10 software calculation.

Selection of the lag order: The lag-order posterior term of the VAR model is designed to exploit the limited sample size to eliminate the time-series correlation of the residual term. The larger the number of model lag periods, the smaller the degree of freedom, and the greater the sample loss. However, the lag order unable to eliminate sequence correlation may lead to error in the established model [20]. In general, the optimal lag order is determined according to the principle of minimum AIC and SC values. If AIC and SC are not minimal at the same lag order, then trade-offs are performed using the LR test.

As can be seen from Table 3, the AIC* and the SC information criterion * appear at the third order, which indicates that the minimum value appears at the lag of 3 periods, namely, -15.35634 and -14.20464, respectively, so the optimal lag period is 3.

Johansen's coconsolidation test. The cointegration testing for multivariate and occurrence * represents the rejection of the null hypothesis at a 5% significance level, and that for not occurrence * represents the nonrejection of the null hypothesis. As can be seen from Table 4, there is a cointegration relationship between the trace test and the maximum value test at the significant level of 5%; that is to say, there is a long-term and stable proportional relationship between China's property price index, benchmark five-year loan interest rate, and broad money supply.

2.2.3. Vector Autoregression (VAR) Model. Vector autoregressive (VAR) models are often applied to the time-series data associated with each other and to analyze the dynamic

impact of random noise on the whole variable system. Therefore, the following content is based on the VAR model architecture proposed by C.A.Sims (1980) to analyze the impulse response and variance decomposition between variables, so as to study the dynamic interaction and effect between monetary policy variables such as real estate price and interest rate and generalized money supply in China [21].

Model theory form:

$$Y_t = \alpha_1 Y_{t-1} + \dots + \alpha_p Y_{t-p} + \beta_1 X_1 + \dots + \beta_r X_t + e_t. \quad (4)$$

Organizing the above formula, the following can be obtained:

$$Y_t = \sum_{i=1}^p \alpha_i Y_{t-i} + \sum_{s=0}^r \beta_s X_{t-s} + e_t. \quad (5)$$

In the formula, Y_t is the vector of m-dimensional endogenous variables, X_t is the vector of d-dimensional exogenous variables, α_i and β_s ($i = 1, 2, 3, p$; $s = 1, 2, 3, r$) are the parameter matrix to be estimated, endogenous and exogenous variables have p and r order lag periods, respectively, and e_t is the random error term. In this paper, the Y variable refers to the processed property price, and X_t is the logarithm of the interest rate and money supply of the exogenous variable.

Because in the traditional VAR model, only in the variable or variable first-order difference is divided into stationary sequence, or the stability of the model is stable, to pulse response analysis and variance decomposition, the variables, in the case of the real estate sales index is the first

TABLE 5: Results of VAR model ecological tests.

Roots of the characteristic polynomials		
Endogenous variable: LNY D(LNX2) D(LNX1)		
The lag period is selected: phases 1–3		
Roots	Module of plural roots	
0.868466	0.8685	
0.7062–0.4991i	0.8648	
0.7062 + 0.4991i	0.8648	
–0.0871–0.8556i	0.8600	
–0.0871 + 0.8556i	0.8600	
0.2108–0.3186i	0.3820	
0.2108 + 0.3186i	0.3820	
–0.3311	0.3311	
–0.1481	0.1481	

Data source: EvIEWS 10 software calculation.

order single whole nonstationary sequence, so they first order difference into the model, and test the stability of the sequence and the model [22].

Model stationarity test:

As shown in Table 5 and Figure 1, the characteristic roots of the VAR model all fall in the unit circle, and the corresponding modules of each characteristic root are less than 1, indicating that the characteristic roots of the model are stable; that is, the model is stable. Thus, the pulse response function analysis with a standard deviation for this VAR can be proceeded [23].

Pulse response analysis: The pulse response function describes how the residual of the shock responds to the endogenous variable. The pulse response applied in this paper is an effective method to analyze the correlation between domestic loan interest rate, money supply, and real estate prices; by depicting the pulse function, the dynamic influence on the response element can be seen [24].

First, with two monetary policy factors as the impact element, the property price is treated as the response element. The solid blue line in Figure 2 shows the pulse response of property prices to the positive impact of one unit of standard deviation of interest rate and money supply as the number of forecast periods increases. The red dashed line indicates the confidence region of 2 standard deviations from the pulse response image.

From Figure 2, we can know that in the short term, an impact of interest rate has a positive effect on the housing price. After about 4 issues, the highest value is about 0.025, the fifth period becomes negative, and the negative effect of the seventh period reaches the maximum of about -0.050, and then, it begins to gradually stabilize. This shows that the 5-year loan interest rate still has a negative impact on the housing price, but the effect of interest rate policy adjustment has a lag. In the short term, the rising interest rates will cause the real estate developers to transfer the increased costs of capital and materials to the sales prices, and the housing prices will tend to rise [25, 26].

In the medium and the long term, the supplier real estate developers are facing greater pressure of capital recovery, while the residents as consumers have more space for adjustment in the long term. They are more and more flexible

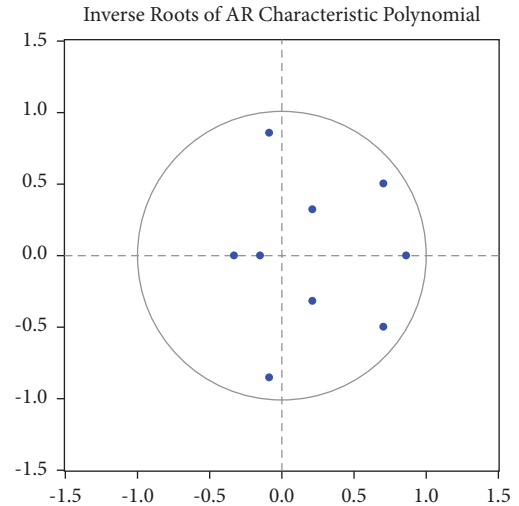


FIGURE 1: Results of the exogenous unit root test of the VAR model.

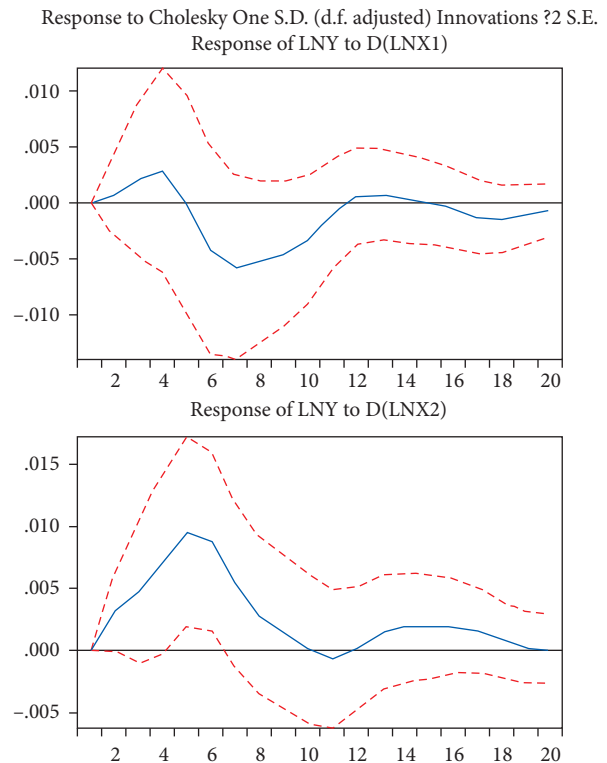


FIGURE 2: Figure of the impact of interest rate and money supply indicators on housing prices. Data source: EvIEWS 10 software calculation.

to housing prices, thus leading to the decline of housing prices, and the effect of interest rate policy is gradually obvious. However, for the money supply, we can know that one unit of new interest rate can quickly act on the housing price, exerting a growing positive impact on the housing price. As can be seen in the figure, the first four housing prices experienced a period of rapid growth, by about the fifth period, the monetary policy has a maximum effect of about 0.01, and the 0 effect level line is outside the confidence

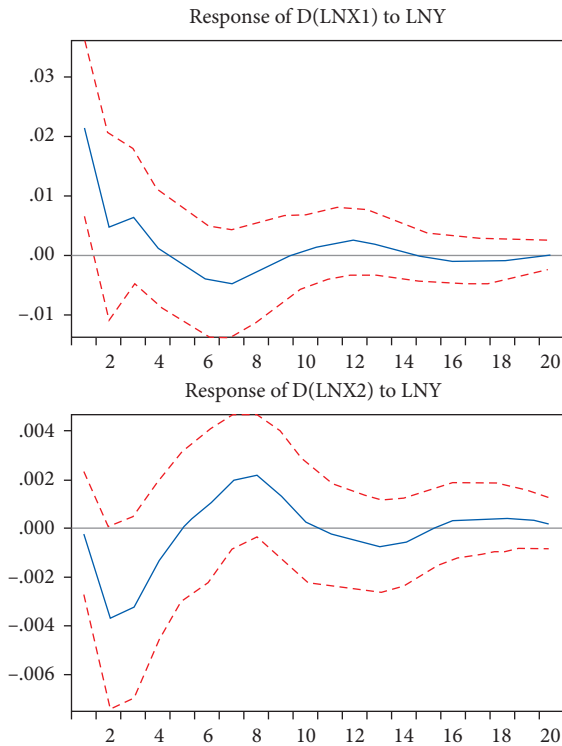


FIGURE 3: Map of the impact of house prices on interest rate and money supply indicators. Data source: EvIEWS 10 software calculation.

domain, so the effect is significant. This effect lasts long until about issue 10. To Phase 12, a slight positive effect will be on housing prices after the impact on housing prices is gradually stable.

Therefore, it is believed that the positive effect of the change in the total amount of borrowing funds caused by the increase in the money supply on the real estate consumers and suppliers is greater than the negative effect of the increase in the real estate supply caused by the suppliers. In general, the government authorities can play a good regulation effect on housing prices through the two policy tools of money supply and loan benchmark interest rate.

Secondly, the real estate price is the impact element, and the two monetary policy factors are the response element. From Figure 3, we can see that the real estate price has a positive effect on the interest rate in the first four periods, but the effect gradually decreases over time. For the money supply, the real estate price fluctuates with alternating positive and negative effects in 10 periods, and then gradually stabilizes. It can be seen that interest rates and money markets are related to the real estate market.

Predicted variance decomposition: The variance decomposition [27–35] is conducted to attribute the variance of the endogenous variables, to analyze the contribution of each structural impact to its change, and to judge the importance of the impact of different variables. Therefore, the variance decomposition of the real estate price index can more clearly explore the importance of the variables affecting it. Table 6 presents the process of the 20-stage

TABLE 6: Table of the variance breakdown of real estate prices.

Period	S.E.	LNy	D(LNX1)	D(LNX2)
1	0.0101	100.0000	0.000000	0.0000
2	0.0192	97.2638	0.1191	2.6171
3	0.0255	94.2916	0.7319	4.9765
4	0.0290	88.7940	1.5121	9.6940
5	0.0310	80.6483	1.3280	18.0237
6	0.0326	73.3941	2.9602	23.6457
7	0.0338	69.8970	5.6382	24.4649
8	0.0346	68.4683	7.6201	23.9116
9	0.0351	67.4528	9.1061	23.4412
10	0.0352	66.8783	9.8898	23.2319
11	0.0353	66.8983	9.9339	23.1678
12	0.0355	67.2197	9.8540	22.9263
13	0.0357	67.4683	9.7601	22.7716
14	0.0359	67.5033	9.6782	22.8185
15	0.0359	67.3772	9.6349	22.9878
16	0.0360	67.1596	9.6299	23.2105
17	0.036117	66.95296	9.7209	23.3261
18	0.036173	66.84415	9.8486	23.3073
19	0.036199	66.80092	9.9214	23.2777
20	0.0362	66.7772	9.9545	23.2683

Data source: EvIEWS 10 software calculation.

variance decomposition, and the data in the first column are the standard error after the prediction of each stage of the LNY. The last three columns represent the extent to which each variable contributes to the predicted standard deviation of property prices in each issue.

It can be seen that the impact of real estate prices is gradually declining and gradually stabilizing in Phase 11, around 67%. However, the explanatory power of interest rate on the standard deviation of housing price prediction was generally increased and gradually stabilizing at nearly 10% from the first phase (0) to Phase 10. Similarly, the explanatory power of money supply was basically gradually increased and gradually stabilized at 23% in the 15th period. Therefore, in general, the control ability of money supply policy is greater than the ability of interest rate to control housing prices.

3. Suggestions

3.1. Suggestions on the Real Estate Market

3.1.1. Monetary Policy Recommendations. Focus on the regulation of the money supply: China's financial market is still gradually improved, the degree of market capitalization is relatively low, and a perfect interest rate liberalization mechanism has not yet been formed. Interest rates are less sensitive to monetary policy in the long-term and equilibrium stable relationship of the three. Compared with interest rates, the money supply and social and economic development and inflation levels have stronger correlation, so the monetary authorities should put the money supply as the best control target, pay close attention to housing prices, timely take countercyclical control strategy, do monetary control that is given priority to, appropriately raise interest rates, and curb house prices rise too fast. At present, due to

the COVID-19 epidemic, China has released a large amount of liquidity in a short period of time, but due to the rapid effect of money supply, it will bear the rise of housing prices in a short period of time. Therefore, in order to ensure the healthy and sustainable development of the property market, some regulation policies can be introduced in time, such as the implementation of the maximum price for new buildings according to the time and price of developers, the restriction of the purchase of multiple commercial houses, and the differentiated down payment ratio of the first and multiple houses at the current stage to achieve the goal of promoting economic recovery, to meet the reasonable real estate demand, and to avoid real estate speculation and speculation again.

3.1.2. Interest Rate Policy Recommendations. *Flexible use of various loan interest rate policies:* For example, to further improve the differential interest rate policy of non-first-time homebuyers, there are various loan interest rate policies such as provident fund loan, commercial loan portfolio loan, and other related housing loan interest rate policies. We should further improve the effect of interest rate policy transmission channel, strive to promote domestic and regional interest rate liberalization, improve the sensitivity of real estate prices to interest rates, and determine the appropriate regulation time. The interest rate regulation policy has an obvious lag effect, in the medium- and long-term interest rate policy on the housing price, adjustment effect will appear. When the macroeconomic situation changes, China's monetary authorities from the understanding of the problem (i.e., the understanding of the time lag) to the regulatory policy formulation and implementation (i.e., the decision time lag), and then to the effective interest rate policy (i.e., the external time delay), each link takes a certain time. This requires the central bank to make a timely and accurate forecast of the housing price and the economic trend, make policy formulation in advance, and reasonably grasp the implementation time, so as to avoid the effect of the policy in the wrong time to achieve the ideal regulation effect or even cause adverse impact on the economy. For example, during the current epidemic period, the economy is stimulated by lowering interest rates, but we should also take into account the possibility of regret for rising housing prices in the future, and timely adopt some indicators such as money supply exchange rate for macrocontrol to ensure the stability of housing prices in the future.

3.2. Suggestions to Consumers. *Rational view of real estate price changes and the use of information to accurately grasp the timing of house purchase:* Housing price fluctuation is the result of a variety of economic factors. It is a complex system, but it is still in line with the role of the law of value. Its price still fluctuates around the value in the long run. Real estate prices are closely related to the implementation of national monetary policy, as buyers, whether for any purposes, such as to try to avoid overconfidence and survivor deviation error, to take the initiative to study the policy impact on the housing prices, combined with the macroeconomic form,

local specific situation, and monetary authority decisions, to grasp the overall trend of price fluctuations, using monetary policy effective delay, to choose the optimal purchase time, and to reduce their purchase cost to realize the value of assets.

Establish the correct concept of housing purchase: Housing not only has the consumption attribute of self-living, but also has the investment attribute of investment products. At the same time, due to the influence of China's idea of safe land relocation, it seems that every family must own their own housing; this traditional concept actually increases the housing demand and becomes the driving force for China to maintain high housing prices. But in other developed countries around the world, house rental is already very common. With the economic development of China, now new ideas, such as long-term rental apartments, gradually flourish in China. It is hoped that Chinese consumers can also accept the new concept of rental housing and relieve the pressure of domestic housing demand. At the same time, the relevant departments should also effectively protect the legitimate interests of the renters.

3.3. Advice to Real Estate Developers. At present, the real estate enterprises for the operation of real estate development cash flow mostly depend on bank loans, to prevent real estate excessive reliance on bank funds cause financial risks, should draw lessons from the successful experience at home and abroad, efforts to broaden the channels of investment and financing, the transformation of financing mode, more through the real estate trust business, money and capital markets, multi-channel direct financing mode to obtain funds. This not only has a positive significance to the security of developers' funds, but also is conducive to promoting the implementation effect of China's monetary policy and reducing the abnormal fluctuations of housing prices. On the contrary, commercial banks should also strengthen the supervision and risk control system of the funds invested in the real estate field, and improve the loan authorization and approval system and the whole process of the loan management mode. At the same time, we will actively take innovative measures to implement differentiated mortgage business to control the direction of capital flow, and promote the central bank's accurate measurement and release of the market money volume.

4. Conclusion

Through the cointegration test, it can be considered that the real estate price has a long-term stable relationship with the interest rate and the broad money supply. The authorities can control the real estate prices by reasonably adjusting the interest rates and the money supply to ensure the reasonable and stable operation of the real estate market. At the same time, although the monetary policy has a certain effect on regulating the housing price, the impact of the monetary policy is limited, and the effect also varies with different monetary policies. Therefore, we should not rely too much on the adjustment of monetary policy but reasonably choose the types of monetary policy.

Through the pulse response and the variance decomposition, the magnitude of the impact effect of different monetary policy variables on real estate prices and the contribution to the change in housing prices can be observed. Interest rate policy has a lag effect on real estate prices. In the short term, housing price is not sensitive to interest rate, and there is a lag period of 5–7 periods when using interest rate to adjust housing rate. However, in the medium and long term, the 5-year loan interest rate still has a negative impact on the housing price and lasts for a long time, and the regulation effect is gradually obvious over time. For the money supply, it can be known that one unit of new interest rate can quickly act on the housing price, exerting a gradually increasing positive impact on the housing price. Although there is a two-way effect of money supply on housing price from the perspective of the mechanism of action, it can be seen that the positive effect of money supply on housing price is greater than the reverse effect.

Therefore, the authorities to adopt expansionary monetary policy to increase the amount of money in circulation can immediately play a positive effect on housing prices. In the short term, the control of money supply can achieve better effect of housing price than the interest rate. From the contribution of various monetary policy factors to the fluctuation of housing price, in the long run, the impact of money supply changes on the housing price is greater than the interest rate, so the overall ability of money supply is greater than the ability of interest rate to control the housing price. The central bank can use the money supply to regulate the property market to achieve better results.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Research on Enterprise Digital Precision Marketing Strategy Based on Big Data

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The combination and application of big data and machine learning in the offline consumer market makes the formulation of marketing strategies more scientific. The use of machine learning can make statistics and analysis of users' consumption behavior and classify customers according to users' consumption behavior, so as to realize the personalized promotion of marketing content. In this context, this paper carries out research on enterprise digital precision marketing strategy based on big data. Starting from the actual application, this paper analyzes the current problems faced by consumption data sharing, as well as the characteristic needs of precision marketing for consumer groups, introduces homomorphic encryption technology, completes the structural design, process design, and algorithm design of the scheme in combination with the actual scenario that enterprises need to carry out precision marketing for customers based on consumption data, describes each design link in detail, and verifies the feasibility of the algorithm in the scheme.

1. Introduction

As the incremental era of mobile Internet has gradually entered the end, the traffic dividend of the Internet has almost disappeared, and the mobile Internet is entering a new era, that is, the era of stock. Being "user-centered" has always been the focus of major e-commerce brands [1–3]. It is becoming more and more important to mine the flow value of brand crowd assets and conduct targeted and accurate operations [4–8]. Therefore, for major brand owners, in addition to paying attention to the rise of transaction volume, how to precipitate and consume brand group assets and make efficient use of user stock value, so as to drive the breakthrough of the boundary of the incremental market, has become the core of common concern of major e-commerce platforms and many brands [9–14].

In the actual scene, there are still many complex difficulties and challenges [15–18]. First, there is a distance between enterprises and users. The actual contact between them is limited. It is very difficult to have close communication between them. Second, the phenomenon of

consumers' "clutching" has also gradually increased, and strange user needs have emerged, making it more difficult for enterprises to analyze these user needs. Therefore, there are still many difficulties for the majority of enterprises to achieve the goal of being "user-centered." At present, the technical capabilities of enterprises provide limited help to real business scenarios [19–22].

In order to solve these problems, this paper carried out research on enterprise digital precision marketing strategy based on big data. Aiming at the limitations of the original homomorphic encryption algorithm, the range of homomorphic encryption data processing is extended to rational numbers. Aiming at the problem that the k-means algorithm cannot cluster on the ciphertext domain of large integer classes, the algorithm is improved and rewritten. Aiming at the problem that it is difficult to locate the customer category after clustering, the k-means algorithm is improved by changing the generation method of the initial center point to distinguish the customer category so that the algorithm is more suitable for the scheme designed in this paper.

2. Consumer Data Sharing Analysis

2.1. Status Analysis. With the development of intelligent commerce in the whole society, the forms of online consumption are becoming more and more abundant. However, the proportion of online consumption in total consumption is still less than 20%, which means that compared with the online consumption market, the offline market is broader [17, 20]. Therefore, when the Internet economy enters the second half, the strategic focus of enterprises is transformed into offline traffic, digital drive and intelligent operation are gradually reflected in the real consumption economy, and the value of big data in offline consumption is also increasingly prominent. However, there are still some problems with offline consumption. The lack of innovation in the marketing content put in by the merchants has resulted in a poor marketing effect for a merchant in this mall when the competition in the same category is fierce. In addition, the current marketing methods cannot fully play a role in the face of new types of consumers. The new marketing methods need to accurately meet the latest preferences of target consumers and formulate targeted marketing strategies.

The combination and application of big data and machine learning technology in the offline consumer market makes formulating marketing strategies more scientific. The use of machine learning can make statistics and analysis of users' consumption behaviors and classify customers according to their consumption behaviors in order to realize the personalized promotion of marketing content. However, training machine learning models requires a large amount of data. Consumers' personal information and consumption records are illegally collected, stored, used, and even sold by economic interests. It violates personal privacy and brings the danger of personal and property damage to consumers [19]. Considering the security of consumer information, how to safely collect and use these data is an urgent problem to be solved.

Homomorphic encryption allows the encrypted ciphertext to be processed, which can not only ensure the security of data processing, that is, the original data will not be leaked when processing the ciphertext data, but also ensure that the decryption is correct, that is, the user who has the private key can complete the processing. The data are decrypted, and the correct operation result can be obtained. In addition, how to propose a privacy protection model suitable for consumption data application scenarios on the premise of meeting data privacy, security, and regulatory requirements so that the model can use data from all parties at a low cost, efficiently and accurately, and according to a large amount of consumption data is of great scientific and practical significance to formulate specific marketing strategies more scientifically.

2.2. Scheme Design Goals. After analyzing the characteristic requirements for the safe sharing of consumption data and considering the requirements for privacy in consumer data sharing and precise marketing to consumers, the scheme should meet the following design goals.

2.2.1. Data Validity. To ensure that the shared data are authentic and credible, a strict identity authentication mechanism is required to ensure that only legitimate identities can log in to the system and share user consumption data, preventing other malicious competitors from sharing data.

2.2.2. Data Confidentiality. The purpose of the scheme is to ensure the privacy of customer consumption data. The customer data uploaded by the mall must be kept confidential, and the confidentiality of the data must also be guaranteed during the data processing process.

2.2.3. The Correctness of the Results. The correct processing of multiparty customer data is the basic requirement of the financial data sharing scheme, and the scheme design must ensure the correctness of the data clustering results.

2.2.4. Efficiency. The scheme needs to use high-efficiency homomorphic encryption and clustering algorithms to ensure the efficiency and practicability of consumption data sharing and precision marketing.

2.2.5. Realization of Precision Marketing. To carry out differentiated marketing according to different customer groups, tap the potential value of customers, and maximize profits, it is necessary to analyze the basic information, behavior information, and consumption data of consumers to conduct customer segmentation and achieve precise marketing.

3. Customer Segmentation

3.1. Theory Introduction. In essence, customer segmentation is a process of customer aggregation [23, 24]. Similar customers are gathered into groups according to the customer's values, needs, and consumer preferences. Enterprises and merchants can provide targeted products, services, or marketing for different customer groups according to the results of customer segmentation so that both parties can benefit from it. The key to winning in the consumer market competition lies in the grasp of market demand and customer characteristics, and customer segmentation can play the following roles in the market competition: (1) customer identification and positioning—due to the differences in the living environment and consumption level, consumers have diverse needs. Merchants can grasp the needs of different customers through segmentation, explore the potential needs of a target consumer group, and then launch targeted products and services; and (2) market analysis and grasp—since consumers' consumption habits and levels are roughly unchanged, from the perspective of market analysis, segmentation can evaluate the current and potential value of customers. For some merchants, it is possible to locate customers who bring more significant benefits and customers who bring less revenue through customer segmentation based on big data, which is conducive to adopting different marketing strategies.

Customer segmentation is based on customer historical consumption behavior, which can be divided into the RFM, customer loyalty-based, and customer value matrix methods.

3.1.1. RFM Method. It is widely used in database marketing. In the RFM model proposed by Hughes in 1994, the customer group is divided according to the interval, frequency, and amount of consumption behavior. Specifically, R (recency) refers to the time interval from the last consumption to the present. The shorter the interval, the greater the R; F (frequency) refers to the number of times the consumer consumes within a period. The larger the value is, the greater is the consumer's desire to consume. RFM predicts the future based on recent consumption behavior, all variables are real data, and the analysis results are more accurate. However, this method needs to be processed from three dimensions, the calculation is more complicated, and the final obtained customer group has many categories. There will also be multicollinearity between the number of consumption F and the total consumption M.

3.1.2. Customer Loyalty-Based Method. Customer loyalty is a key factor in analyzing customer behavior. Dick and Basu define true loyal customers as customers who satisfy behavioral and attitude loyalty; that is, they need frequent purchasing behavior and a high attitude orientation. Loyalty reflects the stability of customers. However, this method's strength of loyalty is also challenging to measure, which generally needs to be obtained through indirect analysis.

The above two methods are based on the historical data of existing customers. They cannot analyze the behavior of potential customers, and the prediction results of the behavior of old customers are only valid for a short period.

The customer segmentation method is not the only constant but should be evaluated and changed in real time according to the actual market demand and the method's effectiveness. For merchants, the current segmentation method is dynamically selected corresponding to the current product positioning and marketing needs.

3.2. Customer Segmentation Variable Selection. The ultimate purpose of customer segmentation is for businesses to carry out differentiated marketing for different customer groups, tap the potential value of customers, and maximize profits; according to the different positioning of each merchant's products, it can more accurately select which high-quality customers can bring high profits to the merchants among a large number of consumers and can also quickly select which are the consumer customers who can continue to pay attention.

Customer segmentation is usually based on the standard's interval, frequency, and amount of consumer behavior. Still, in the same period, the two variables of consumption times and total consumption have multicollinearity, so this paper transforms the total consumption amount into the average consumption amount. Since the

consumption data comes from the same shopping mall, according to the consumer's member id, the backstage of the mall can obtain the average consumption amount by summarizing the consumption records, and the data can be tracked and recorded multiple times. It is beneficial for merchants to retrieve the average consumption amount in different periods according to different needs, and the data are reliable and targeted. And since there are many customer groups obtained from customer segmentation from the three dimensions of the interval, frequency, and amount, two dimensions of consumption frequency and average consumption amount are selected to simplify the results of customer segmentation. It is necessary to disperse all customers in a two-dimensional matrix of customer value.

The high-quality customers in this method have a high consumption frequency and average consumption amount, and the overall consumption level of such customers is relatively high. Therefore, sending them a short message about our store's new products during marketing can attract such people before consuming. At the same time, the influence of the brand and the multidimensional high-quality services provided by the merchants to them, and the in-purchase price highlight the particularity of customers, which can attract them to the store for long-term consumption. The focus of marketing is to invite customers to the store.

Consumption-type customers have a lower consumption frequency but higher average consumption amount; their consumption frequency is not as high as that of high-quality customers, so it is mainly through increasing the frequency of consumption and increasing customer stickiness. Pre-deposit and other preferential methods improve the integration of product and customer binding and guide customers to repurchase multiple times. To stimulate high-frequency consumption of customers, we can rely on festivals and the way to give products value, combine product consumption attributes with cultural and emotional attributes, and increase the frequency of customer demand.

The frequent customers in the value matrix have a high consumption frequency, but the average consumption amount is not high. By sending them discounted text messages to thank old customers, it can attract them to come to the store for consumption. Such customers pay more attention to cost performance and use bidding to acquire customers in the initial publicity stage. For example, the activities of three-level fixed-file exchange products can stimulate the growth of consumption amount. In the stage of stabilizing customer sources and expanding new customers, group purchase discounts and discounts can be adopted to stimulate consumption and increase sales.

Finally, uncertain customers with low consumption frequency and average consumption amount should be relatively unfamiliar with the mall or have low intention to visit the store. If ultra-low-cost auxiliary preferential products and gifts on arrival were used to stimulate customers' interest in the store experience or provide additional experience activities in addition to the products themselves, it can enhance the impression of such customers in the mall

during the activities, and at the same time can enhance the purchase intention.

In recent years, the e-commerce industry has shown a trend of rapid development. The frequency of people's consumption in shopping malls has dropped significantly. At the same time, the number of physical stores has shown a basically saturated trend. In this context, physical stores' deep grasp of customer characteristics and actual needs is the key to competing in the consumer market, carry out different attraction activities for potential customers, implement targeted marketing plans for old customers, and launch package services that better meet the needs of different customer groups. To achieve the above goals, conducting a comprehensive and detailed division method of customer groups is necessary.

4. Scheme Design

4.1. Scheme Structure Design. In order to maximize the analysis and utilization of consumption data, the data owner of the, e.g., mall needs to provide the consumption data generated in all stores in his or her mall, but in order to ensure the privacy of information, homomorphic encryption is required in the system before sharing the consumption data; in order for data users (a merchant who needs to send marketing short messages) to carry out personalized marketing to all consumer groups in the mall according to their own product characteristics, attract specific users, or tap potential users, the merchant can propose the required number of customer classification in the system and corresponding marketing messages; the third-party computing center performs the K -means clustering processing on the data according to the provided encrypted consumption data and the required number of customer classifications, and returns the results to the system database after the processing; and advertising operators can view the classification results of user consumption data, set different SMS templates according to the user's mobile phone number and the corresponding marketing SMS, and finally send SMS in batches.

To sum up, the plan includes four participating entities: consumption data owner (shopping mall), consumption data user (a merchant who needs marketing), third-party computing center, and marketer. The overall framework of the scheme is shown in Figure 1.

In this solution, although the data owner (mall) has all the registration information and consumption records of consumers, the consumption data are encrypted into ciphertext in the system and then uploaded, which ensures the security of the data from the source. The third-party computing center retrieves the ciphertext from the database and does not have access to the real consumption data; when a merchant needs to send a marketing message, the required number of customer categories and the corresponding marketing template are entered into the system. After classifying customers according to their needs, merchants only have the right to view customer classifications. The system automatically anonymizes personal information, such as consumers' phone numbers. Merchants cannot obtain personal information for private marketing, ensuring consumers' privacy and security.

Advertising operators read the merchant's preset k value and short messages from the system, set the corresponding marketing short messages according to the classification results, and then send short messages in batches with one click, without touching sensitive information such as phone numbers, which not only ensures the integrity of consumer information without leakage, but also ensures the precise marketing to different consumer groups.

The main worksheets for which the various participating entities in the program are responsible are shown in Table 1.

4.2. Scheme Process Design. The main steps of the precision marketing plan based on consumption data and homomorphic encryption algorithm include the following:

- (1) The data owner (mall) downloads the consumption data upload template and imports the user data into the template according to the specifications;
- (2) In the data management of the consumption data encryption system, the user consumption data for a certain period is encrypted and uploaded to the database for use by advertising operators and third-party computing centers;
- (3) Advertising operators set the required number of customer categories to set the value of k according to their own needs and hand them over to a third party for processing;
- (4) The third-party computing center reads the dataset, performs K -means clustering on the ciphertext according to k , and imports the output result into the customer classification of the file; and
- (5) According to the generated customer classification results and the specific marketing SMS provided by the merchant, the advertising operator sets the corresponding marketing SMS in the marketable list and sends it.

5. Improvement of Clustering Algorithm Based on K -Means

Currently, the clustering algorithm, as an essential machine-learning data mining technology, is widely used in customer segmentation. The customer segmentation technology based on a clustering algorithm has been applied in various areas as early as the 19th century, such as retail, financial stocks, banking, e-commerce, telecommunications, tourism, aviation, and other industries.

The similarity function of the K -means algorithm is mainly determined based on the distance between the data, and the distance measurement method constitutes the primary method of clustering [25–27]. The algorithm in this paper adopts the Euclidean distance because the Euclidean distance is mostly used to analyze individual differences in values, such as using user behavior indicators to analyze the similarity of user values.

The validity evaluation of the clustering algorithm measures the accuracy of the clustering results. In general, unsupervised clustering evaluation is more complex than

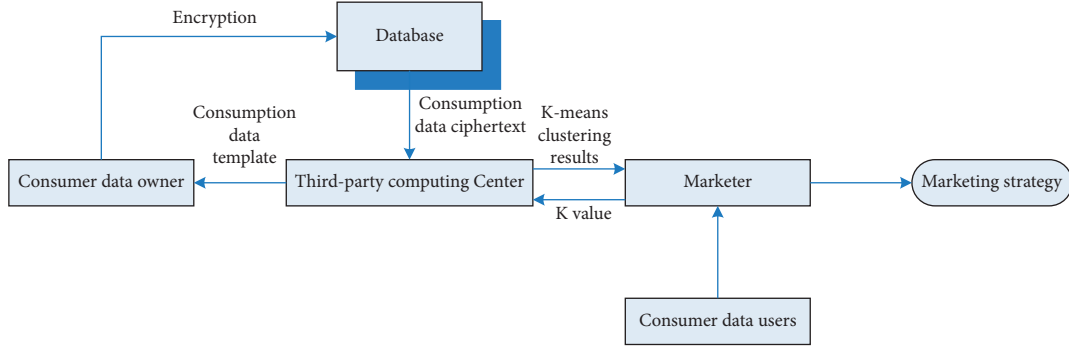


FIGURE 1: Overall framework of the scheme.

TABLE 1: Participating entities and main work.

Entity	Main work
Consumption data owner	Encrypt and upload consumption data
Consumption data user	The default number of customer classifications required is k Preset corresponding marketing SMS
Marketer	Read preset k value and set Read marketing text messages Set the corresponding marketing SMS according to the customer classification results Send SMS in batches
Third-party computing center	Read ciphertext Read the k value K-means clustering of ciphertexts based on k values

supervised learning evaluation. External quality evaluation methods often cannot be applied because the labels of clustering results cannot be obtained. Therefore, many domestic and foreign literature papers have proposed internal quality evaluation and relative quality evaluation methods for clustering algorithms to evaluate unsupervised clustering results. However, these evaluation indicators' tightness and separation performance are relatively simple, and the measurement effect is one-sided. If tightness does not consider interclass effects, separation does not consider intraclass effects. Therefore, it is necessary to comprehensively evaluate the clustering results using an overall index that can simultaneously measure closeness and separation.

The silhouette coefficient $s(i)$ takes into account both compactness and separation, and the calculation formula is shown as follows:

$$s(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}}. \quad (1)$$

That is,

$$s(i) = \begin{cases} 1 - \frac{a(i)}{b(i)}, & a(i) < b(i), \\ 0, & a(i) = b(i), \\ \frac{b(i)}{a(i)} - 1, & a(i) > b(i), \end{cases} \quad (2)$$

a_i represents the average distance from the sample to other samples in class C . The smaller the a_i is, the more the sample i should belong to this category. b_i represents the smallest value of the average distance b_{ij} from sample i to all samples in other classes c_j . The larger the b_i is, the less the sample i belongs to other classes. Therefore, the $s(i)$ value is between -1 and 1 . The closer the $s(i)$ is to 1 , the more reasonable the clustering is, and vice versa.

The traditional K-means clustering is a learning method that depends on the number of clusters. This method does not require supervision and randomly selects k points and then performs continuous clustering. First, k points are randomly chosen as the starting cluster centers. Then, according to the principle of the shortest distance, the samples are continuously calculated, and new cluster centers are constantly iterated in the iterative process so that the cluster centers can achieve a stable optimal clustering scheme.

5.1. Algorithm Improvement. K-means in this scheme uses the Euclidean distance formula to calculate the distance between the two points, but due to a large number of ciphertext bits, common codes cannot perform large number operations, so this scheme first performs the K-means clustering algorithm. For optimization and improvement of the algorithm, it is necessary to rewrite the K-means calculation method, make it cluster on the ciphertext field of the large integer class, improve the clustering effect, and perform more accurate segmentation of the vast and multidimensional consumer population.

Although the improved K-means algorithm can effectively cluster encrypted data, according to the requirements of this solution, it is necessary to carry out precise marketing to different types of customer groups after the encrypted data are successfully clustered, so after the clustering is completed, the problem of indistinguishable customer categories arises.

To solve the above problem of how to distinguish what kind of customer the customer is, this scheme proposes a method based on the value matrix. In the K-means clustering, the method of the initial center point is changed, and the initial center point is limited to different areas; that is, different types of customers are located in the value matrix, and the categories of customers are distinguished by marking points.

The specific operation steps are as follows: if customers need to be clustered into k categories, then there is class a in the abscissa and class b in the ordinate, and there are $a \times b = k$ classes in total.

It is necessary to find the maximum coordinate value (x_{\max}, y_{\max}) and the minimum coordinate value (x_{\min}, y_{\min}) in all the data to be clustered. First, according to formula (3), the abscissa of the center point of different types of regions can be obtained:

$$\begin{aligned} X_{k_{ij}} &= \frac{x_{\max} - x_{\min}}{a} \cdot i + x_{\min} - \frac{x_{\max} - x_{\min}}{a} \cdot \frac{1}{2} \\ &= \frac{x_{\max} - x_{\min}}{a} \left(i - \frac{1}{2} \right) + x_{\min}. \end{aligned} \quad (3)$$

In the same way, the obtained ordinate is given by

$$Y_{k_{ij}} = \frac{y_{\max} - y_{\min}}{b} \cdot \left(j - \frac{1}{2} \right) + y_{\min}. \quad (4)$$

Therefore, the k_{ij} coordinates of the center point of the clustering area are as follows:

$$\left(\frac{x_{\max} - x_{\min}}{a} \cdot \left(i - \frac{1}{2} \right) + x_{\min}, \frac{y_{\max} - y_{\min}}{b} \cdot \left(j - \frac{1}{2} \right) + y_{\min} \right). \quad (5)$$

Assuming that $k = 4$ at present, then $a = 2$ and $b = 2$; then, according to formula (5), k_{11} , k_{12} , k_{21} , and k_{22} area center points can be obtained. Then, according to the positioning of k_{11} , k_{12} , k_{21} , and k_{22} , the initial center point of the K-means algorithm is randomly generated within the corresponding area. This can not only ensure the effective operation of K-means, but also simply fix the initial cluster center point on the regional center point, make the clustering result more dynamic, and distinguish different categories of customers according to their positioning.

Due to the uncertainty of consumption data, the data to be clustered may not be evenly distributed. Still, according to the range of the maximum and minimum values of the data, the relative customer category area can be dynamically obtained. It is concluded that the customer category whose initial center point is k_{11} is relatively uncertain customers, and k_{22} is a high-quality customer compared with k_{21} , which can achieve clustering.

5.2. Improved K-Means Algorithm Flow. Based on the ciphertext, the system uses the K-means clustering algorithm and the Euclidean distance to calculate the distance between the each point and the center point for clustering. The algorithm 1 is as follows.

6. Experiments

6.1. Experimental Environment. For the simulation, the experimental platform we use is the Windows 10 64-bit operating system; the CPU is Intel(R) Core (TM) i5-8210Y CPU @ 1.60 GHz, the programming language of clustering is Java, and the encryption part is implemented in C++.

The security parameters are set in the encryption experiment based on the following considerations: first, to ensure actual security, the security level is set to $\lambda = 80$; then, to ensure the correctness of the ciphertext field, set $\omega = 2^{30}$, $l = 100$, eBound = 1000; and for the possible plaintext space, specify $p = 10$ and $q = 2^{128}$. Furthermore, we evaluate performance with different values of the parameter n , representing the number of data items.

6.2. Relationship between Clustering Efficiency and Number of Plaintext Bits. After ensuring the stability and efficiency of encryption, we need to test the efficiency of the improved K-means clustering algorithm. The correctness of the encryption algorithm has been verified, so we can directly perform K-means clustering on the encrypted ciphertext and then compare it with the plaintext clustering effect of the same dataset to verify the improved K-means that means the efficiency and accuracy of the algorithm. We still measure clustering time and silhouette coefficient values by averaging 60 runs.

Since the improved K-means clustering algorithm supports the processing of large integers based on encryption, the K-means clustering test is first performed on ciphertexts with different digits to compare the efficiency and accuracy of the clustering algorithm. To save time and cost, we select 600 sets of two-dimensional data for comparison, the default number of clusters is 4, and the test results are shown in Table 2.

Since the minimum number of ciphertext bits is 16 bits, this experiment starts from 16 bits of ciphertext bits and increases sequentially until processing 21 bits of ciphertext. As the number of ciphertext bits increases, the time of the K-means clustering algorithm running on the ciphertext increases linearly, and the corresponding plaintext clustering time also increases linearly; since the maximum number of digits corresponding to the plaintext data is 6, it is much smaller than the number of digits of ciphertext data, so the clustering time on the plaintext is generally shorter than that on the ciphertext.

The silhouette coefficient $s(i)$ is between -1 and 1 , and the larger the value is, the more reasonable the clustering result is. As the number of ciphertext bits increases, the values of $s(i)$ are maintained between 0.38 and 0.43 , which shows that the improved K-means clustering algorithm can perform stable and correct clustering operations. However,

Input: ciphertext, number of clusters k

Output: ciphertext clustering result

- (1) Find the maximum value (x_{\max}, y_{\max}) and minimum value (x_{\min}, y_{\min}) of all points. Within the maximum and minimum distances, according to formula (3.5), initialize k points around k_{ij} as the cluster centroid;
- (2) For each ciphertext point, assign it to the corresponding cluster according to its Euclidean distance from the centroid;
- (3) Calculate the average value in each cluster as a new cluster centroid, and repeat step (2);
- (4) Determine whether the centroid has changed. If it does not change, the clustering has converged. Otherwise, go to step (2);
- (5) Output the clustering results.

ALGORITHM 1: K-means algorithm.

TABLE 2: Relationship between clustering time and ciphertext bits.

Ciphertext bits (m)	Ciphertext clustering time (ms)	Silhouette coefficient $s(i)$	Corresponds to the plaintext bit n	Plaintext clustering time (ms)	Silhouette coefficient $s(i)$
16	123	0.41045	1	7	0.43664
17	139	0.39489	2	35	0.40069
18	163	0.42436	3	36	0.42502
19	189	0.40496	4	48	0.40352
20	196	0.41033	5	49	0.41132
21	219	0.38029	6	68	0.37841

TABLE 3: Relationship between the clustering time and the number of clusters k .

Dataset	The number of clusters k	Plaintext clustering time (ms)	Plaintext contour system $s(i)$	Ciphertext clustering time (ms)	Plaintext contour system $s(i)$
Testset 1	$k=2$	33	0.33752	73	0.34358
	$k=3$	86	0.36077	179	0.36052
	$k=4$	66	0.37619	221	0.37741
	$k=5$	138	0.39518	313	0.39512
Testset 2	$k=2$	26	0.34869	63	0.34789
	$k=3$	50	0.37136	127	0.37172
	$k=4$	70	0.39679	214	0.39734
	$k=5$	87	0.37538	298	0.38129
Testset 3	$k=2$	31	0.36964	82	0.35596
	$k=3$	53	0.38191	136	0.37893
	$k=4$	65	0.39742	171	0.39752
	$k=5$	83	0.37479	221	0.37853

in terms of clustering accuracy, although the number of bits of plaintext is relatively short, the gap between the silhouette coefficient of clustering on the plaintext and the silhouette coefficient of clustering on the ciphertext is very small. The error is about 0.01, indicating that the improved K-means clustering algorithm can cluster the data well regardless of the number of data bits.

6.3. Relationship between Clustering Efficiency and the Number of Clusters. According to the experiment above, when the length of ciphertext is 20 bits, the clustering time decreases slightly, so it is possible to control the ciphertext based on 20 bits and continue to test the relationship between clustering efficiency and other variables. A total of 500 sets of two-dimensional data were randomly selected to test whether the change in the number of clusters impacts the clustering efficiency. Three datasets were tested, averaging 50

runs to measure the clustering time, and the silhouette coefficient values are recorded in Table 3.

As the number of clusters increases, the running time of the K-means clustering algorithm on both the plaintext and the ciphertext increases linearly. After the test, the processing time of the improved clustering algorithm for 600 groups of the 20-bit ciphertext 2D data is maintained at about 0.3 seconds, and the silhouette coefficient is also maintained between 0.34 and 0.4. It is worth noting that when $k=4$, the silhouette coefficient is higher than other values, and the clustering effect is the most reasonable when clustering 4 classes.

6.4. Relationship between Clustering Efficiency and Data Volume. From the experiment above, when $k=4$, the value of the silhouette coefficient is relatively high, which means that the effect of clustering is relatively reasonable at this

TABLE 4: Relationship between clustering time and data volume.

The amount of data	Ciphertext clustering time (ms)	Ciphertext silhouette coefficient $s(i)$
100 groups	49	0.3732
200 groups	84	0.41644
500 groups	177	0.40273
1000 groups	350	0.41748
2000 groups	907	0.40576

time, and when the length of ciphertext is 20 bits, the algorithm runs faster, so we test on this basis, which reflects the effect of data volume on clustering efficiency. The values are recorded in Table 4.

As the amount of data increases, the running time of the K-means clustering algorithm on the ciphertext increases linearly. After testing multiple datasets, the improved clustering algorithm takes about 1 second to process two-dimensional data of 2000 groups of the 20-bit ciphertext, and the silhouette coefficient can reach the level of 0.4. Therefore, it can be concluded that the greater the amount of data, the longer the time required for this clustering algorithm, but the clustering effect is excellent and stable.

7. Conclusions

In the context of big data, this paper carries out research on enterprise digital precision marketing strategy. First, it analyzes the privacy problems faced by the current consumption data sharing scheme, puts forward the objectives that the precision marketing scheme based on consumption data needs to meet, and completes the precision marketing scheme design based on homomorphic encryption from the perspective of customer segmentation. This research has completed the design of precision marketing scheme based on consumption data and homomorphic encryption algorithm. This paper studies and analyzes the impact of the existing consumer data leakage on consumers. In order to improve the effect of merchants' marketing to consumers, homomorphic encryption is introduced into consumer data sharing. At the same time, combined with K-means clustering algorithm, the precise marketing scheme based on consumer data and homomorphic encryption algorithm is designed in detail.

This paper still has some limitations and deficiencies worthy of further discussion and research: in the improved k-means clustering algorithm proposed in this paper, the similarity function of clustering only uses the simple Euclidean distance to calculate. If the two-dimensional data in the system have a large difference in the number of data bits, the results of K-means clustering will be affected by the value of large bits, resulting in the clustering results that cannot match the value matrix used in this paper. When selecting customer segmentation variables, this paper only simplifies the complex RFM scheme into two-dimensional parameters and applies them to the value matrix. In the subsequent customer segmentation, we should consider the impact of more parameters on the results of customer segmentation, so as to improve the accuracy of precision marketing again.

Data Availability

The dataset can be obtained from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Permanent Magnet Flux Linkage Identification Method of the Model Predictive Current Control System for PMSM

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Accurate identification of permanent magnet flux linkage can effectively improve the control performance of model predictive current control system of permanent magnet synchronous motor (PMSM). This paper reviews the existing identification methods of permanent magnet flux linkage of PMSM first and then proposes an identification method of permanent magnet flux linkage based on an improved unscented particle filter, the problem of particle diversity reduction of the traditional unscented particle filtering algorithm is solved, and the identification performance of permanent magnet flux is improved. Simulation research and experimental verification of the proposed method are carried out, and the simulation and experimental results confirm the effectiveness of the proposed method.

1. Introduction

PMSM has been widely used in the fields of new energy power generation, servo drive, and electric vehicles due to its advantages of high power density, small maintenance, and good control performance. The current control strategy with excellent performance is beneficial to meet the control requirements of fast current response and good dynamic characteristics of the PMSM drive system [1]. Because the model predictive current control (MPCC) algorithm has the advantages of good dynamic current control performance, direct measurement of control variables, simple implementation, and low cost function construction without designing weight coefficients [2], it is widely used in the drive system of PMSM.

However, the MPCC algorithm is very sensitive to the change of controlled object parameters, and the mismatch between controlled object parameters and MPCC algorithm control parameters will lead to obvious prediction errors and steady state control errors and even cause algorithm instability [3]. A large number of research achievements show that the changes in permanent magnet flux linkage have the most obvious influence on the control performance of the

MPCC system for PMSM [4–6], whereas limited by installation space and heat dissipation conditions, the permanent magnet material of PMSM is usually susceptible to the influence of armature reaction and operation temperature increase, resulting in permanent magnet flux linkage reduction, and then, the control performance of the MPCC system for PMSM is reduced. There are usually three types of methods to solve the above-mentioned problem, and the first method is to compensate for the negative influence caused by permanent magnet flux linkage change as disturbance or to reduce that negative influence by enhancing the robustness of the PMSM drive system [4, 5]. Another type of a method is to combine the MPCC algorithm with intelligent control algorithms to suppress the negative influence of permanent magnet flux linkage change on the PMSM drive system control performance [6], and the third type of a method is to identify permanent magnet flux linkage based on an online identification algorithm [7–13], and then, the parameter mismatch and control performance degradation of the MPCC algorithm for the PMSM drive system caused by permanent magnet flux linkage change are solved; this type of a method can fundamentally solve the mismatch problem between controlled object parameters

and control parameters, but it needs to overcome the influences of controlled object nonlinear, measurement noise, and other factors to achieve accurate dynamic identification of permanent magnet flux linkage.

In order to realize accurate identification of permanent magnet flux linkage, the least square method [7], Luenberger observer [8], model reference adaptive algorithm [9], immune algorithm [10], genetic algorithm [11], self-learning particle swarm algorithm [12], and adaptive variation difference algorithm [13] have been proposed in the relevant literature. However, the identification results of the Luenberger observer and least square method are susceptible to measurement noise, and the model reference adaptive algorithm is difficult to determine a reasonable adaptive law; the genetic algorithm and particle swarm optimization are model-free identification methods, and their identification results lack determined theoretical support with strict mathematical significance [14].

As Bayesian filtering provides a unified framework for solving the state estimation problem of stochastic systems, it can provide a solution with deterministic mathematical significance for permanent magnet flux linkage identification of PMSM. The state estimation method represented by the extended Kalman filter and its improved algorithm has been widely used in permanent magnet flux linkage identification of PMSM [15]. However, the extended Kalman filter is a suboptimal filtering algorithm, and if the estimated system does not satisfy the local linear condition or the state noise and measurement noise do not meet the requirements of a Gaussian distribution, the estimation error increases significantly. Different from the extended Kalman filter, the particle filter uses a weighted sum of a random sample to represent the posterior probability density function of the random system; because of the dispersion of random samples and the wide applicability of the Monte Carlo method to generate a random sample, this algorithm gets rid of the constraints of Gaussian distribution on state estimation [16], but its state estimation process does not consider the latest information of the estimated system, which reduces the estimation accuracy, and this algorithm has serious particle degradation problem.

In this paper, an improved unscented particle filter algorithm is proposed to accurately identify the permanent magnet flux linkage of the MPCC control system for PMSM. The importance sampling of the particle filter algorithm is modified first by the unscented Kalman filter algorithm, which is called the traditional UPF algorithm, to solve the particle degradation problem of the particle filter algorithm. Then, the traditional UPF algorithm is improved by the differential evolution (DE) algorithm, which is called the improved UPF algorithm (IUPF), and the IUPF algorithm is implemented in this paper to ensure particle diversity in the course of permanent magnet flux linkage identification and then improve the state estimation performance and achieve the highly accurate identification of permanent magnet flux linkage. Compared with previous studies, the proposed permanent magnet flux linkage identification algorithm overcomes the problem that the

identification results of the least square method and Luenberger observer method are sensitive to the measurement noise, and on the other hand, it overcomes the problem of the self-learning algorithm and genetic algorithm that have a large amount of calculation, at the same time, can also effectively solve the problem of the filtering accuracy of the traditional Bayesian filtering algorithm that is affected by non-Gaussian noise or its existing particle degradation and particle diversity reduction, which lays a foundation for the accurate identification of permanent magnet flux linkage.

The structure of this paper is as follows: the principle of the model predictive current control algorithm, differential evolution algorithm, and IUP algorithm is presented in Section 2; Section 3 presents the PMSM state equation for permanent magnet flux linkage identification; the simulation research and experimental verification are carried out in Section 4 and Section 5, respectively; the sixth section gives the research conclusion.

2. Principle of the MPCC Algorithm, DE Algorithm, and IUPF Algorithm

2.1. MPCC Algorithm

2.1.1. Prediction Model. In the d - q axis synchronous rotation coordinate system, the PMSM dynamic current equation can be expressed as

$$\begin{cases} \frac{di_d}{dt} = -\frac{R_s}{L_d}i_d + \omega_e \frac{L_q}{L_d}i_q + \frac{1}{L_d}u_d, \\ \frac{di_q}{dt} = -\frac{R_s}{L_q}i_q - \omega_e \frac{L_d}{L_q}i_d + \frac{1}{L_q}u_q - \frac{\omega_e}{L_q}\psi_f. \end{cases} \quad (1)$$

where $u_{d,q}$, $i_{d,q}$, and $L_{d,q}$ represent d - q axis stator voltage, d - q axis stator current, and d - q axis stator inductance, respectively, ω_e is rotor electric angular speed, R_s is stator resistance, ψ_f is permanent magnet flux linkage, and d/dt represents a differential operator.

If the current sample period is short enough, the discrete model of equation (1) can be expressed by the Taylor series and expressed in the following equation:

$$\begin{cases} \frac{di_d}{dt} = \frac{i_d(k+1) - i_d(k)}{T_s}, \\ \frac{di_q}{dt} = \frac{i_q(k+1) - i_q(k)}{T_s}. \end{cases} \quad (2)$$

In equation (2), T_s represents the sampling period, $i_d(k)$, $i_q(k)$, and $i_d(k+1)$ and $i_q(k+1)$ represents the d - q axis stator current at the moment of $(k)T_s$ and $(k+1)T_s$, respectively. Equation (1) is discretized by equation (2) to obtain the discrete current predictive model of PMSM, which is expressed as follows:

$$\begin{cases} i_d^p(k+1) = \left(1 - \frac{T_s R_s}{L_d}\right) i_d(k) + T_s \frac{u_d(k)}{L_d} + T_s \omega_e(k) \frac{L_{q_i}}{L_d} i_q(k), \\ i_q^p(k+1) = \left(1 - \frac{T_s R_s}{L_q}\right) i_q(k) + T_s \frac{u_q(k)}{L_q} \\ \quad - T_s \omega_e(k) \frac{L_{d_i}}{L_q} i_d(k) - T_s \omega_e(k) \frac{\psi_f}{L_q}. \end{cases} \quad (3)$$

In equation (3), $i_d^p(k+1)$ and $i_q^p(k+1)$ represent $(k+1)$ th d - q axis predictive current, respectively.

2.1.2. Cost Function Design. The three-phase PMSM drive system powered by a two-level inverter has eight voltage vectors. In order to achieve high-performance stator current tracking of PMSM drive systems with the MPCC algorithm, a reasonable cost function should be defined, and the voltage vector with the minimum cost function should be taken as the optimal voltage vector of the PMSM drive system in the next sampling period.

In this paper, the expression of the defined cost function is

$$g_i = [i_d^* - i_d^p(k+1)]^2 + [i_q^* - i_q^p(k+1)]^2 + f[i_d^p(k+1), i_q^p(k+1)]. \quad (4)$$

In equation (4), $i = 0, 1, \dots, 7$; i_d^* and i_q^* represent d axis and q axis reference current, respectively, and $f[i_d^p(k+1), i_q^p(k+1)]$ is the nonlinear equation, which is expressed in the following equation:

$$f[i_d^p(k+1), i_q^p(k+1)] = \begin{cases} \infty, & i_d^p(k+1) > i_{d\max}, \\ \text{or}, & i_q^p(k+1) > i_{q\max}, \\ 0, & i_d^p(k+1) < i_{d\max}, \\ \text{and}, & i_q^p(k+1) < i_{q\max}. \end{cases} \quad (5)$$

In equation (5), $i_{d\max}$ is the d -axis current limiting value, and $i_{q\max}$ represents the q -axis current limiting value. According to equation (5), if the predictive current generated by the voltage vector exceeds $i_{d\max}$ and $i_{q\max}$, the cost function is infinite, and its corresponding voltage vector will be discarded. If the predictive current is within the allowable range, the value of equation (5) is 0, and then, the cost function of (4) only has the first two terms; the optimal voltage vector with the minimum cost function is calculated, and then, it is applied to the next control cycle of the PMSM drive system.

2.2. The Principle of the DE Algorithm. The DE algorithm is a global optimization algorithm, and its implementation process is as follows [17]:

- (1) Initializing population. The initialization expression is

$$x_{j,i}^0 = x_{j,i}^{\min} + r, (0, 1)(x_{j,i}^{\max} - x_{j,i}^{\min}), \quad (6)$$

where $x_{j,i}^{\max}$ and $x_{j,i}^{\min}$ represent search space upper limit value and lower limit value, respectively, $x_{j,i}^0$ represents j th dimension of the i th individual in the 0th generation, and $\text{rand}(0,1)$ represents a random number evenly distributed between (0,1).

- (2) The mutation process. The mutation strategy can be expressed as

$$v_i^{g+1} = x_{r_3}^g + F(x_{r_1}^g - x_{r_2}^g), \quad (7)$$

where $x_{r_i}^g$ represent r_i th individual of the g th population; F is the zoom factor, which is generally a small positive number between 0 and 2, and it needs to meet the requirement of $i \neq r_1 \neq r_2 \neq r_3$.

- (3) Crossover process. The process is designed to generate a test vector and can be expressed as

$$u_{j,i}^{g+1} = \begin{cases} v_{j,i}^{g+1}, & \text{rand}(0, 1) \leq cr \text{ or } j = j_{\text{rand}} \\ x_{j,i}^g, & \text{other.} \end{cases} \quad (8)$$

In equation (8), cr is the crossover probability, generally taken as a small positive number between 0 and 1. $v_{j,i}$ is the variation vector and $x_{j,i}$ is the target vector, and the cr value determines the proportion of $v_{j,i}$ and $x_{j,i}$ in the test vector. F and cr determine the convergence speed and search capability of the DE algorithm. Small cr and larger F are beneficial to improving the global search capability of the algorithm, whereas larger cr and small F are beneficial to improving the convergence speed and local search capability of the algorithm.

- (4) Greedy selection. Calculating the fitness of $u_{j,i}^{g+1}$ in the crossover process and making the selection according to the following equation:

$$x_{j,i}^{g+1} = \begin{cases} u_{j,i}^{g+1}, & f(u_{j,i}^{g+1}) \leq f(x_{j,i}^g) \\ x_{j,i}^g, & \text{other} \end{cases}, \quad (9)$$

where $f(\cdot)$ represents the fitness function.

- (5) Boundary treatment. Individuals out of range are treated according to the following equation:

$$x = \begin{cases} x_{\min}, & x < x_{\min}, \\ x_{\max}, & x > x_{\max}, \\ x, & \text{other.} \end{cases} \quad (10)$$

2.3. IUPF Algorithm. The UPF algorithm generates an important density function based on the unscented Kalman filter algorithm, which can solve the particle degradation problem under the traditional particle filter framework. The specific implementation steps of the UPF algorithm are as follows:

- (1) Algorithm initialization. Setting $k=0$, extracting N particles from the prior probability distribution $p(x_0)$, that is

$$\{x_0^{(i)}\}_{i=1}^N \sim p(x_0), \quad (11)$$

where N is a particle number and $x_0^{(i)}$ represent a particle set. Setting $\omega_0^{(i)} = 1/N$, meanwhile, setting $k=0$.

- (2) Importance density sampling. Obtaining each random sampling point $x_k^{(i)}$ and the recommended distribution function $N(\bar{x}_k^i, P_k^i)$ based on the UKF algorithm and extracting particles from the recommended distribution function, it can be expressed as

$$\hat{x}_k^{(i)} \sim N(\bar{x}_k^i, P_k^i). \quad (12)$$

The particle weights are calculated and normalized.

- (3) Resampling a particle set according to the resampling algorithm, obtaining the new particle set expressed as $\{x_k^{(i)}, \tilde{\omega}_k^{(i)}\}$, and setting $\tilde{\omega}_k^{(i)} = 1/N$.
- (4) Outputting the estimation results of the state vector, which is as follows:

$$\begin{cases} \hat{x}_k = \sum_{i=1}^N \tilde{\omega}_k^{(i)} x_k^{(i)}, \\ P_k = \sum_{i=1}^N \tilde{\omega}_k^{(i)} (x_k^{(i)} - \hat{x})(x_k^{(i)} - \hat{x})^T. \end{cases} \quad (13)$$

Where \hat{x}_k and p_k represent the estimates of the state vector and the estimation error covariance matrix at time k . Setting $k=k+1$, return to step 2 and repeat the algorithm.

The IUPF algorithm proposed in this paper utilizes the DE algorithm to improve the resampling process of the traditional UPF algorithm, which can solve the problem of traditional UPF algorithm particle diversity reduction. A new optimal particle set was obtained, and its normalized weights were calculated according to the following equation:

$$\tilde{\omega}_k^{(i)} = \frac{\omega(x_k^{(i)})}{\sum_{i=1}^N \omega(x_k^{(i)})}. \quad (14)$$

In equation (14), k represents the k^{th} iteration and i represents the i^{th} particle.

3. State Equation of the Identified System

Compared with state vectors such as the stator current, permanent magnet flux linkage almost causes no change during a control cycle of the PMSM drive system [7, 8, 10]. Combined with the PMSM dynamic current equation shown in (1), the state equation used for the identification of permanent magnet flux linkage is obtained, which is expressed in the following equation:

$$\begin{cases} \frac{di_d}{dt} = \frac{u_d}{L_d} - \frac{R_s}{L_d} i_d + \frac{\omega_e L_q}{L_d} i_q, \\ \frac{di_q}{dt} = \frac{u_q}{L_q} - \frac{R_s}{L_q} i_q - \frac{\omega_e L_d}{L_q} i_d - \frac{\omega_e \psi_f}{L_q}, \\ \frac{d\psi_f}{dt} = 0, \end{cases} \quad (15)$$

where d/dt represents the differential operator. The state vector, the output vector, and the input vector of the state equation are defined as x , y , and u , respectively, which can be expressed as

$$\begin{cases} x = [i_d \ i_q \ \psi_f]^T, \\ u = \left[\frac{u_d}{L_d} \ \frac{u_q}{L_q} \right]^T, \\ y = [i_d \ i_q]^T. \end{cases} \quad (16)$$

According to (16), the permanent magnet flux linkage ψ_f is included in the state vector of the identified system, and its online identification can be easily achieved by state vector estimation based on the proposed IUPF algorithm.

4. Simulation Study

In this paper, the proposed method was simulated in the MPCC system of PMSM, and the system structure is shown in Figure 1. In Figure 1, the controlled motor is an interior PMSM, and its parameters are listed in Table 1; the speed and current sampling period and the simulation step size of the PMSM drive system are all set at 0.1 ms, and the load torque is set at 50 N m. Non-Gaussian random noise with an amplitude of 3 is injected into the measurements, and the reference speed of the PMSM is shown in Figure 2. For balancing the identification stability, identification speed, and identification accuracy of the proposed algorithm, the particle number is set at 50 in the simulation study.

The speed response in Figure 2 is actual speed, Figure 3 shows the d -axis reference current and its response, and Figure 4 shows the q -axis reference current and its response. According to Figures 2 to 4, when the actual controlled object parameters are adapted to the MPCC algorithm control parameters, the MPCC algorithm can achieve fast tracking of PMSM speed without overshoot and accurate control of d - q axis current.

Figures 5 and 6 show the identification results of the permanent magnet flux linkage based on the traditional UPF algorithm and the IUPF algorithm with the same particle number, respectively. Combined with the design value of the permanent magnet flux linkage shown in Table 1, the reference speed shown in Figure 2, and the non-Gaussian random noise injected into the measurements, it can be seen that in the non-Gaussian measurement noise environment

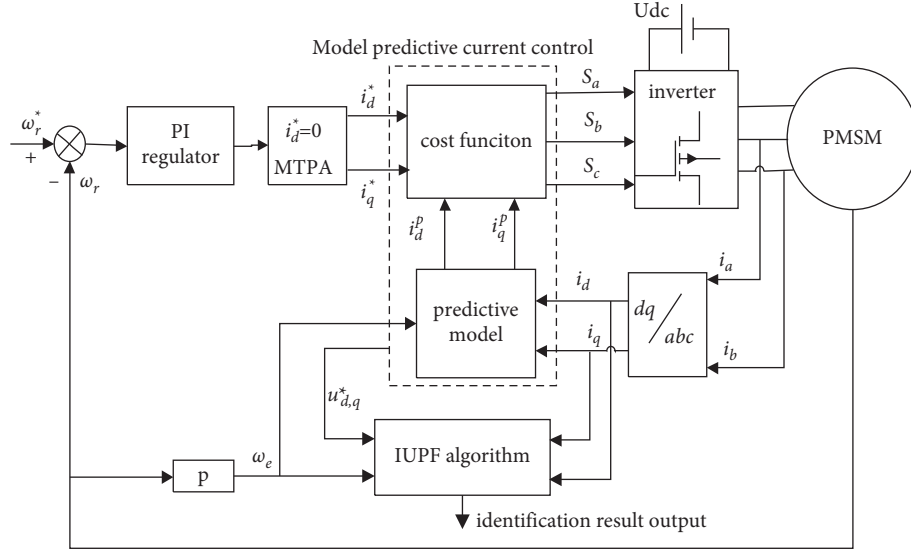


FIGURE 1: The model predictive current control system of PMSM.

TABLE 1: Controlled motor parameters.

Parameters	Rated value	Parameters	Rated value
Power	50 KW	d -axis inductance	2.517 mH
Speed	900 rpm	q -axis inductance	5.99 mH
Pole pairs	4	Permanent magnet flux linkage	0.173 Wb
Stator resistance	0.0154 Ω	Rotational inertia	0.00625 kg·m ²

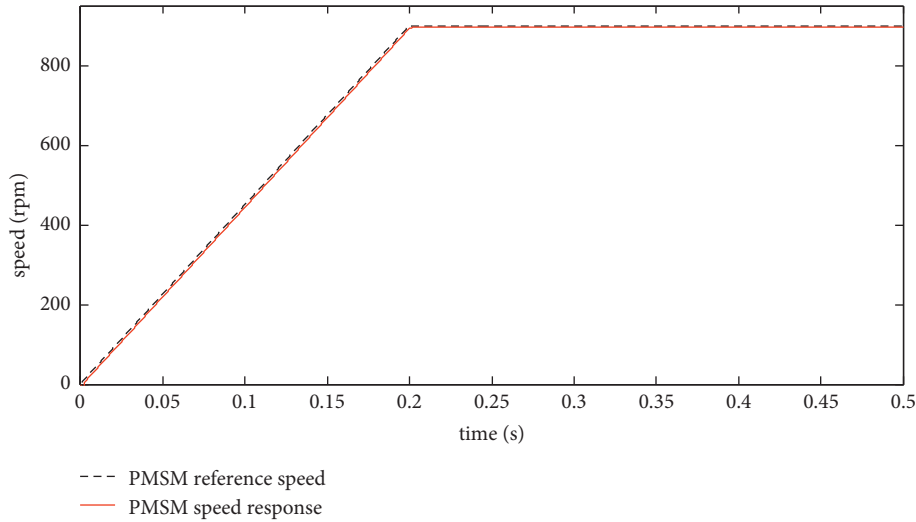


FIGURE 2: Reference speed and its response of PMSM.

and dynamic and steady operation conditions of the PMSM drive system, the accurate identification of permanent magnet flux linkage with smaller identification variance can be realized with the IUPF algorithm, and the IUPF algorithm has better identification performance than the traditional UPF algorithm.

Figure 7 shows the particle weight distribution of the traditional UPF algorithm and the IUPF algorithm after 5000 iterations. According to Figure 7, during the implementation of the traditional UPF, the small weight particle

number is constantly reduced, and the large weight particles are constantly duplicated, which leads to a significant decrease in particle diversity; then, the identification performance of traditional UPF algorithms which employ particle dispersion to approximate the system state is reduced, whereas the weight of each particle is not equal in the iterative process of the IUPF algorithm. Therefore, it maintains a perfect particle diversity, which is also an important reason why the IUPF algorithm can obtain smaller

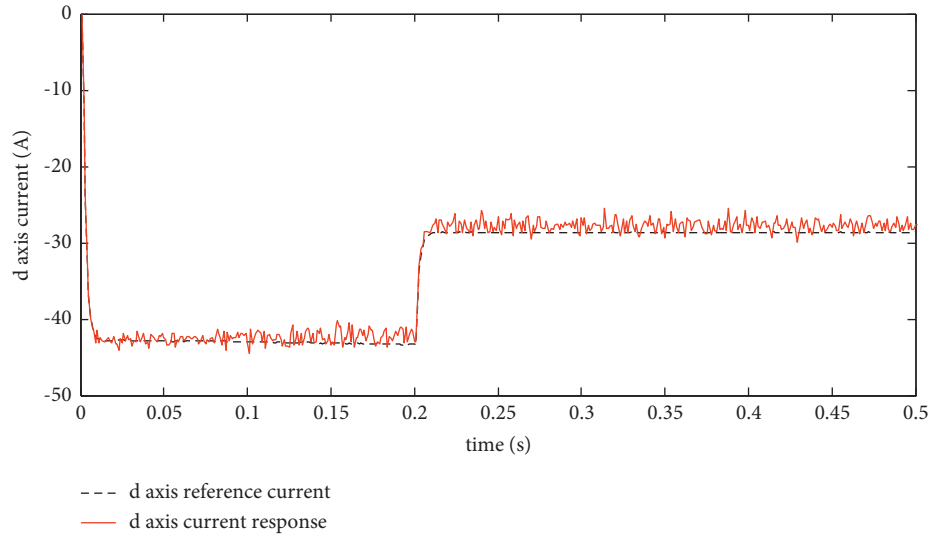
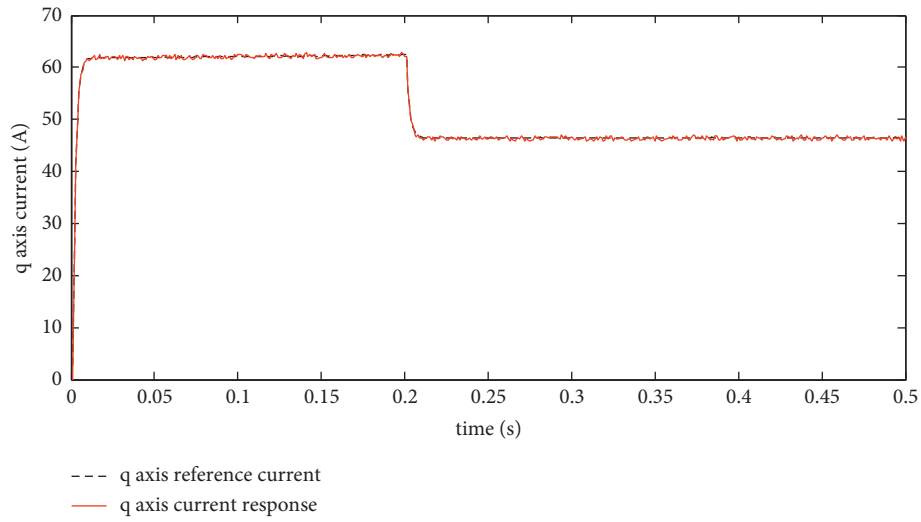
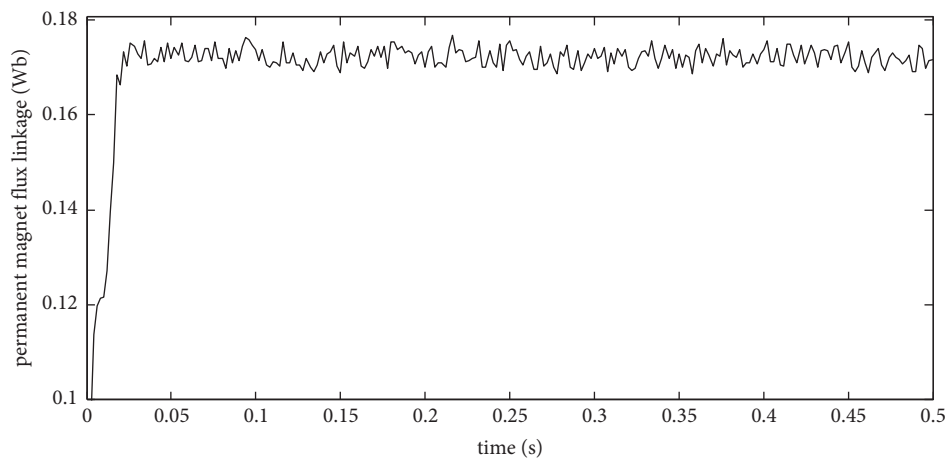
FIGURE 3: *d*-axis reference current and its response.FIGURE 4: *q*-axis reference current and its response.

FIGURE 5: The simulation identification result based on the traditional UPF algorithm.

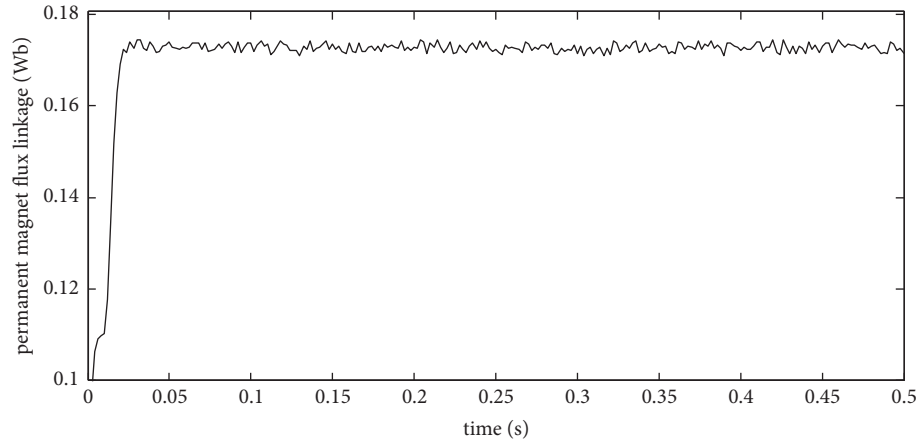


FIGURE 6: The simulation identification result based on the IUPF algorithm.

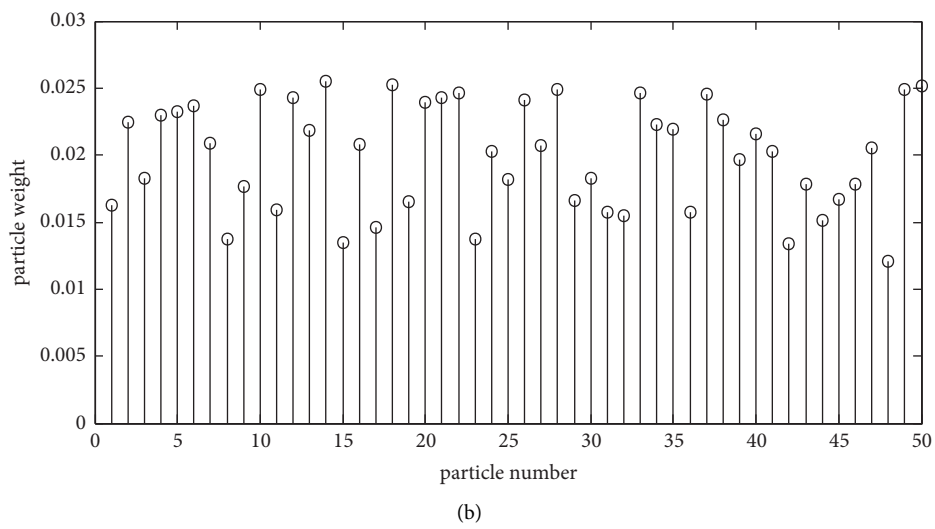
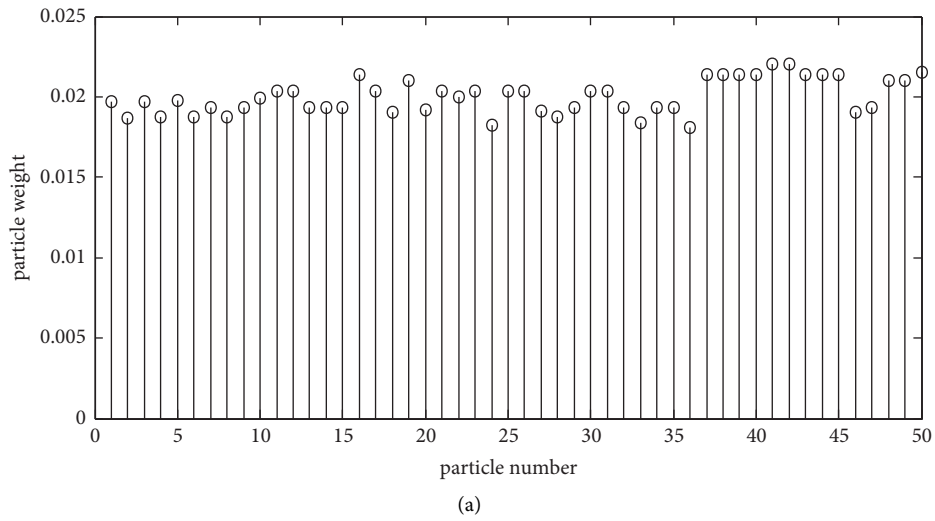
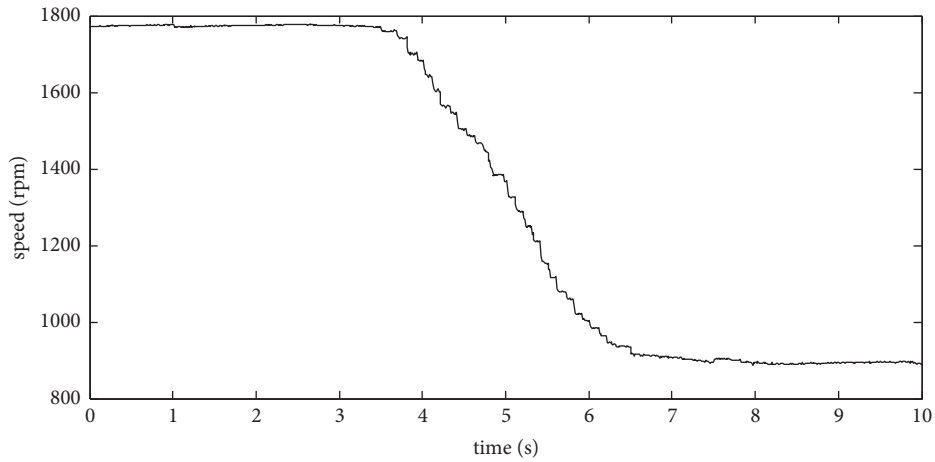
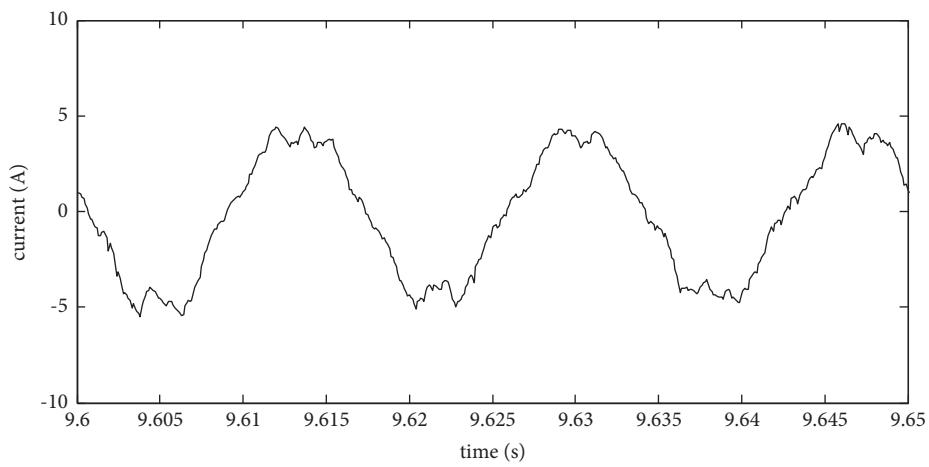


FIGURE 7: The particle weight of the traditional UPF and IUPF algorithm. (a) The particle weight of the traditional UPF algorithm. (b) The particle weight of the IUPF algorithm.



(a)



(b)

FIGURE 8: The measured rotor speed dynamic and stator current of PMSM. (a) The measured rotor speed waveform. (b) The measured stator current waveform.

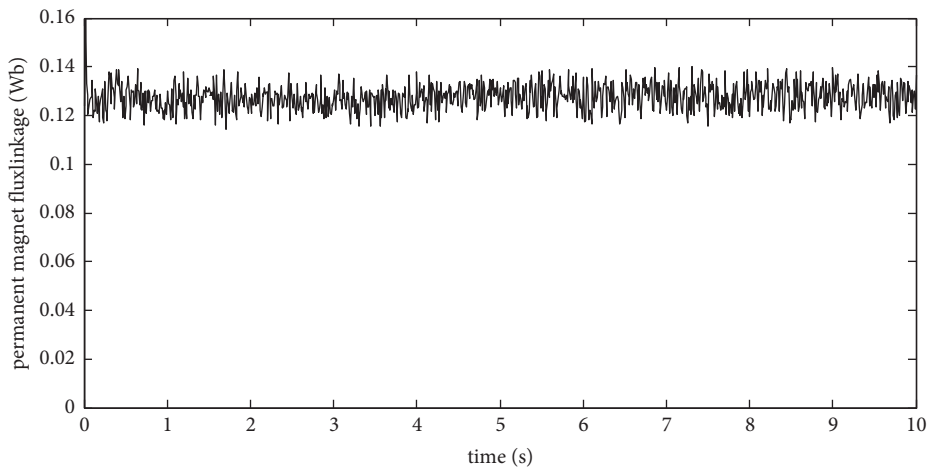


FIGURE 9: The experimental identification result based on the traditional UPF algorithm.

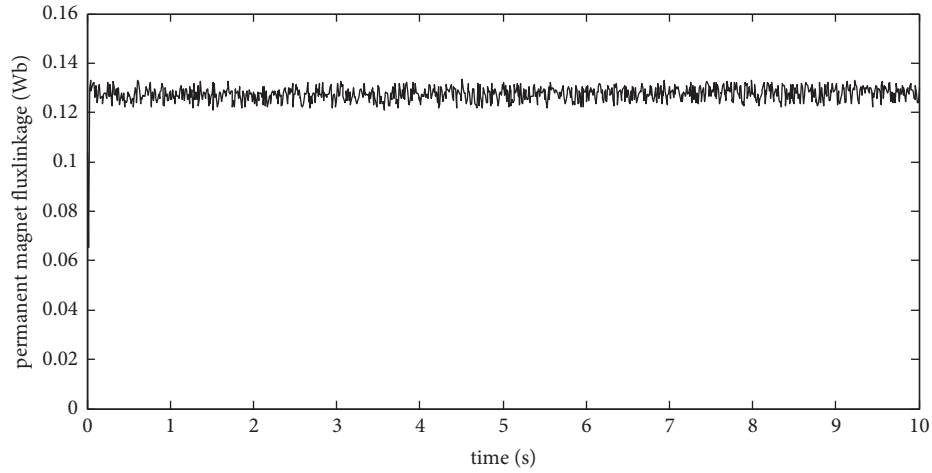


FIGURE 10: The experimental identification result based on the IUPF algorithm.

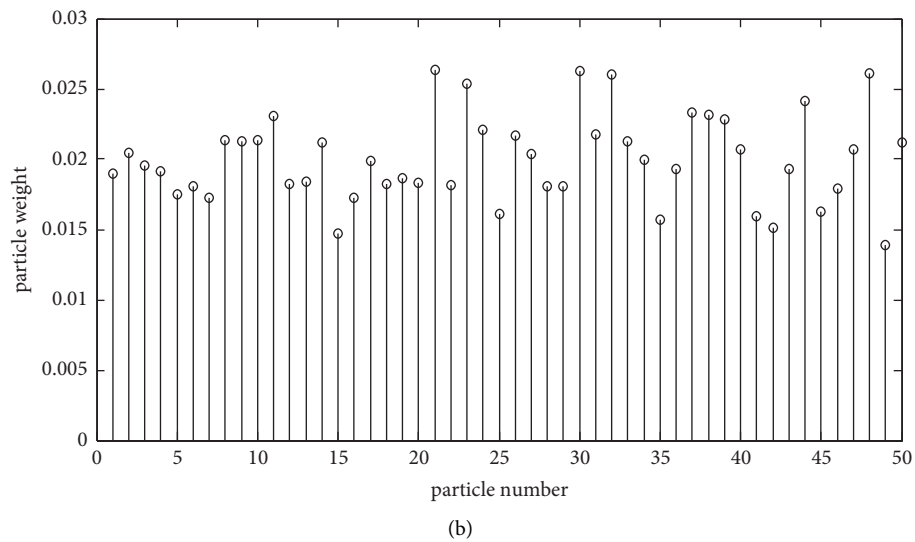
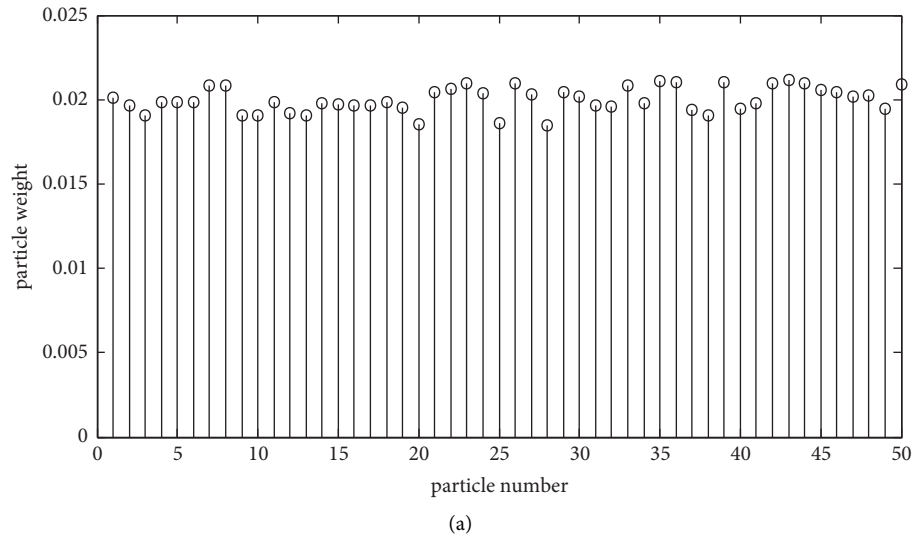


FIGURE 11: The particle weight of the traditional UPF and IUPF algorithm. (a) The particle weight of the traditional UPF algorithm. (b) The particle weight of the IUPF algorithm.

identification variance and more smooth identification results of permanent magnet flux linkage in the MPCC system for PMSM.

5. Experimental Study

In order to realize the experimental study of the IUPF algorithm proposed in this paper, an experimental platform of the MPCC system for PMSM was developed. The experimental motor is a face-mounted PMSM, whose parameters are as follows: rated voltage is 380 V, the permanent magnet flux linkage is designed to be 0.1278 Wb, stator resistance is $0.28\ \Omega$, stator inductance is 1.273 mH, pole pairs is 4, the moment of inertia is $0.00214\ \text{kg}\cdot\text{m}^2$.

Taking both the steady state and dynamic state conditions of the MPCC system for PMSM to experimentally study the identification performance of the proposed IUPF algorithm, the discrete period of the IUPF algorithm and the control period of the PMSM drive system are all set at 0.1 ms, load torque is set at 3 N·m, and the particle number is also set at 50. The measured speed waveform from 1800 rpm to 900 rpm is shown in Figures 8(a) and 8(b), and they show the measured current waveform when the speed drops to 900 rpm.

The experimental identification result of the traditional UPF algorithm and the IUPF algorithm is shown in Figures 9 and 10, respectively. From Figures 9 and 10, it can be seen that the proposed IUPF algorithm can accurately identify permanent magnet flux linkage under both dynamic and steady operating conditions of the MPCC system for PMSM, and the identification result has a smaller variance than that of the traditional UPF algorithm. The experimental results are consistent with those of simulation.

The particle weight distribution of the traditional UPF algorithm and the IUPF algorithm after a certain number of iterations is shown in Figure 11. According to Figure 11, with the execution of the UPF algorithm, its particle diversity decreases significantly, while the IUPF algorithm can always maintain the diversity of particle weight during its iteration, which is very beneficial to improving the identification performance of the proposed IUPF algorithm. The experimental results are also consistent with the simulation results.

6. Conclusions

Aiming at the MPCC system of PMSM, a novel identification method based on the IUPF algorithm for permanent magnet flux linkage is proposed in this paper. Simulation research and experimental verification of the proposed method are carried out, and the research results provide a basis for realizing high-performance control of the MPCC system for PMSM under the condition of permanent magnet flux linkage variation, and the following conclusions are obtained.

- (1) When the actual controlled object parameters are adapted to the MPCC algorithm control parameters, the MPCC algorithm can achieve fast tracking speed of PMSM without overshoot and accurate control of d-axis current and q-axis current, and the PMSM

drive system with the MPCC algorithm has perfect speed and current control performance.

- (2) The IUPF algorithm can always keep the diversity of particle weights during its iteration, which effectively solves the problem of the particle diversity decrease with the traditional UPF algorithm.
- (3) The IUPF algorithm can achieve accurate identification of permanent magnet flux linkage under non-Gaussian measurement noise and steady state and dynamic state operation conditions of the MPCC system for PMSM, and the identification result has smaller variance. The proposed IUP algorithm is suitable for both interior PMSM and surface mounted PMSM.

Data Availability

The data presented in this study are available on request from the corresponding author at hact@haue.edu.cn.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Evaluation and Analysis Model of Economic Development Level for Latin American Countries

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This study is devoted to the analysis of high-quality economic development in Latin American countries. Under the guidance of the new development concept strategy, the evaluation index system for the high-quality economic development level of Latin American countries is constructed from the six dimensions of economic strength, innovation, coordination, green, openness, and sharing, and the entropy weight method is used to calculate the weight of each evaluation index. Based on UTM projection coordinate quantification and K-Means clustering algorithm, the spatial effect clustering model of Latin American countries is established. According to the two dimensions of geographical location and comprehensive index, Latin American countries are divided into different economic zones, and the agglomeration effect in the process of economic development of Latin American countries is analyzed from a spatial perspective.

1. Introduction

Latin America is the region with the largest concentration of middle-income economies. It is also the region that first became independent, started the modernization process, crossed the low-income stage, and entered the middle-income stage [1–6]. As early as the early 1960s and 1970s, most Latin American countries have got rid of the poverty trap and entered the middle-income stage.

Latin American countries have always been the pioneers of the developing world in actively exploring and trying to use new economic development theories to guide practice [3]. Therefore, Latin American countries are called the experimental field of development economics. Since their independence in the early nineteenth century, Latin American countries have successively explored and applied the theory of comparative advantage, the theory of structuralism, the theory of neoliberalism, and the theory of socialism in the twenty-first century to guide their economic development for a period of time. Among them, the theory of structuralism and the theory of socialism in the twenty-first century were put forward and founded by the people of Latin American countries according to the development

difficulties of Latin American countries, which not only affected Latin America itself, but also has had a broad impact on other developing regions [5]. In the developing world, Latin American countries are also the first to implement the neoliberal theory.

However, after guiding the practice of Latin American countries for a period of time, these development theories ended in failure. At present, the mainstream economic academia mainly analyzes the growth and development dilemma of Latin American countries from the perspective of total factor productivity and innovation emphasized by the new growth theory and from the perspective of institution, corruption, and democracy emphasized by the new institutionalism theory. Either these analyses point out the problem but are difficult to go deep into the root cause of the problem, and then it is difficult to give constructive suggestions (referring to the analysis of innovation), or they reverse the results and causes of development and make it difficult to convince people (referring to systems and democracy).

Evolutionary economics is another set of economic theory system juxtaposed with mainstream economics. Since the international financial crisis in 2008, evolutionary

economics has developed very rapidly [6]. The Neo-Schumpeterian School of evolutionary economics has developed into a more influential school. The Neo-Schumpeterian School of technology and innovation studies more deeply the dynamic process of technology and innovation, so it is more insightful. In particular, the theory of national innovation system proposed later is regarded as a standard by many countries to guide the construction of their own innovation system. In recent decades, there have been many analyses of the development dilemma of Latin American countries from the perspective of national innovation system theory. However, the theory of national innovation system is mainly a set of theories put forward for developed countries, which is not well suited to the practice of developing countries. A connecting factor is needed to better integrate the national innovation system and the economic development of developing countries. Evolutionary development economics is a relatively new school of evolutionary economics. Through the analysis of policy experience in the process of catching up and surpassing developed countries from underdevelopment to development, as well as the absorption and creative synthesis of historical development ideas, this school has found the internal mechanism to enhance national wealth and put forward the view that high-quality production activities with increasing returns are the carrier of wealth and innovation, and economic development is the specific core of production activities, which have a deeper and clearer understanding of the development difficulties of developing countries.

On the basis of the above research, this paper is committed to establishing a mathematical model for the evaluation and analysis of the economic development level of Latin American countries and carries out mathematical calculation and analysis from a quantitative point of view, so as to provide a mathematical tool for the study of the national economic development level.

2. Construction of Evaluation System for High-Quality Development Level of Latin American Countries

2.1. Construction of the Evaluation Index System. From the perspective of the connotation of high-quality development, promoting high-quality development is to meet the real needs of the general public continuously and to adhere to the comprehensive unity of five development concepts based on improving economic strength. This paper comprehensively considers the current situation of economic development of Latin American countries, based on the research on the connotation of high-quality development and the five development concepts of innovation, coordination, green, openness, and sharing in the new era, and draws on relevant research results. A country-level high-quality development evaluation index system [7–12] has been constructed, including six subsystems: economic strength, innovative development, coordinated development, green development, open development, and shared development.

2.1.1. Economic Strength. Improving economic strength is still the key task of high-quality development of Latin American countries. Under this dimension, this article sets up three secondary indicators of the economic scale, development level, and investment intensity. Under the economic scale, this article sets up two indicators of regional GDP and industrial output above the designated size. Under the development level, this article sets up two indicators of general public budget revenue and regional average GDP. Under the investment intensity, this article sets up two indicators of fixed asset investment and total industrial investment. The economic scale of country-level high-quality development is measured from three aspects: economic scale, development level, and investment intensity.

2.1.2. Innovative Development. Innovative development belongs to the key content of high-quality development in the Latin American countries. Under the dimension of innovation and development, this article sets up two secondary indicators of innovation vitality and innovation potential. Under the vitality of innovation, this article sets up two indicators for the number of invention patents authorized and the R&D investment in industrial enterprises above the scale. Under the potential of innovation, this article sets up three indicators: the single-digit number of industrial enterprises above the designated size, the balance of various deposits in financial institutions, and the number of full-time teachers per 100 primary and secondary school students. These five indicators are used to measure the degree of innovation in the country's economic development, which also constitutes a representative indicator of the innovation-driven development of the country.

2.1.3. Coordinated Development. Coordinated development is the central link in the high-quality development of Latin American countries. Under the dimension of coordinated development, this article sets up two secondary indicators of social development coordination and people's life coordination. Under the coordination of social development, this article sets up three three-level indicators: the secondary industry's added value as a proportion of GDP, the added value of the tertiary industry as a proportion of GDP, and general public budget revenue as a share of GDP. Under the coordination of people's livelihood, this article sets up three three-level indicators, retail sales of consumer goods per capita, urbanization rate, and highway density. These indicators can not only fully measure the coordination between people's life and social development, but also reflect the reality of the current country development.

2.1.4. Green Development. Achieving green development plays a vital role in promoting the high-quality development of Latin American countries. Under the green development dimension, this article sets up two secondary indicators which are livability and energy conservation and environmental protection. Under livability, this article sets up two indicators: the ratio of good days and the green area

coverage. Under energy conservation and environmental protection conditions, this article sets up two indicators, the comprehensive utilization rate of solid waste and the comprehensive sewage treatment. It is mainly used to measure the green development level in the current high-quality development of counties.

2.1.5. Open Development. Open development is an indispensable part of the high-quality development of Latin American countries and plays a vital role in the development of Latin American countries. This article sets up two indicators, the total import and export volume and the level of actual utilization of foreign capital, which can have high representativeness for the opening level of the Latin American countries.

2.1.6. Shared Development. Shared development is the ultimate destination of high-quality development in the Latin American countries. Under the economic sharing, this article sets up three indicators of per capita annual GDP, per capita deposit balance, and per capita disposable income of residents. Under the living security, this article sets up three indicators: the rate of the urban registered unemployment, the number of beds per 10,000 people, and the number of health technicians per 10,000 people. The above indicators can not only mainly cover the shared development level of the country but also confirm the high-quality development level of the country to a certain extent.

To sum up, from the six dimensions of economic strength, innovative development, coordinated development, green development, open development, and shared development, a country-level high-quality development level evaluation system was constructed, including 12 secondary and 29 three-level indicators, as shown in Table 1.

2.2. Data Processing and Computation

2.2.1. Entropy Weight Method. At present, there are many references for multi-index evaluation methods in academic research, which are mainly divided into two categories: subjective evaluation and objective evaluation. The subjective evaluation method mainly uses the evaluator to determine the weight of each index subjectively through his psychological cognition, education level, life experience, etc. The objective evaluation method is to analyze the fluctuation of data through scientific methods to find the relationship between the data, determine the weight of each index, and evaluate it. To avoid the subjectivity and some objective limitations of artificially determining the weight of indicators and further improve the validity and reliability of this paper, this paper uses the entropy weight method in the objective evaluation method to calculate the weight of each indicator in the evaluation system of high-quality development in the country area. The specific calculation steps [13–16] are as follows:

(1) Data standardization processing

$$\text{Positive indicator: } x'_{ij} = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}}, \quad (1)$$

$$\text{negative indicator: } x'_{ij} = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}}.$$

In the formula, x_{ij} is the original value of the i -th sample and the j -th index, and x'_{ij} is the standardized index value.

Since the normalized value will appear logarithmic, the standardized data needs to be further calculated later, so this paper adopts the translation value to avoid the influence of the logarithm.

$$L_{ij} = x'_{ij} + a. \quad (2)$$

In the formula, L_{ij} is the value after translation, and the translation amplitude a is set to 0.0001.

(2) Calculate the proportion of the i -th country in this indicator under the j -th indicator (p_{ij}):

$$p_{ij} = \frac{L_{ij}}{\sum_{i=1}^n L_{ij}} \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m). \quad (3)$$

In the formula, n is the number of samples (counties), and m is the number of indicators.

(3) Calculation of index information entropy:

$$e_i = -k \sum_{j=1}^m p_{ij} \ln(p_{ij}). \quad (4)$$

In the formula, $k = 1/\ln(n)$, $0 \leq e_j \leq 1$.

(4) Calculation of difference coefficient:

$$g_i = 1 - e_i. \quad (5)$$

(5) Weights of indicators:

$$w_j = \frac{g_i}{\sum_{j=1}^m g_i} \quad (j = 1, 2, \dots, m). \quad (6)$$

2.2.2. Determination of Indicator Weights. According to the above calculation steps of the entropy weight method [13–16], this paper uses the relevant indicator data from 2015 to 2018 of the Latin American countries. The weights for each year are obtained separately, and the average of the four-year weights is used as the comprehensive weight of each indicator. The calculation results are shown in Table 2.

2.2.3. Calculation of Composite Index. To further compare the high-quality development level of Latin American countries and the gap with the high-quality development level of the top counties, this paper further calculates the comprehensive development index of each Latin American

TABLE 1: Evaluation index system of high-quality development level of Latin American countries.

First-level indicator	Secondary indicators	Three-level indicator	Unit
Economic strength (A1)	Economic scale (B1)	Regional GDP (C1)	Billion/yuan
		Industrial output above the designated size (C2)	Billion/yuan
	Development level (B2)	General public budget revenue (C3)	Billion/yuan
		Regional average GDP (C4)	Billion/yuan
	Investment intensity (B3)	Fixed asset investment (C5)	Billion/yuan
		Total industrial investment (C6)	Billion/yuan
Innovative development (A2)	Innovation vitality (B4)	Invention patents authorized (C7)	Number
		R&D investment in industrial enterprises above the scale (C8)	Billion/yuan
	Innovation potential (B5)	Single-digit number of industrial enterprises above the designated size (C9)	Number
		Balance of various deposits in financial institutions (C10)	Billion/yuan
		The number of full-time teachers per 100 primary and secondary school students (C11)	Name/hundred
Coordinated development (A3)	Social development coordination (B6)	The secondary industry's added value as a proportion of GDP (C12)	%
		The added value of the tertiary industry as a proportion of GDP (C13)	%
		General public budget revenue as a share of GDP (C14)	%
		Retail sales of consumer goods per capita (C15)	Yuan
	People's life coordination (B7)	Urbanization rate (C16)	%
		Highway density (C17)	km/10,000 square kilometers
Green development (A4)	Livability (B8)	The ratio of good days (C18)	%
		The ratio of green area coverage (C19)	%
	Energy conservation and environmental protection (B9)	The comprehensive utilization rate of solid waste (C20)	%
		The rate of comprehensive sewage treatment (C21)	%
Open development (A5)	Open level (B10)	Total import and export (C22)	Billion/dollars
		Level of foreign capital utilization (C23)	Billion/dollars
Shared development (A6)	Economic sharing (B11)	Annual GDP per capita (C24)	Ten thousand yuan
		Per capita deposit balance (C25)	Ten thousand yuan
		Per capita disposable income of residents (C26)	Yuan
		The rate of the urban registered unemployment (C27)	%
	Living security (B12)	The number of beds per 10,000 people (C28)	Piece/10,000 people
		The number of health technicians per 10,000 people (C29)	Number/10,000 people

country by using the weight of each index calculated in the previous section.

Since the units of each indicator in the indicator system are different (such as urbanization rate: 35%, GDP: 100 billion), it cannot be directly calculated, so we need to perform dimensionless processing on it. The specific processing formula is as follows:

$$f(x) = \frac{X}{X^*} (X^* \neq 0). \quad (7)$$

Among them, X is the specific indicator that needs to be dimensionless in the indicator system, X^* is the indicator quantification benchmark, and the value of X^* is the median of each indicator in the 2018 data of the top 100 counties. The median is used here as the representative level of high-quality development in the country. Compared with the average, the median is determined by its middle position in the dataset to avoid being affected by

extreme values. To a certain extent, the representativeness of the median to its dataset is improved, so the median can better represent the general level of this dataset than the mean.

Therefore, the final calculation formula of the comprehensive development index S of each country is as follows:

$$S = \sum_{i=1}^n \omega_i x_i (n = 1, 2, \dots, 29). \quad (8)$$

3. K-Means Clustering Model of Spatial Effects of Latin American Countries

3.1. Principle of K-Means Clustering Algorithm. K-Means defines the centroid of a cluster as the mean value of the points in the cluster. It is a complex clustering algorithm

TABLE 2: The comprehensive weight of each index of the high-quality development evaluation system for Latin American countries.

First-level indicator	Secondary indicators	Three-level indicator	Comprehensive weight
Economic strength (A1) 0.2782	Economic scale (B1) 0.1122	Regional GDP (C1)	0.0616
		Industrial output above the designated size (C2)	0.0506
	Development level (B2) 0.1234	General public budget revenue (C3)	0.0614
		Regional average GDP (C4)	0.0620
	Investment intensity (B3) 0.0425	Fixed asset investment (C5)	0.0175
		Total industrial investment (C6)	0.0253
Innovative development (A2) 0.2228	Innovation vitality (B4) 0.1237	Invention patents authorized (C7)	0.0731
		R&D investment in industrial enterprises above the scale (C8)	0.0505
	Innovation potential (B5) 0.0991	Single-digit number of industrial enterprises above the designated size (C9)	0.0299
		Balance of various deposits in financial institutions (C10)	0.0575
		The number of full-time teachers per 100 primary and secondary school students (C11)	0.0118
Coordinated development (A3) 0.1152	Social development coordination (B6) 0.0480	The secondary industry's added value as a proportion of GDP (C12)	0.0126
		The added value of the tertiary industry as a proportion of GDP (C13)	0.0128
		General public budget revenue as a share of GDP (C14)	0.0225
	People's life coordination (B7) 0.0672	Retail sales of consumer goods per capita (C15)	0.0335
		Urbanization rate (C16)	0.0082
		Highway density (C17)	0.0254
Green development (A4) 0.0397	Livability (B8) 0.0198	The ratio of good days (C18)	0.0147
		The ratio of green area coverage (C19)	0.0051
	Energy conservation and environmental protection (B9) 0.0199	The comprehensive utilization rate of solid waste (C20)	0.0048
		The rate of comprehensive sewage treatment (C21)	0.0152
Open development (A5) 0.1283	Open level (B10) 0.1283	Total import and export (C22)	0.0695
		Level of foreign capital utilization (C23)	0.0588
Shared development (A6) 0.2158	Economic sharing (B11) 0.1574	Annual GDP per capita (C24)	0.0763
		Per capita deposit balance (C25)	0.0454
		Per capita disposable income of residents (C26)	0.0357
		The rate of the urban registered unemployment (C27)	0.0216
	Living security (B12) 0.0584	The number of beds per 10,000 people (C28)	0.0228
		The number of health technicians per 10,000 people (C29)	0.0140

based on dividing. The model is relatively simple, is easy to operate, and has good applicability to larger datasets. All K-Means receives are unlabeled datasets, which is an unsupervised learning algorithm. During the clustering process, K is used as a parameter to select n objects randomly, and each object represents a cluster's initial average value. These objects are then divided into K clusters. And calculate the center distance of the remaining objects from each cluster and assign it to the nearest cluster to achieve similarity clustering. At this time, the mean value of each cluster will change, and it is necessary to recalculate the mean value of the corresponding cluster and iterate until the test function begins to converge.

Define a sample set containing n data as Ω , shown as

$$\Omega = \{x_i | x_i = (x_{i1}, x_{i2}, \dots, x_{is}), \quad i = 1, 2, \dots, n\}, \quad (9)$$

where $x_i = (x_{i1}, x_{i2}, \dots, x_{is})$ is a s -dimensional vector representing the s different features of the i -th data.

The cluster center point C is shown as

$$C = \{c_j | c_j = (c_{j1}, c_{j2}, \dots, c_{js}), \quad j = 1, 2, \dots, k\}, \quad (10)$$

where $c_j = (c_{j1}, c_{j2}, \dots, c_{js})$ is the center point of the j -th cluster, and each center point c_j contains s different features, where k is the total number of clusters.

Definition 1. Let the Euclidean distance between two data pieces x_i and c_j be $\text{dis}(x_i, c_j)$; then $\text{dis}(x_i, c_j)$ can be expressed as

$$\text{dis}(x_i, c_j) = \sqrt{\sum_{l=1}^d (x_{il} - c_{jl})^2}. \quad (11)$$

Definition 2. The center point c_j of the same cluster is shown as follows, where $N(\varphi_j)$ represents the number of data pieces in the same cluster.

$$c_{js} = \frac{1}{N(\varphi_j)} \sum_{x_i \in \varphi_j} x_{is}. \quad (12)$$

Definition 3. The criterion function is a parameter to measure the effect of the entire clustering. Only when it converges can each cluster achieve the best independence, which is shown as

$$E = \sum_{j=1}^k \sum_{x \in \varphi_j} \text{dis}(x_i, c_j). \quad (13)$$

3.2. Selection of the Optimal K Value of K-Means Clustering Algorithm. Now we will analyze the spatial distribution characteristics of high-quality development levels in Latin American countries, that is, the relationship between the relative position of each country and the level of development. In this paper, the horizontal position coordinates, vertical position coordinates, and comprehensive index of each country are used as the three characteristics of the cluster analysis datasets for K-Means cluster analysis [17–23]. At the same time, the K value needs to be selected. K is a parameter the user specifies, that is, the number of expected clusters. The selection of the K value directly determines the effect of clustering. Currently, there are two different methods to determine the K value, external and internal, and the division is based on whether there is a benchmark for reference. An irrelevant method to determine the K value when there is a benchmark for reference is called a supervised method. In the absence of a benchmark reference, an intrinsic method is used to determine the K value. The effect of clustering is judged by the degree of cluster dispersion, called an unsupervised method.

3.2.1. External Method. Many metrics can be used to evaluate the performance of clustering models in extrinsic methods. Entropy and F-measure are typical representatives [24–26]:

Entropy: it indicates the degree of chaos in the system; the greater the entropy, the more chaotic the system. The specific calculation process of the entropy of each cluster i is shown as follows, where L is the number of classes, $p_{ij} = m_{ij}/m_i$ represents the probability that the data in cluster i belongs to class j , m_i represents the number of datasets in cluster i , and m_{ij} is the sum of the number of values in class j in cluster i , e represents the total entropy of all clusters, K represents the sum of the number of clusters, and m represents the total number of datasets.

$$e_i = - \sum_{j=1}^L p_{ij} \log_s p_{ij}, \quad (14)$$

$$e = \sum_{i=1}^K \frac{m_i}{m} e_i.$$

F-measure: it describes the probability that a cluster contains an object of a single specified class and contains all objects of that class. The calculation process of cluster i with respect to class j is shown as

$$F(i, j) = \frac{2 \times \text{precision}(i, j) \times \text{recall}(i, j)}{\text{precision}(i, j) + \text{recall}(i, j)}. \quad (15)$$

3.2.2. Internal Method. When the benchmark of the dataset is lacking, it is necessary to use an internal method to judge the quality of the clustering effect. The silhouette coefficient and the elbow method are the representative calculation methods.

Silhouette coefficient: Assuming that there are n objects in the datasets D , clusters C_1, C_2, \dots, C_k indicate that the datasets are divided into k clusters, and $o \in C_i (1 \leq i \leq k)$, $s(o)$ represents the silhouette coefficient of the object o , $a(o)$ represents the average distance between objects in the cluster where o is located, and $b(o)$ represents the minimum average distance between objects except for the cluster where o is located; then:

$$s(o) = \frac{b(o) - a(o)}{\max\{a(o), b(o)\}},$$

$$a(o) = \frac{\sum_{o' \in C_i, o' \neq o} \text{dist}(o, o')}{|C_i| - 1}, \quad (16)$$

$$b(o) = \min_{C_j: 1 \leq j \leq k, j \neq i} \left\{ \frac{\sum_{o' \in C_j} \text{dist}(o, o')}{|C_j| - 1} \right\}.$$

Elbow method: The core idea is that as the value of K increases, the similarity of the number of samples in each cluster will also increase, and the clustering error (SSE) of all samples will gradually decrease. And when K gradually increases and does not reach the optimal value, the aggregation degree of each cluster will be greatly improved so that the value of SSE will also be significantly reduced; when K gets closer to the optimal value, the decrease of SSE will gradually decrease until K reaches the optimal value. Continuing to increase the value of K at this time will gradually flatten the decline of SSE, and the inflection point will be the optimal point. The core indicator SSE is shown as

$$SSE = \sum_{i=1}^k \sum_{p \in C_i} |p - m_i|^2, \quad (17)$$

where C_i is the i -th cluster, p is the sample point in C_i , and m_i is the centroid of C_i (the mean of all samples in C_i).

4. K-Means Cluster Analysis of High-Quality Development in Latin American Countries

4.1. Selection of the Optimal K Value for the K-Means Clustering Algorithm in Latin American Countries. The method for selecting the value of K has been introduced in the previous article, which is mainly divided into two categories:

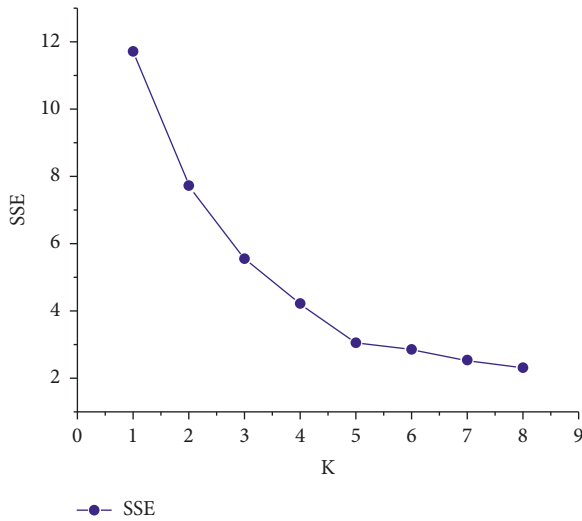


FIGURE 1: Using the elbow method to select the optimal K value.

the internal method and the external method. The external method is suitable for the situation with the benchmark, and the internal method is suitable for the case without a benchmark.

The clustering of Latin American countries belongs to no benchmark clustering [27–30]. Therefore, this paper chooses the internal method in the clustering method to determine the K value. The internal methods are mainly divided into the contour coefficient method and the elbow method. Compared with the elbow method, the silhouette coefficient not only introduces the degree of separation but also limits the degree of clustering. The obtained K value is not necessarily the optimal result, and it is even cumbersome to select the optimal K value again with the help of SSE. This paper uses the elbow method to choose the optimal clustering number K value after preprocessing the data. Figure 1 shows using the elbow method to select the optimal K value.

It can be seen from Figure 1 that the K value decreases gradually from 1 to 8. When $K=5$, an inflection point occurs, and the decline rate tends to be stable eventually. Then an inflection point is $K=5$ which should be the optimal K value point. So, for the number of clusters in Latin American countries dataset, the optimal number of clusters should be 5. Therefore, when K-Means clustering is performed on Latin American countries in this paper, $K=5$ is substituted.

4.2. Spatial Effect Analysis of Country Development in Latin American Countries. This paper uses python to perform a K-Means clustering analysis on the dataset. It obtains the scatter effect diagram of the K-Means clustering algorithm, as shown in Figure 2.

It can be seen from Figure 2 that the clustering effect of the scatter plot based on the K-Means clustering algorithm is relatively apparent. Based on the geographical location and comprehensive index, the quantitative clustering of Latin American countries is divided into five regions, among which the points in the regions are relatively points outside

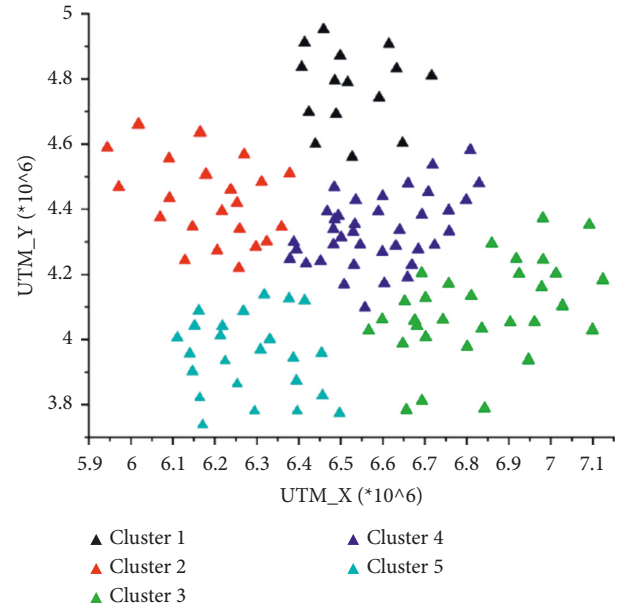


FIGURE 2: K-Means cluster scatter plot countries in Latin American countries.

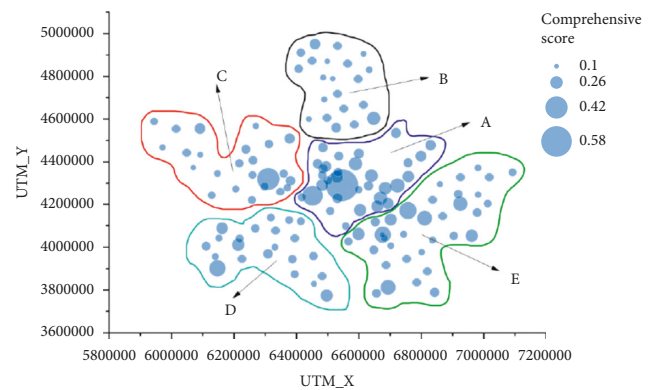


FIGURE 3: Cluster area of Latin American countries based on K-Means clustering.

the region that have more similar features. This figure shows that the high-quality development characteristics of countries in the same cluster have a certain similarity and regionality. To a certain extent, it reflects that the development level of each country in Latin American countries has a specific regional clustering, but the effect of clustering needs further analysis.

From the K-Means clustering results calculated here, the clustering distribution of Latin American countries based on K-Means is obtained, as shown in Figure 3. It can be seen from the figure that Latin American countries can be divided into five development clusters, namely, five economic belts. At the same time, most agglomeration areas have one or more countries with a relatively high level of development. Because of the influence of countries with higher levels of development, these communities come together to form development clusters.

5. Conclusions

This paper attempts to carry out systematic research and discussion by following the logic of “the theoretical analysis framework of the high-quality economic development of Latin American countries, the construction of the evaluation system of the high-quality economic development of Latin American countries, the establishment of the spatial effect clustering model of Latin American countries, the evaluation of the high-quality economic development level of Latin American countries, and the spatial effect analysis of the development of Latin American countries based on K-Means clustering algorithm.”

The interpretation of this study on the high-quality economic development of Latin American countries needs to be improved. In the process of evaluating the high-quality economic development of Latin American countries, the construction of the index system is not comprehensive enough and lacks more data support. In the future, with the progress of statistical technology, the index system can be improved through more channels. At the same time, this paper makes a cluster analysis on the high-quality economic development level of Latin American countries based on the spatial distance and comprehensive index, which can be further subdivided in the later research. According to the regional development characteristics, this paper makes a cluster evaluation and analysis on the high-quality economic development level of Latin American countries and further analyzes the complementarity of their development.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Retraction

Retracted: Study of Surface Roughness of Cutting Isothermally Hardened Ductile Iron in Tosa Knife Forging Technique Based on Intelligent Calculation

Mathematical Problems in Engineering

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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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Research Article

Study of Surface Roughness of Cutting Isothermally Hardened Ductile Iron in Tosa Knife Forging Technique Based on Intelligent Calculation

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With a long history of more than 600 years of development, the Achang Tosa knives have always been handmade and made in strict accordance with tradition and absorbing the essence of foreign cultures. It is not only a tool or a gift, but also a “knife culture” and a local “folk culture” with local ethnic characteristics in Yunnan. In this paper, we begin our research on the Achang Tosa knives by compiling literature and conducting field research to investigate the “knife culture” jointly created by the Achang and neighboring ethnic groups by studying the forging process of the Achang Tosa knives. Three sets of specimens were prepared and the mechanical properties were determined by combining the existing isothermal quenched ductile iron (ADI) material production, and a high-speed cutting test was carried out with a CC650 ceramic tool to investigate the relationship between the machined material, tool material, and cutting dosage-surface roughness during high-speed cutting of ADI; based on the particle swarm algorithm, a theoretical model between surface roughness and cutting parameters was established to provide theoretical guidance for the optimal production process of ADI in high-speed cutting. It provides more valuable experience for the protection of intangible cultural heritage of ethnic minorities and also provides reference for the development and protection of unique crafts of other ethnic minorities.

1. Introduction

The Tosa knife, also known as the Achang knife, is called “Mengshuo cap” in Achang language and is named after the Tosa and Lasa areas in Longchuan County, Dehong Dai and Jingpo Autonomous Prefecture, where the Achang people live [1]. According to folklore, historical records, and archaeological objects, the Achang knife is the oldest surviving combat knife in China [2]. With its unique forging technology and rich cultural connotation, it reflects the integration and unity among the hardworking and simple Achang people and various ethnic groups and shows the living customs, national history, and wisdom crystallization of the Achang people [3].

Since the founding of New China, individuals and various organizations have never stopped researching the history of the Achang people and their knife craftsmanship

[4]. As early as in the 1970s [5], a professor did an in-depth investigation on this topic and published a paper on “The iron making of the Achang,” which was published in “History and Culture of Southwest China” in 1987, and then a program produced by CCTV showed the Tosa knife and its making process for the first time in front of people all over the country, which received wide attention from the academic and social circles. More and more scholars have studied it in detail, and the Achang Tosa knife has been more and more familiar and loved by more and more people, coming into people’s lives [6]. The Five Series of Ethnic Issues published by the Yunnan Provincial Editorial Committee and Yunnan Ethnic Publishing House and the Achang Iron Making Technology and Related Issues by [7, 8] also contain studies on the Achang and their knife crafts, such as the wrong copper technology, quenching technology, carburization technology, and decoration technology.

In addition, foreign studies have been done to some extent on the Achang and their knife craftsmanship, but most of these studies were conducted on the history of the late Qing Dynasty and the World War I and II period when the British and French were stationed in Burma, and there are very few studies specifically on the Achang, and it is difficult to guarantee the quality of these studies because of the language barrier [9, 10]. This study starts from the technological craft of Tosa knife, mainly using documentary research method, ephemeral and cotemporal research methods, field survey method, and application of comprehensive analysis to analyze the value of the craft, to understand the historical changes of ethnic minorities, to find out many urgent problems behind the craft, and to focus on the bloodline between ethnic groups, especially how, in the social environment of extremely flooded cultural industrialization, traditional handicrafts of ethnic minorities are more in need of inheritance and protection by today's society [11, 12].

Austempered Ductile Iron (hereinafter referred to as ADI) is isothermally quenched at different temperatures to achieve high strength, high toughness, high fatigue, and wear resistance in the field of mechanical engineering; it is regarded as a high-tech material [13] and has been widely and successfully used in aerospace, vehicles, ships, and heavy industries internationally. However, due to the similarity of its processing properties and forged steel, the lack of a unified national standard, and the large differences in the material of ADI materials produced by various manufacturers, in the use of traditional processing methods and tools to process ADI, the tool wear is serious, which is a more difficult material to machine, often using time-consuming and labor-intensive annealing and grinding processes [14, 15].

Ceramic tools are internationally recognized as the most promising high-speed cutting tools, and their hardness is second only to diamond and polycrystalline cubic boron nitride tools, which significantly improve the machining efficiency, machining accuracy, and surface quality of parts and contribute to the realization of green manufacturing [16–19].

Surface roughness is an important indicator of the performance of the cutting process. At present, the change law of surface roughness in high-speed cutting is still in the research stage, and its formation mechanism is not perfect [20, 21]. With the improvement of workpiece quality requirements and the popular application of automated machining, the forecast of surface roughness will become an important research direction for the quality analysis of metal cutting [22, 23].

Three different sets of specimens were prepared and CC650 ceramic tools were used to perform high-speed cutting tests to investigate the relationship between machining material, tool material, cutting dosage, and surface roughness during high-speed cutting of ADI; the theoretical model between surface roughness and cutting parameters during high-speed cutting of ADI was established based on particle swarm algorithm to analyze the influence law and provide useful theoretical guidance for the optimal production process of high-speed cutting of ADI [24, 25].

2. Achang Tosa Knife Forging

Yunnan has a long history of using iron as a rich cultural resource. The Achang Tosa knife is the most famous of them all. The production process of the Achang Tosa knife is tedious, but the skills of the knife maker are very important. Among them, material selection and quenching skills are especially important. If the material selection is not suitable, no quenching can make a qualified Tosa knife, and if the quenching is not appropriate, even the best material will be wasted.

2.1. Material Selection and Refining. Before the Second World War, due to the scarcity of steel, woolen iron was the main material for making Tosa knives; after the Second World War, discarded old steel or new steel billets were the main material; nowadays, the raw material for making Tosa knives is mainly spring steel of Dongfeng car or discarded railroad rails; generally, one kilogram of iron can be bought for more than one yuan. The selected raw materials will be heated at high temperature in the furnace, while using a bellows or blower to increase the heat. Hardness is the resistance of the material to harder objects pressed into it, is a measure of the hardness and softness of the material, hardness can directly affect the material wear resistance index) can be completed practice material.

2.2. Forging and Repairing. The fired raw materials will be clamped out, and the master and apprentice will work together on the treadle to complete the beating. The master makes a small hammer, the apprentice with a sledgehammer overfires it, with forging, repeatedly until the steel is cold and hard, and then the steel will be red, and forging will be continued, so that it needs to repeat the link many times or even dozens of times, until the beaten shape is satisfactory. And this satisfactory standard refers to the idea that the knife leaf toughness is up to standard, toughness of the term generally corresponds to brittleness, with toughness of the knife being not easy to break, not easy to open, and tough, with fatigue resistance. The seven-colored knife of Achang Tosa knife is made of seven layers of steel; after 18,600 times of forging, the traces of forging can be seen in the blade. After repeated forging, the master uses small hammers and other tools to refine the overall shape of the blade and make final adjustments to the shape.

2.3. Leaf Decoration and Hardening. Generally, ethnic craft knives spend a lot of effort in this step to improve their ornamental value. Agricultural tools are generally not decorated with leaves, decorative leaves are first polishing treatment of the knife leaves, and master craftsmen in accordance with the requirements of the knife on the knife leaves use special tools to complete the pattern outline, cutting surface groove, and burin (mostly used in flowers and plants and other patterns of carving), in the pattern of gold and silver or copper, inlaying nonferrous metals and other steps. Quenching is also known as “dipping fire”; “dipping fire” is the industry term for quenching process,

which originated in the process of processing methods, but also the most important part of the Tosa knife making process. Quenching is the process of dipping a hot workpiece heated to a certain degree into a medium, which is completed after repeated operations. The knife is cooled to a certain temperature, and then the knife body or all of it is repeatedly polished to improve the hardness of the prop. This process is different from other processing (welding, cutting process, etc.); in general, it is mainly by changing the organization of steel to achieve the purpose of improving performance, without changing its shape and size. Steel in quenching commonly uses cooling media as oil, water, brine, mineral oil, etc. Cooling in oil is slower, cooling in water is faster, and cooling in brine is faster, according to different requirements to choose the cooling medium. Tosa knives have been developed for more than 600 years and have a reputation of being “soft as a finger, sharpening iron like mud.” When measuring whether a knife maker has excellent skills, the level of quenching skills is an important indicator. In the background of mechanical production, as Tosa knives became more and more famous, more and more foreign craftsmen and young artisans were eager to make quick profits, which led to the lack of mastery of quenching skills, and the quality of knives was greatly compromised.

2.4. Shank Making, Sheath Making, Belt Making, and Assembly. After completing the above process, the production of knife accessories is also very delicate. Based on the shape of the blade and the weight of the blade, the sheath and the handle are made, which requires not only the master knife maker to judge the material of the handle according to the blade, but also the imagination and aesthetic vision to choose the matching sheath. The material of the hilt and sheath of Tosa knife is very careful; the hilt and sheath are generally divided into wood and metal materials, with the process of wrapping brown silk, inlaid with copper ring, pinch silk enamel, and so on. Wooden material includes brown silk (wrapped), chicken wing wood, sourwood, Indian mahogany, small leaf rosewood, cow horn, antler, etc. Metal materials include rigid texture, copper texture, and Burmese silver texture, etc. Knife sheaths are divided into wooden sheaths, half-shell sheaths, silver sheaths, leather sheaths, etc., with a wide range of styles, exquisite selection of materials, and unique craftsmanship. The belt making refers to the process of fixing the knife handle and sheath with the materials taken locally, and the materials used are several kinds of woven belts of bamboo scrimshaw and cotton thread. After the above process, the forging process of Tosa knife is completed.

3. Experimental Research Method

3.1. Workpiece Material Preparation. The test materials were prepared at Qishuyan Rolling Stock Technology Research Institute of CSR Group: ductile iron made of 60 mm diameter, 400 mm long cylindrical specimen, first by 890°C insulation 2 h to austenite, and then in the nitric acid tank at

300°C, 350°C, and 400°C isothermal 1 h after air cooling. The chemical composition of the specimens before heat treatment is shown in Table 1, and the mechanical properties of ADI materials are shown in Table 2.

3.2. Machine Parameters. They include CYNC-400P general CNC lathe, main motor power 4 KW, maximum bed rotation diameter 400 mm, maximum workpiece length 1000 mm, and maximum spindle speed 2500r/min.

3.3. Tools. The inserts for the ceramic tools ($\text{Al}_2\text{O}_3/\text{TiC}$) were produced by the famous Swedish company Sandvik, with the model number SNGA120408T01020 SNGA432T-0320 CC650, and their dimensions were 12 mm \times 12 mm \times 4.8 mm. All insert geometries are the same: $\gamma_o = -6^\circ$, $\alpha_o = 6^\circ$, $\lambda_s = -4^\circ$, $K_r = 75^\circ$, $K'_r = 15^\circ$, $r_\epsilon = 0.8$ mm, $b_{r1} = 0.1$ mm, $\gamma_{01} = -26^\circ$.

3.4. Test Content. According to the specific test conditions to arrange the cutting process, the surface roughness of the workpiece was measured by T1000A portable roughness measuring instrument (Harbin Gauge and Cutting Tools Group Co., Ltd.). Based on the particle swarm algorithm, the theoretical model between the surface roughness and cutting parameters was established during the high-speed cutting of ADI, and the influence law was analyzed. The cutting method is dry cutting.

4. Cutting Parameters on the Impact of Surface Roughness

The surface roughness achieved by dry cutting ADI material is the key factor to achieve the process of “turning instead of grinding”; at the same time, it is also an important indicator to evaluate the quality of the machined surface in the cutting process; the study of surface roughness has a direct impact on the cutting performance of the analyzed material. Considering that the surface quality of the workpiece is affected by the cutting dosage (i.e., cutting speed, feed rate, depth of cut), workpiece performance, tool parameters, etc., the CC650 tool was used to establish the high and low level values of cutting speed, feed rate, and depth of cut for three ADI specimens under the same conditions, and the average value of the two was taken as the middle level. The surface roughness was then measured with a surface roughness measuring instrument, and based on this, the roughness values obtained were compared. Finally, according to the displayed results, it is possible to know how to choose the cutting dosage to obtain the minimum surface roughness when making such cuts. The specific experimental data are shown in Tables 3–5.

As can be seen from Table 3, the workpiece surface roughness values of group 3 and group 7 are the smallest. At this time, the cutting speed of both groups is high level, the feed is low level, while the depth of cut of the former is at high level and the depth of cut of the latter is at low level. Group 3: $v = 280$ m/min (high level), $f = 0.08$ mm/r (low level), and $a_p = 0.2$ mm (high level). Group 7: $v = 280$ m/min (high level), $f = 0.08$ mm/r (low level), and $a_p = 0.1$ mm (low level). Then

TABLE 1: Chemical composition of the specimens before heat treatment (%).

C	Si	Mn	P	S	Mg	Re	Al	Ti
3.1–3.9	2.0–3.0	≤0.4	≤0.10	≤0.03	≥0.02	≥0.02	≤0.05	≤0.004

TABLE 2: Mechanical properties of ADI materials.

Group no.	Isothermal temperature (°C)	Tensile strength (Pa)	Elongation (%)	Fracture condition	Hardness
ADI1	300	1385	1.80	Normal	45.8HRC
ADI2	350	1390	2.80	Normal	41.5HRC
ADI3	400	1080	1.55	Normal	37.8HRC

TABLE 3: CC650 cutting ADI1 experimental data table.

Group no.	v (m/min)	f (mm/r)	a_p (mm)	R_a (μ m)
1	285	0.25	0.25	1.86
2	155	0.25	0.25	1.89
3	285	0.09	0.25	0.77
4	155	0.09	0.25	0.96
5	285	0.25	0.12	1.79
6	155	0.25	0.12	1.93
7	285	0.09	0.12	0.77
8	155	0.09	0.12	0.90
9	220	0.15	0.16	1.16

TABLE 5: CC650 cutting ADI3 experimental data sheet.

Group no.	v (m/min)	f (mm/r)	a_p (mm)	R_a (μ m)
1	285	0.25	0.25	2.05
2	155	0.25	0.25	2.07
3	285	0.09	0.25	0.45
4	155	0.09	0.25	0.58
5	285	0.25	0.12	1.57
6	155	0.25	0.12	1.69
7	285	0.09	0.12	0.56
8	155	0.09	0.12	0.52
9	220	0.15	0.16	0.96

TABLE 4: CC650 cutting ADI2 experimental data sheet.

Group no.	v (m/min)	f (mm/r)	a_p (mm)	R_a (μ m)
1	285	0.25	0.25	1.72
2	155	0.25	0.25	1.73
3	285	0.09	0.25	0.46
4	155	0.09	0.25	1.64
5	285	0.25	0.12	1.62
6	155	0.25	0.12	1.46
7	285	0.09	0.12	0.52
8	155	0.09	0.12	0.61
9	220	0.15	0.16	0.99

FIGURE 1: Machining workpiece surface (200 \times). $v = 280$ m/min, $f = 0.08$ mm/r, and $a_p = 0.2$ mm.

comparing these two groups with groups 1 and 5, it will be found that the cutting speed and feeds have a relatively large effect on the surface roughness of the workpiece, while the effect of depth of cut is relatively small.

Table 4 shows that the workpiece surface roughness value of group 3 is the smallest; at this time, its cutting speed is high level, feed is low level, and depth of cut is high level. That is, $v = 280$ m/min (high level), $f = 0.08$ mm/r (low level), and $a_p = 0.2$ mm (high level). Comparing this group with group 1, group 4, and group 7, it is also found that the effect of cutting speed and feed on the surface roughness of the workpiece is relatively large, while the effect of depth of cut is relatively small.

In Table 5, the surface roughness of the workpiece is also the smallest in group 3, which is $0.46 \mu\text{m}$. The levels of cutting parameters are the same as those in Table 5, and the order of influence of each parameter on the surface roughness of the workpiece is also similar. Figure 1 shows the 200 \times micrograph of the workpiece surface corresponding to group 3 in Table 4.

The results obtained from the above three sets of experiments are very normal. From the formula for calculating surface roughness

$$R_{\max} = \frac{f^2}{8\gamma_\epsilon}. \quad (1)$$

It can be seen that the maximum residual height of the machined workpiece surface is mainly determined by the feed in the case of a consistent blunt radius of the tool. The test proves that the dry cutting ADI can also obtain a small surface roughness. Most of the workpiece surface roughness values in the experimental group cutting dosage are below $1.6 \mu\text{m}$, and the lowest is even $0.45 \mu\text{m}$, which reaches the level of grinding. This is due to the high hardness and toughness of the ADI material, and the plastic deformation during machining, the extrusion between the tool and the machined surface to a certain extent to improve the surface quality. At the same time, the self-lubricating property of CC650 ceramic tools is

better, and the friction coefficient between the workpieces is smaller, so the friction between the tool and the workpiece during the turning process is smaller, and it is not easy to form a stagnant layer and chip tumor on the front tool surface; therefore, a better surface quality can be obtained. This also proves that the ceramic tool cutting isothermal quenching ductile iron can be achieved by “turning instead of grinding.”

5. Particle Swarm Algorithm for Cutting Surface Roughness Prediction Model

The Particle Swarm Optimization algorithm was developed by James Kennedy and Russell Eberhart from a study of bird population behavior, using biologist Frank Heppner’s biological population model. The algorithm discovers the optimal region in the complex search space through the interaction between particles, which has the advantages of simplicity, easy implementation, powerful function, convergence, and generality. The application of the particle swarm algorithm to the identification of the parameters of the cutting surface roughness prediction model is of great practical importance to achieve preprocessing prediction and then optimize the control of the cutting surface quality and improve the cutting efficiency.

5.1. Establishment of Mathematical Model

- (1) Experimental scheme: Through the analysis of the relationship between cutting parameters on surface roughness, and combined with the actual cutting conditions, the experimental design variables were determined as cutting speed v_c , feed f , and back draft a_p , and the measured uncontrolled quantity was surface roughness R_a . The mathematical and theoretical model of surface roughness prediction was established as shown in the following equation:

$$R_a = kv_c^x f^y a_p^z = e^{x_1} v_c^{x_2} f^{x_3} a_p^{x_4}. \quad (2)$$

- (2) Objective function: According to the mathematical theory model formula of surface roughness prediction shown in equation (2), the objective function of equation (3) can be established as follows:

$$\min(x_1, x_2, x_3, x_4) = \sum_{i=1}^9 |e^{x_{i1}} v_{ci}^{x_{i2}} f_i^{x_{i3}} a_{pi}^{x_{i4}} - R_{ai}|, \quad (3)$$

where the constraint, i.e., the solution space, is expressed as shown in

$$X_{\min} \leq X_i \leq X_{\max}, \quad (4)$$

where X_{\min} , X_{\max} are the upper and lower limits of the variable values, respectively.

- (3) Description of the particle swarm algorithm of the prediction model: Let $X_i = (x_{i1}, x_{i2}, x_{i3}, x_{i4})$ be the current position of particle i ; $V_i = (v_{i1}, v_{i2}, v_{i3}, v_{i4})$ be the current flight speed of particle i ; $P_i = (p_{i1}, p_{i2}, p_{i3}, p_{i4})$ be the best position

experienced by particle i , i.e., the position experienced by particle i with the best target value. The best position at this point is the individual best position, or the local optimum. The local best position is updated as shown in the following equation:

$$P_i(t+1) = \begin{cases} P_i(t) \\ X_i(t+1) \end{cases} \quad (5)$$

Let the best position through which all particles in the population pass be $P_g(t)$, and its updated expression is shown in (6) below.

$$P_g(t) = \min\{f(P_0(t)), f(P_1(t)) \dots f(P_n(t))\}, \quad (6)$$

where $f(\cdot)$ is the objective function. The speed evolution equation can be described as shown in (7), where the first part of the evolution equation is the previous speed of the particle, the second part is the “cognitive” part, i.e., the particle’s own experience and its own learning, and the third part is the “social” part, i.e., the social information sharing among the particles.

$$V_{ij}(t+1) = v_{ij}(t) + r_1 r_{1j}(t)[p_{ij}(t) - x_{ij}(t)] + r_2 r_{2j}(t)[p_{ij}(t) - x_{ij}(t)]. \quad (7)$$

Its position evolution equation can be described as shown in

$$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1). \quad (8)$$

The particle swarm algorithm of the prediction model can be described as follows:

Step 1. Initialize the initial position and initial velocity of the particles.

Step 2. Calculate the adaptation value of each particle according to equation (3).

Step 3. For each particle, perform local update according to equation (5).

Step 4. Update globally for each particle according to equation (6).

Step 5. Evolve and update the velocity and position of the particles according to evolution equations (7) and evolution equation (8).

Step 6. If the end condition is not satisfied, return to the second step of the cycle.

5.2. Computer Simulation Experiments

- (1) Simulation experiments: The computer simulation program is built according to the description of the particle swarm algorithm of the prediction model. The number of particle swarm is set to 30 and the

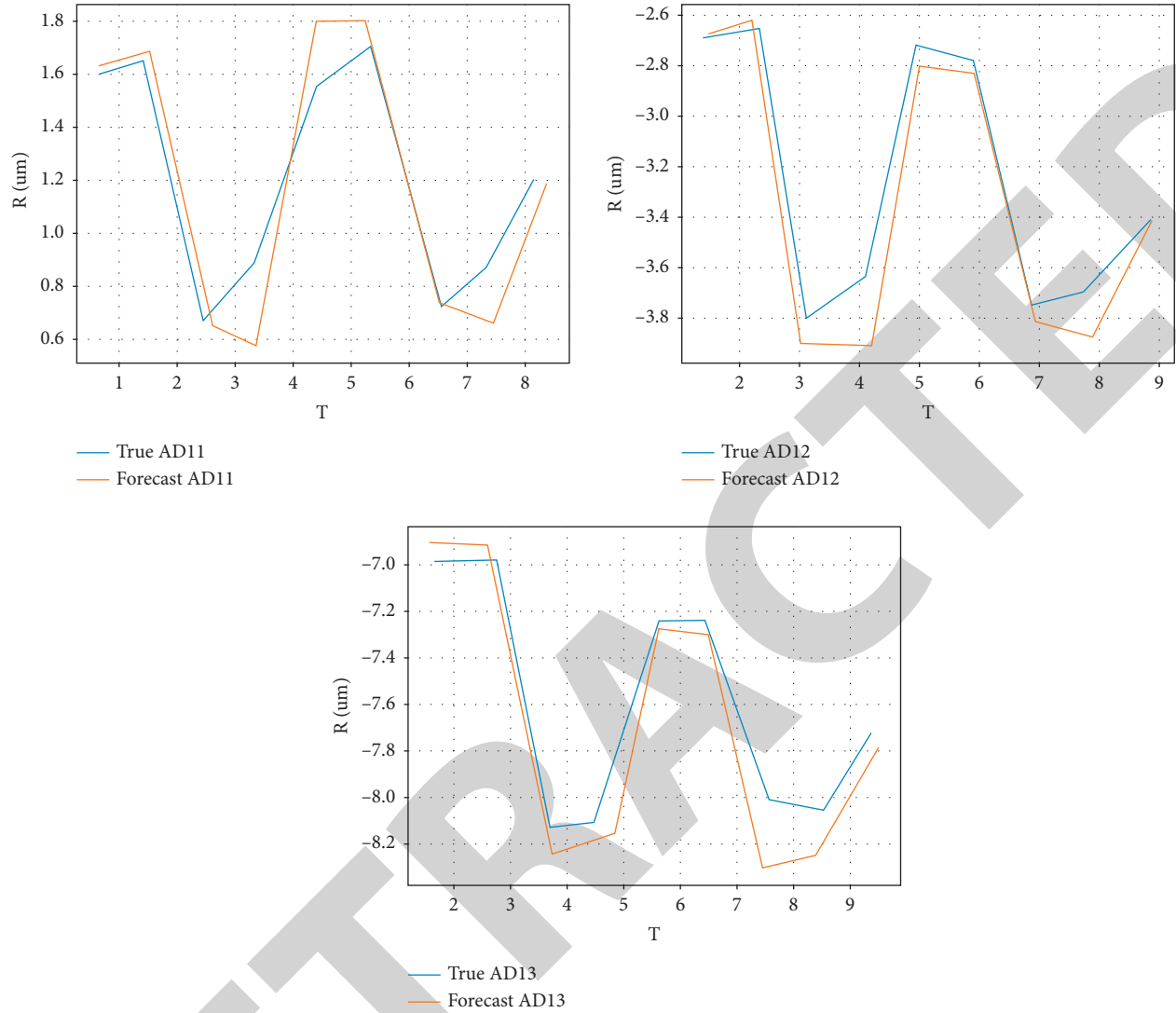


FIGURE 2: Comparison of measured and predicted values of ADI surface roughness.

number of iterations is 500, and the experimental results are shown in equations (9)–(11). The comparison between the measured surface roughness and the predicted value of the simulation experiment is shown in Figure 2.

$$R_a = e^{2.195764} v^{0.027044} f^{1.049691} a_p^{0.000003}, \quad (9)$$

$$R_a = e^{2.806886} v^{0.024307} f^{1.418497} a_p^{0.082919}, \quad (10)$$

$$R_a = e^{3.859964} v^{0.006420} f^{1.633840} a_p^{0.339267}. \quad (11)$$

- (2) From Figure 2, we can see that the particle swarm algorithm applied to the identification of roughness model parameters can meet the expected requirements; the average prediction error of each group is basically about 10%. However, in actual production, the prediction accuracy may

be affected due to factors such as shrinkage in ADI material, hard particles, or accuracy of measurement data, especially in this experiment, which is still the primary of particle swarm algorithm.

- (3) The effect of workpiece material on surface roughness: The workpiece material has a significant effect on the surface roughness of high-speed hard turning. According to the above three sets of experiments, the roughness values obtained from cutting ADI three specimens under different cutting parameters are compared, and the influence of workpiece material properties on the surface roughness can be seen more clearly (see Figure 3).

The test results show that the workpiece material properties play a significant role in the machined surface roughness during high-speed hard turning, which determines the selection of reasonable cutting dosage.

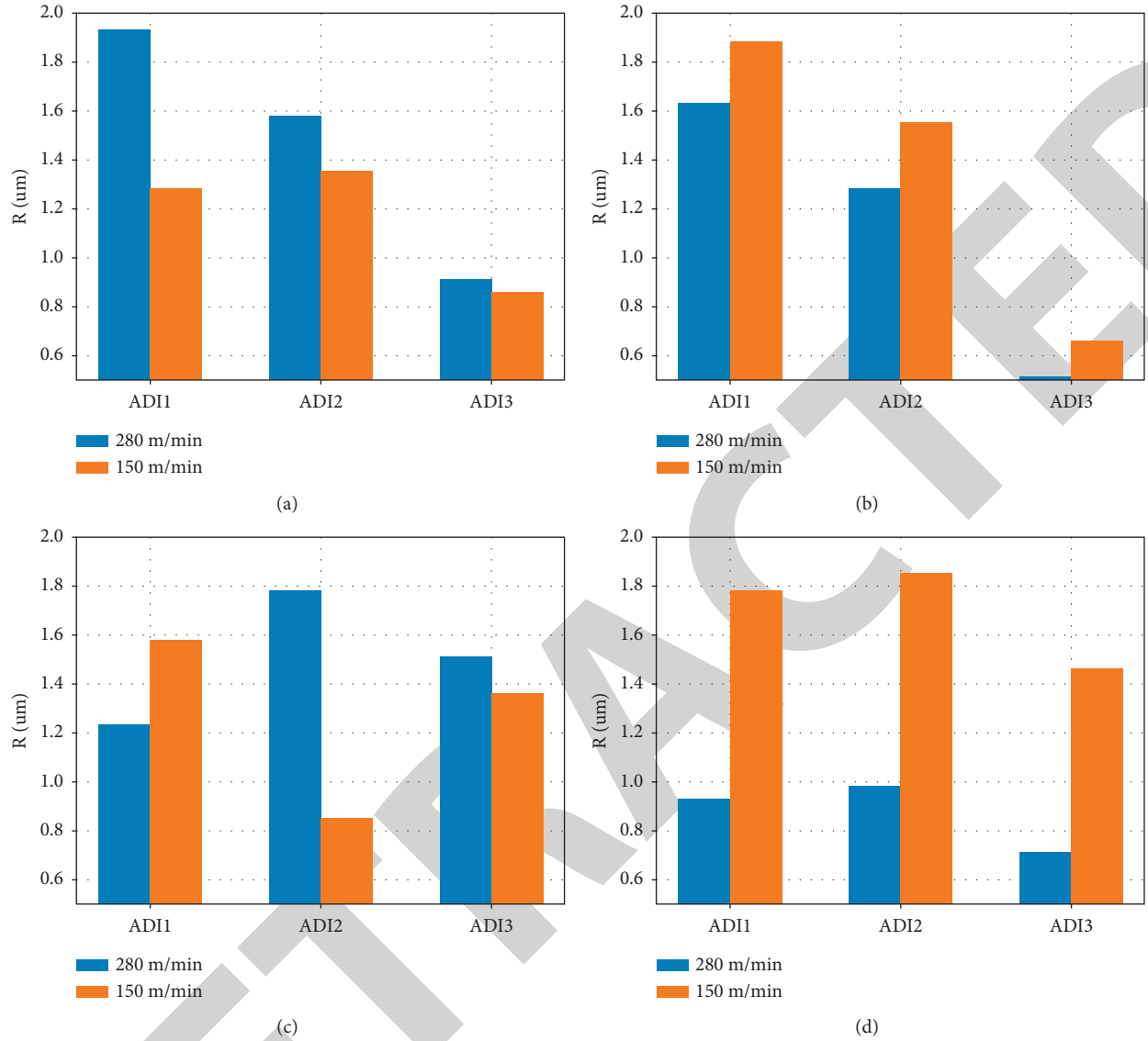


FIGURE 3: The influence of workpiece material properties on surface roughness. (a) $f = 0.2 \text{ mm/r}$, $a_p = 0.1 \text{ mm}$. (b) $f = 0.2 \text{ mm/r}$, $a_p = 0.2 \text{ mm}$. (c) $f = 0.08 \text{ mm/r}$, $a_p = 0.2 \text{ mm}$. (d) $f = 0.08 \text{ mm/r}$, $a_p = 0.1 \text{ mm}$.

6. Cutting Process on the Impact of Surface Roughness

In the cutting process, the actual process system is a very complex vibration system; the ideal state without processing vibration and environmental impact does not exist. The vibration in the system causes a slight change in the relative position between the workpiece and the tool, which eventually increases the surface roughness of the workpiece and reduces the surface quality. Scholars found that machine tool spindle vibration, guide vibration, and tool vibration have high frequency, small amplitude characteristics, chip tumor, external interference, machine tool rigidity, and high-speed rotating parts; unbalance will also cause cutting vibration, resulting in changes in the microscopic characteristics of the machined surface.

In the CC650 cutting ADI2, when cutting with cutting parameters $v = 280 \text{ m/min}$, $f = 0.08 \text{ mm/r}$, and a_p

$= 0.2 \text{ mm}$, the machining process experienced severe vibration with harsh noise, and the machined surface roughness was $R_a = 1.25 \mu\text{m}$. The surface roughness was reduced to 0.45 under the same cutting conditions after taking vibration elimination measures. In addition, the presence of vibration aggravates the breakage and failure of the ceramic tool, which also has a negative impact on the machined surface quality.

7. Conclusion

- (1) There is an optimal cutting dosage when cutting ADI with CC650, and the appropriate cutting dosage can be selected to reduce tool wear, improve labor productivity, and reduce cost, which further proves that the ceramic tool cutting isothermal quenched ductile iron can be achieved by "turning instead of grinding."

- (2) In the test, it is found that the closer the tool is to the lathe fixture, the better the surface quality of the workpiece is obtained. Due to the heavy workpiece, the surface quality was affected by the presence of small vibrations even though the root of the workpiece was supported by the tailstock.
- (3) The theoretical model between the surface roughness of the workpiece and the cutting parameters in the dry high-speed cutting of three ADI processes with CC650 ceramic tools was established based on the particle swarm algorithm with

$$\begin{aligned}
 ADI1: R_a &= e^{2.195764} v^{0.027044} f^{1.049691} a_p^{0.000003}, \\
 ADI2: R_a &= e^{2.806886} v^{0.024307} f^{1.418497} a_p^{0.082919}, \\
 ADI3: R_a &= e^{3.859964} v^{0.006420} f^{1.633840} a_p^{0.339267}.
 \end{aligned} \quad (12)$$

The microparticle swarm algorithm is able to identify the parameters of the surface roughness prediction model, and further research is needed to improve the algorithm and combine it with neural networks to identify the parameters of surface roughness, cutting temperature, cutting force, and other prediction models.

8. Discussion

The Achang Tosa knife forging process embodies the strong ethnic culture of Yunnan's various ethnic groups. Its unique forging process and rich cultural connotation reflect the integration and unity of the hardworking and simple Achang people and various ethnic groups. During the field research, we learned that the completion of a "Tosa knife" requires the participation of multiple ethnic groups from material selection to production to carving. It has played an indelible role in the unity of ethnic minority regions in the border areas. For more than 600 years, the Achang, Jingpo, Lisu, and other minority peoples have worked together through thick and thin to create a chapter of which we can be proud. The traditional forging process has been tested and verified over the years and will eventually play a significant role in people's lives, meeting their needs and having a certain collection value. The fact that people buy Tosa knives to achieve the effect of calming down the house and warding off evil spirits shows that Tosa knives are no longer mere production and living tools but have a spiritual dimension. The forging process has undergone a long history of evolution and renewal of forging skills, further reflecting the improvement of social productivity level. The process of making the knife, from the primitive manufacturing of traditional techniques to the improvement of modernization, is the process of creating life for the people of Yunnan minority areas. However, with the rapid development of productivity, the production of Tosa knife has also produced the phenomenon of modern commodity reproduction for quick success and profit, coupled with the national social security needs, which to a certain extent limits the inheritance and development of Tosa knife, and its characteristic

national traditional craft is also dying out at an untold speed. During the research process, it was found that many departments and folk craftsmen did not deeply understand the national significance of the Tosa knife for the Achang people but only talked about the Tosa knife and how much wealth and income it had created and failed to think about where the "tomorrow" of the Tosa knife with its huge benefits was from the aspect of national cultural preservation.

From the perspective of economic development and legal policies, the flexible and rational formulation of legal policies directly leads to significant economic improvement. From the policy and economic support of Tosa knife production and processing, that is, to support the economic development of more than 20,000 people, it is understood that, through the support, the Tosa knife industry in the quality, production, and price of the knife has a large step forward, from the original several yuan a hand, to now several thousand dollars a hand, or even to tens of thousands of dollars a hand. At the same time, the shoddy props are rampant in the market, bringing serious obstacles to the long-term development of Tosa knives. There is an urgent need to change the production mode, business philosophy, and sales method while preserving the traditional forging process and invest in the research and development of new products to meet people's needs for quality of life and art appreciation, so that the Achang Tosa knife is not only a kind of knife or minority gift knife, but also the "Tosa knife culture" with local ethnic characteristics of Yunnan after transformation. It is not only a kind of knives or minority gift knives, but also the "Tosa knife culture" and "Achang culture" of Yunnan.

From the perspective of inheritance value and national culture protection, both the national cultures of the world and the five thousand years of Chinese civilization are deeply penetrated in the whole process of the emergence, rise, and fall and development of the nation, and it is the main expression carrier of national culture inheritance. The Tosa knife has a history of more than 600 years, and when it comes to the development of ethnic minorities, the first and foremost issue that should be addressed is inheritance. Without inheritance, how can there be development? Without good protection of minority cultures, how can we talk about development if we cannot protect them in the face of the subtle influence and changes of modern social life on the way of life of minority areas? This urgently requires the participation of the government, society, and its members. Efforts are being made to preserve the culture and achievements of ethnic minorities. The traditional Tosa knife craft takes at least four years to be passed down, but the penetration of popular culture is changing the perceptions of young people, with the number of local youths working outside the home increasing year by year and the Tosa knife business being replaced by foreigners. Over the past hundred years, the Tosa knife has also gone through several ups and downs, just like the fate of people. Today, in the face of modernization, the increasingly developed mechanization, and the replacement of manual production by batch production, the exquisite skills of Achang Tosa knife are in danger of being lost and need to be rescued and protected.

The crisis of minority culture inheritance and preservation is more acute than ever before in history.

Data Availability

The experimental 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 to report regarding the present study.

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Research Article

A Design Thinking Technique of Letting Problems Solved by Self

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This paper puts forward the thinking mode of problems solved by self, which can turn complaints into wishes that resembles needs beyond user's expectation and imagination. Inferring the framework for solving problems from existing problem materials, the proposed technique employs literal logic to manipulate mathematical strategies, so that rational thinking can guide the development of affectional contexts, and automatically generate solution concepts, systematically and systemically. Through the demonstration of a design case study and comparative analysis of the effectiveness of related creative techniques the feasibility, novelty, advancement, and practicality of the proposed model are verified. The proposed tool can assist its users to think outside the black box and create "needs that adopters yet to aware."

1. Introduction

The well-known sentence "The only constant in the world is change" [1] points out that the essence of knowledge innovation from the past to the future is the pursuit of innovation and change. "Change" is often regarded as a "problem," while the essence of "innovation" is "seeking change," compared with normality and stability [2]. Therefore, innovation has also become a "problem" to be solved.

Another annoying language of "Think outside the box" is often heard, when encountering difficult problems [3]. The "problem" is considered as the "inertial thinking framework," limiting the creation development, so how to break the inertial thinking framework has become the crux and dilemma of many scientific research. Patent is one of the important indexes for calculating the achievements of many scientific research projects [4], so that many scientists have summarized and developed theories, technologies, methods, and tools for developing innovation, such as TRIZ method, based on patent big data [5]. The logic of "induction" is to find out the basic or common law inference mode from the existing knowledge materials or experience affairs, so the problems of experience innovation or emotion design cannot be solved.

Scientists rely on objective data calculation and experimental methods to create scientific research achievements, and artists mostly rely on intuitive understanding and personal life feelings to create art. Designers are between the two and should consider the operation of enterprises with the highly compound and complex problems treated and more serious "framework" trapped [6]. If we only summarize the innovative thinking methods required by designers from the perspective of scientific objective or understanding experience, it is easy to fall into the trap of "existing framework." Therefore, it is necessary to find another perspective or different thinking modes to seek breakthrough.

Design is often defined as "a purposeful creative behavior" [7]. If the purpose of creative behavior is to develop a high innovation with unstable purpose, design itself has become an unstable or undefined activity. In addition, design is defined as a kind of "mean to solve problems" or "mean to meet user needs," so as to clarify the purpose of design activities [8]. However, the consumers are difficult to point out their adoption needs clearly in today's market environment where supply is much higher than demand with more emphasis on "unprecedented" innovative experience [9]. Owing to "not having," it is "hard to say," which makes it difficult to effectively extend the design means to

solve problems for customers, so even the enterprise customers who entrust design innovation themselves are difficult to grasp the dynamics and changes of users' needs.

The study aims at analyzing the ways of thinking and types of feasible strategies to solve problems, establishing conceptual framework that can break through the framework, and develop a thinking technique of letting problems solved by self from the dilemma of inertial thinking framework, so as to verify the feasibility, practicability, progress, and other related characteristics of the proposed model and method through case analysis.

2. Problem: Inertial Thinking Framework

People will habitually use the previously acquired knowledge or experience framework to solve the difficulties when encountering difficulties, and when the difficulties cannot be completely and mostly solved, they are called "problems" [10].

Because people do not know how to solve the problem, and it sometimes is more difficult to confirm that the faced problem is a complete and core problem, seemed to be trapped in "problem space" [11], a designer or problem solver who claims to be a problem solver empathically replaces the trapped, who may be enterprise customers, product users, or any individual or group seeking assistance and find a way out, and the problem solver is a broad definition of professional skills, which can be engineers, lawyers, accountants, designers, and other people with different functions [12]. Therefore, the problem solver is in the problem space, trying to find a way out for the trapped, and creating all kinds of tools or solutions conducive to extricating or improving the difficulties through various technical methods according to the attributes of individual problems.

The above situation is mainly composed of four components: problem space, difficult problems, problem solvers, and conciliators. The problem space consists of known problems and hidden problems; difficult problems refer to currently known problems that are temporarily defined and yet to be solved; a rescuer means a trapped person or a rescuer entrusted by him; conciliator refers to all kinds of effective solutions or technical means that can extricate themselves from problems or solve difficult problems [13]. Nine thinking strategies in three categories that can effectively produce solutions are obtained based on the framework, problems, and problem solvers (see Figure 1).

Among them, although A1–A3 and B1–B3 solution strategies are effective, the problem solvers are still trapped in the thinking framework with the immutable problem essence [14]. Although B1–B3 solution strategies are also effective, the highest quality solution will take "no problem or no impact" as the best solution index, which makes it difficult to achieve creative solutions that are "beyond expectation" or "unexpected"; C1–C2 solution strategies emphasize the management technology of individual or joint solvers, and the quality of solution depends on the quality of problem solvers rather than the quality of management technology [15], so it is still difficult to leave the

dilemma that varies from person to person. Only C3 solution strategy has the originality of thinking beyond the thinking framework, which is planned to be the core to develop target technology and methods.

Two math problems that all middle school students have been tested more or less are taken as examples:

Question one: $(X + 2)(X - 1) = (X + 2)$, $X = ?$

Question two: $(\sqrt{2 + \sqrt{2 + \sqrt{2 + \sqrt{2 + \dots}}}}) = ?$

When answering the first question, examinees will subconsciously delete the $(X + 2)$ on both sides of the equal sign to get the answer of $X = 2$. If the teacher has the spirit of humanistic care, he maybe give full marks; if not, only half of the answer is correct, because if the deleted $(x + 2)$ is equal to 0, then $X = -2$ is also a set of feasible solutions; if you encounter a picky teacher, $X = \pm\infty$ can also be regarded as the other two groups of possible solutions. In this question, the question itself provides clues to the solution, so that examinees can easily solve the problem and save the complex calculation process. When one side of the formula is 0 or 1, the answer will be achieved.

In the question 2, many examinees intuitively regard that the answer must not be an integer, and they do not know how to start calculation because the length of the question is endless and cannot be conducted forced calculation at all. At this time, "cooperation with problems" has become the key to solving problems. The final calculation result of the problem is assumed as Y to multiply with itself to reduce the complexity of the formula to achieve $2 + Y = Y^2$, and then two sets of solutions $Y = 2, -1$ in $Y^2 - Y - 2 = 0$ can be achieved. Because the value in the root sign is greater than zero, the imaginary root of negative number is excluded to leave the only positive solution, and there is no need to use extreme value test.

From the answers to the above two questions, it can be found that the question itself can provide clues and relevant help. Working with questions makes it easier to get answers. The above strategic thinking of solving difficulties is analyzed to summarize the operation induced as follows:

- (1) When defining a problems, we should look at the appearance and explore the "hidden problems."
- (2) When deducing the meaning of the question, we can "assume the question is the answer."
- (3) In problem-solving skills, we can enlarge the problem, eliminate the interference of details, and focus mainly on the core answer.
- (4) In terms of problem-solving strategy, we can skillfully use the "virtual solution" accompanies the hidden problems.
- (5) When confirming the answer, use the "extreme value" test with caution in order to achieve completeness.
- (6) When one side of the equation is a simple value of 0 or 1, the answer is ready to come out.
- (7) In symbolic meaning, the equal sign can be regarded as intermediary medium.

Solution Type	Solution Strategy	Ideological Tendency
A. Problem-based strategy	<ol style="list-style-type: none"> 1. Rearrange known problems and excavate potential problems to facilitate the solution of the overall problem according to redefinition of problem system. 2. The difficulties can be expelled to become others' problems, as long as the trapped are not disturbed. 3. innovate each technology (Lighting / optimizing / windowing, etc) to improve problem quality. 	<p>System-guided thinking (Used in social science and technology R & D)</p> <p>Management-guided thinking (The key technology entrusted by technical department)</p> <p>Technology-guided thinking (Common in natural science and technology R & D)</p>
B. Problem-centered strategy	<ol style="list-style-type: none"> 1. Eliminate hidden problems to reduce problem-solving complexity to facilitate the difficulty-solving. 2. Redefine the difficulties without painstaking treatment, as long as it has nothing to do with the solver, there is no need to bother to deal with it. 3. Minimize the influence degree of difficulties to achieve optimal solution according to design improvement. 	<p>Academic circles (Study in different subjects and do more exercises)</p> <p>Religious world / Philosophical world (Escapism)</p> <p>Engineering field (Finite element analysis and eclecticism)</p>
C. Problem-solver oriented strategy	<ol style="list-style-type: none"> 1. Capable people do more; Submitted to experts; Exclude yourself from the problem; No need to refine problem-solving skills. 2. Organize interdisciplinary team to work in cooperation with a due division of labor, and solve problems individually and break through difficulties together for problem properties. 3. Personify problems, and cooperate with problems to solve each others' problems together. 	<p>Entrust expert mode (The traditional political thinking)</p> <p>Interdisciplinary team model (Escapism)</p> <p>Innovate thinking mode (Break away from the original thinking framework)</p>

FIGURE 1: Strategies for extricating difficulties from the framework.

(8) Practicing math problem solving is in fact learning “strategic thinking.”

According to the above gist, taking the innovative thinking of C3 solution strategies as the core, integrating the advantages of other solution strategies, this paper puts forward the “difficulty solving mode of transforming difficult problem resistance into obtaining solution assistance,” which is called as “problems solved by self.”

Since the advent of information technology, the boundary between natural science and social science has gradually blurred [16], and the natural grammar model can be adopted for algorithm and program transcription, while robots are gradually endowed with artificial intelligence and “artificial humanity” [17]. Aesthetic feeling can also be described by digital, and it appears in the field of Kansei engineering [18]. In the past, the two major scientific thinking with different properties, respectively, focus on the expression and deduction of qualitative and quantitative and will gradually become two sides of combining two into one and integrating into a whole [19]. Therefore, the ideal solution model should also take into account the thinking needs of two different sciences and gradually form a new system view or scientific paradigm.

3. A Design Thinking Technique of Letting Problems Solved by Self

Most of the problems in life or work have high multiplicity and complexity [20]. Here, “problem” is defined as “a

combination of various dissatisfaction attitudes surrounding a specific core problem.” Dissatisfaction may come from explicit complaints or implicit doubts. Doubts are often hidden but not obvious, so they can be regarded as “hidden problems” that jointly constitute the problem space. Complaints are explicit and easy to observe. The implicit doubts can be known only after in-depth investigation and finally appear in explicit form. In order to facilitate the discussion, it is assumed that the doubts are known through investigation, and the doubts are integrated into the complaint discussion. The problem can then be defined as “the complaining combination of a group of complex (n) items with time order or logical context” formula .

$$P = \sum C_i, i = 1 \sim n. \quad (1)$$

In order to reduce the difficulty of problem-solving or increase the effectiveness of teamwork, each complaint can be solved or improved one by one. Therefore, through the way of “assuming the problem as the answer,” the “transformation” function of the equal sign and multiplication is skillfully used, just like the negative number on the left side in mathematics. After moving across the equal sign to the right, it will be transformed into a positive number or multiply itself by square and remove the annoying root sign, so as to “turn resentment into wish” to solve many difficulties. “Transformation” can be any verb related to “change and become,” whose main role is to redefine the problem, eliminate interference details, focus on core clues, and generate favorable solution strategies to facilitate quick

solution. “T” refers to transformation, and output of “complaint” is “expectation.” Through the transformation mechanism, the “expectation” towards positive development can be generated from the negative “complaint” formula .

$$\sum C \cdot T = \sum E. \quad (2)$$

The key transformation mechanism words of “change and become” have essential differences in the meaning of Chinese characters. “Become” mostly refers to the change from one nature to another, belonging to a qualitative change or innovation, and tends to be the logical concept of “nonoriginal” or “qualitative change” in Chinese word meaning. Relatively speaking, “change” mostly refers to the transformation from one type or structure to another with similar essence and different expression forms. It focuses on the improvement and change in degree or quantity. In solving problems, it is similar to concepts such as reducing shortcomings or narrowing the gap with the target value and prefers the logical concept of “negative less” or “quantitative change” in Chinese meaning. For some time-dependent problems, “using time for space” is also a way of thinking to solve problems, so “maintain the same or do not change” can also be regarded as a solution option for transformation.

The above three transformation forms can be represented by three symbol concepts: the pronunciation of $T[-1, 0, \sim 1]$ is the transformation of “Negative one, Identical and Non-one.” The complaints with negative energy apply -1 transformation to reduce the complaint value, and the maximum reduction is to return the negative value to zero. For example, after the function of -1 on “troublesome” and “I do not know,” it can be transformed into “no trouble” and “known”; “no trouble” means that there is still some trouble, and “known” has zeroed the negative image of “I do not know” and transformed “problem” into “no problem.” If the ~ 1 transformation is conducted, then changing the original solution space or redefining the problem space can produce a qualitative change utility different from the original essence. For example: after the ~ 1 transformation of “too high price” and “must pass,” they can be “too high value” or “can pass,” referring that if the “value” is high, the “price” is not expensive; “can” pass means “not necessarily” must pass.

Technology comes from creativity [21], and ideology comes first to lead technology development as the core value and innovation key of the proposed method. Various solutions obtained through different transformation mechanisms fall in different conceptual space positions (see Figure 2). $\sum C \cdot T[0]$ represents the result of transformation in identical formula, which is still the original complaint combination originally at the maximum negative value ($-X$) (use $-X$ to represent the concept of negative number, and the value itself does not represent its distance or quantitative meaning); $\sum C \cdot T[-1]$ represents the result of all negative one transformation, which can approach the realm of “making the problem meaningless” or represent the 0 value of “no problem”; $\sum C \cdot T[\sim 1]$ represents the result of all nonone transformation to achieve new content quality of “imagination.” Because “noncomplaint” is beyond the expected scope of “no problem,” it is called “wish” or “dream solution.”

The so-called “problems solved by self” is the result of the all nonone transformation of negative complaints. Dream solution can be defined as “a set of desire combinations with logical order formula (3).” Mastering the conceptual space location of the solution is helpful for the subordinates of follow-up key work such as product service system design, patent technology layout and market strategic planning.

$$W = \sum C \cdot T[\sim 1]. \quad (3)$$

The problem solver can freely choose any transformation mechanism ($T[-1/0/\sim 1]$) to transform for any complaint component constituting the overall problem, generate a variety of solution forms, and fall in different conceptual space positions. After confirming the conceptual spatial position of the transformation of all identical formula ($T[0]$, all negative one $T[-1]$, all nonone $T[\sim 1]$, the $T[-1]$ transformation using mixed $T[0]$ and $T[-1]$ mechanisms will fall into the conceptual space between $T[0]$ and $T[-1]$, belonging to the predictable range of inertial thinking concept space, so it can also be called as progressive innovation concept space; the transformation result of $T[-1/\sim 1]$ will fall into the open concept space between $T[0]$ and $T[-1]$. Because it is different from the inertial thinking concept space exceeding the existing expectation and imagination range, it can be called radical innovation concept space as a multidimensional concept space, which is presented in plane form for the convenience of discussion. The transformation result of $T[0/\sim 1]$ will be between $T[0]$ and $T[-1]$, scattered in the concept space of progressive and radical innovation.

4. Case Operation Demonstration

Creative ideas can express the content structure and logical ideas through Chinese forms. Different Chinese structures represent different logical thinking [22], where Chinese context and Chinese logic are used as operation tools to demonstrate case operation. The proposed use of solving problem with problem mode requires a high language ability of the operator with clear semantics, accurate, and good text logic [23], so that the text can be controlled like numbers and reduce the fuzzy space in logic as much as possible.

Taking the measurement of breast shape of developing girls as an example to illustrate the operation of the proposed model. The relevant literature of nearly half a century points out that 80%–85% of girls choose inappropriate underwear [24], and girls’ parents and bra shopping guides also lack correct shopping knowledge [25]. Through actual interviews and current situation of girls’ underwear patents and commodities analysis, it is found that between the unprotected vest circumference and adult bra, it not only lacks needed products for girls’ protection and company during their growth but also lacks measurement technologies and methods and tools for appropriate selection of products [26]. Bra products are one of the few blue oceans in the garment industry, and anthropometric problems have not been effectively solved for many years.

The basic reference framework for measuring experience process should be established first to give a new

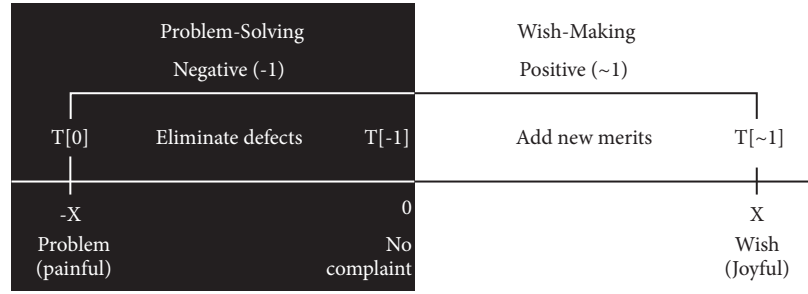


FIGURE 2: Conceptual space of solutions using different transformation mechanisms.

measurement technology and method and use the thinking technology of problem-solving. Based on the standard process or experience connotation of general girl's chest measurement, the general description of the existing measurement system providing measurement services is established from a neutral and objective standpoint, and the 10 procedure steps. Figure 3 shows the results of various transformations based on the standard procedure of chest measurement. Under the chest measurement, standard procedure are obtained. In the eyes of general customers, the obtained content is only a commonly used measurement service with a neutral attitude [27].

The first step in implementing thinking technique of letting problems solved by self is to define problem connotation $P = \Sigma C$. Those with previous unpleasant chest measurement experience or picky people with high negative energy as representatives are invited for focus discussion and questionnaire filling. According to their dissatisfaction experience or ask to adopt the attitude of criticism for progress, the reference content provided is redescribed and ask the subjects to express their dissatisfaction with each procedure step with the Likert Scale five subscale (−5 extreme dissatisfaction, −4 very dissatisfaction, −3 dissatisfaction, −2 some dissatisfaction, −1 slight dissatisfaction, 0 no dissatisfaction). Through interview survey and questionnaire statistics, the contents and extent of various dissatisfaction opinions of representative users on the current chest measurement service system can be analyzed to obtain the complaint combination content under the negative complaint statement (see Figure 4) (ΣC_i , $i = 1 \sim 10$), including qualitative description and quantitative indexes (represented by C-shaped character fold line).

The second step of thinking technique of letting problems solved by self is to implement transformation $\Sigma C \cdot T = \Sigma E$. Taking negative complaint statement (ΣC) as operation object of transformation successively performs all −1 transformation and all ~1 transformation to obtain no problem solution and dream solution and makes story according to statements as an auxiliary tool for subsequent measurement of dissatisfaction and expectation.

First, the significance of all −1 transformation is applied to establish an intermediary 0-value benchmark representing no dissatisfaction or meet expectations as a reference for subsequent comparison. After all −1 transformation ($\Sigma C \cdot T[-1]$), then qualitative statement of the zero-value baseline can be achieved, referring 10 step content that girls with perceived discomfort, identifiable degree of change,

which focuses on the substantive procedures for customers to accept the service of chest measurement system and can be regarded as improvement design concept based on dissatisfied customer experience. Through a measurement method similar to the negative complaint statement, subjects about their dissatisfaction with the qualitative statement of the 0-value baseline are asked to obtain the 0-value baseline shown by the N-shaped character fold line as a reference line to divide problem and no problem.

After confirming the 0-value baseline, the effectiveness of conversion should be examined. The distance from each C_i point to its corresponding N_i point or the sum of the differences between them ($\Sigma(N_i - C_i)$) represents the expectation gap for subjects dissatisfied with current situation for improvement. Theoretically, the quantitative indexes of each step should show dissatisfaction value lower than the expectation ($C_i \leq N_i$); When dissatisfaction value is greater than or equal to the expectation ($C_i \geq N_i$), or $C_i \leq N_i$ with small difference, it can be considered that this step belongs to the conversion with limited efficiency, excluding the utilization of identical formula transformation, and belonging to the negative formula transformation process.

However, all ~1 transformation is conducted to achieve optimal ideal solution or so-called dream solution ($W = \Sigma C \cdot T[\sim 1]$). The Likert scale five subscale is also applied in (0 wait-and-see, +1 small expectation, +2 some expectation, +3 very expectation, +4 full expectation, +5 beyond expectation) with positive expectation measured to invite the subjects to focus on the content of each procedure step in the storyboard to provide their expectation of innovative chest measurement service model. Through interview survey and questionnaire statistics, the expected combination content of dream solution (see Figure 5) is obtained (ΣW_i , $i = 1 \sim 10$), represented by W character fold line; after reviewing the conversion efficiency, the W character fold line is confirmed. Theoretically, the distance from each N_i point to its corresponding W_i point or the sum of the differences between them $\Sigma(W_i - N_i)$ represents the subject's expectation of dream solution. The greater the value, the higher the desire. Although the dissatisfaction degree of C–N line is not directly related or additive to the expectation degree of N–W line, the gap can be regarded as the worst to the best measurement experience gap. The wider the distance, the richer the conceptual differences that can occur.

After confirming the feasibility of turning resentment into wish mode operation, the technical feasibility of whether the dream solution can be realized is analyzed

User Journey	Procedure	Negative Complaint (C)	All Negative One (N)	All Non-one (W)
1	Girls with breast development	Girls with constant change of chest	Girls perceiving discomfort	Girls expecting change
2	Confirm chest size	Difficult to confirm change degree	Identifiable change degree	Predictable change trend
3	Take off clothes	Chest touch with embarrassment	Self-touch chest to measure	Non touch chest measurement
4	Measurement with the assistance	Others' strong subjective experience	Strong personal subjective experience	Objective scientific judgment
5	According to characteristic points	Not rigorous measurement point	Basis for measurement point	Measure coordinate system
6	Measure size with tools	Inaccurate measurement technology	Accurate measurement technology	Systematic measurement technology
7	Convert size to size	Large conversion mode error	Small transformation mode error	Accurate conversion mode
8	Recommend products to buy	No embodiment of symmetry degree	Embodiment of symmetry degree	Direct estimation of compensation
9	Try it on to make fit	Difficult to check abnormal posture	Check abnormal body posture	Inferred abnormal posture
10	Measure next time	No accumulated data changes	Accumulated data changes	Accumulated personal data
Service Quality	General measurement service	Inaccurate measurement services	Low error measurement services	High accuracy measurement services
Element Value	Reference schema(0)	Disappointments and complaints(-X)	Meet expectations(0)	Honor dream(+X)

FIGURE 3: Results of various transformations based on the standard procedure of chest measurement.

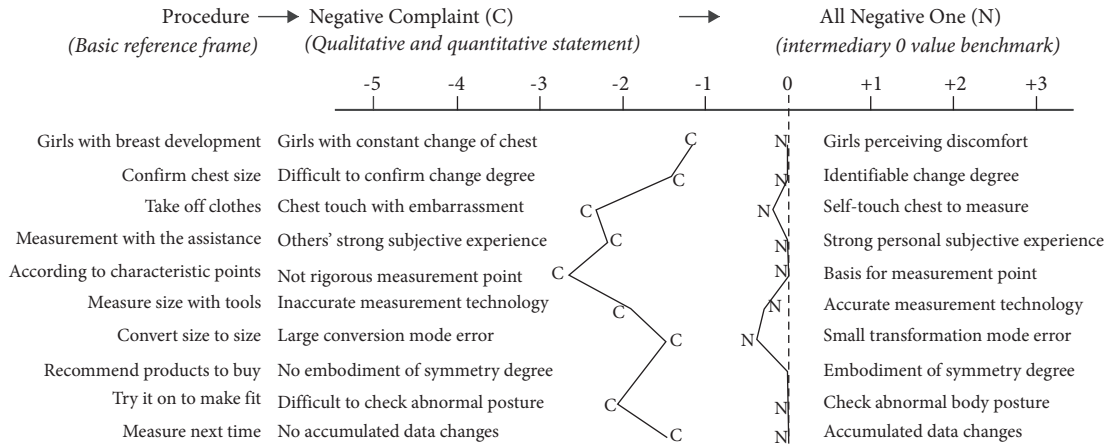


FIGURE 4: Basic reference architecture, negative complaint statement, and intermediary 0 value benchmark.

according to the existing technology or available resources of the operator or his organization, so as to establish a list of required technologies and industrial resources such as relevant technology, R&D, main functional characteristic test, prototype production, and product development [28]. Based on the analysis of the available industrial technology and resources in today's society, the dream is a feasible idea. For the convenience of discussion, the core value of dream solution—FEEL Tech System (FTS)—qualitative statement is taken as the framework to explain technical requirements and feasibility analysis (see Figure 6).

According to the innovative design highlights of FTS structure, it can be judged that the supporting products and service systems required to provide innovative services can be divided into two parts: one is the available technical resources of the affiliated enterprise, and the other is the

additional required technologies and resources difficult to access with need to be created or developed.

The available technical resources required for dream solution practice is the mature and directly or indirectly accessible technologies and resources, and the development of additional required technology and resources has a good technical foundation with limited threshold height to produce patented technology and social and industrial benefits derived from its operation mode [29], promoting healthy development of regional economy and shaping social image of convenient travel, and the proposed dream solution is not far from the concrete realization.

In addition to the no problem solution of all -1 transformation and the dream solution of all ~1 transformation, the model of turning resentment into wish more systematically provides all possible solutions from negative

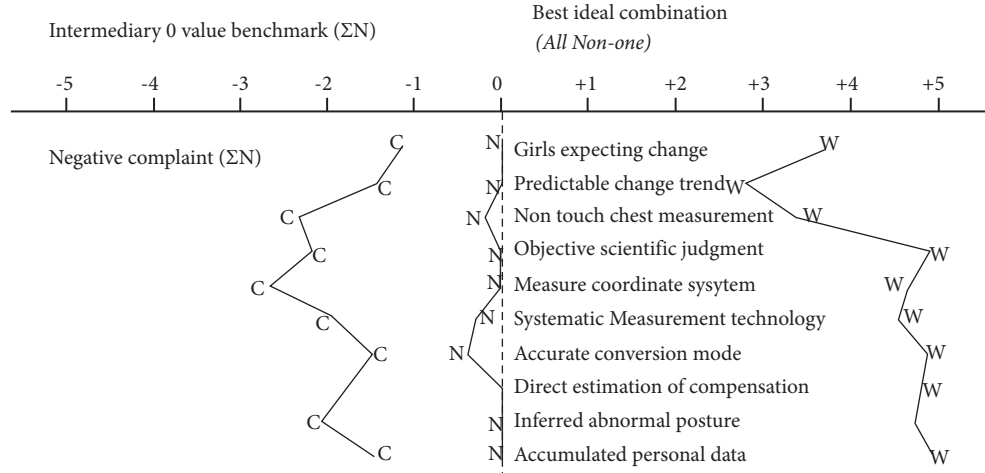


FIGURE 5: Intermediate 0 value benchmark and best ideal solution (dream solution).

User Journey	FEEL Tech System	Design Innovation	Available Technical Resources	Additional Required
1	Girls expecting change	Predicted developmental changes	Group growth big data	Individual growth big data
2	Predictable change trend	Analyze change prediction	Personal data analysis and statistics	Algorithm for size prediction
3	Non touch chest measurement	Non-contact during operation	Wearable measuring platform	Self-Feeling high precision tool
4	Objective scientific judgment	Most accurate Self-Feeling	Application of Humanity Technology	FEEL Tech creation and development
5	Measure coordinate system	Stable reference measuring point	Principles of ergonomics	New coordinate definition operation
6	Systematic measurement technology	Full record of detailed features	Bluetooth data transmission	Position sensing technology innovation
7	Accurate conversion mode	Scientific size transformation	Mapping of existing product sizes	Null
8	Direct estimation of compensation	Asymmetric data	Existing compensation mode application	Correction function mode
9	Inferred abnormal posture	Remind abnormal posture	Body correction sensor system	Visual record of deviation comparison
10	Accumulated personal data	Recorded lifetime data	Synchronous storage in mobile cloud	Null

FIGURE 6: Technical requirements and feasibility analysis of FEEL Tech System.

complaint solution to no problem solution and dream solution. Because each content step can produce at least three combined solutions through the transformation of the negative one, identical formula and nonone ($T[0/-1/\sim 1]$). Relatively speaking, -1 transformation tends to closed directional transformation, and there is a single or a few solutions to reduce or eliminate the content of negative complaints; ~ 1 transformation is an open nondirectional transformation with lateral qualitative adjustment, which can transform the same negative complaint content into multiple groups of heterogeneous solutions.

Theoretically, measuring the experience process by the chest shape of N negative complaints can produce at least 3^N groups of solutions with conservative estimation. If the calculation of the first and last measurement experience steps that are relatively less transformative are excluded, at least 3^{N-2} solutions can be obtained, including at least 2^{N-2} radical innovation ideas. Only a small number of nonone transformation effects can produce radical innovative ideas, such as (N1, C2, W3, C4, N5, W6, N7,

C8, N9, N10) = (due to growth) girls who feel uncomfortable (bra) (N1), it is difficult to confirm the breast shape change degree (C2), (but because of shyness, they hope) non-touch measurement (W3), (coupled with strong subjective experience of others (C4) in the measurement process), (to ensure scientificity) the measurement base point (more) should be based on (N5), the measurement technology (provided to you) should be systematic (W6), (and) the transformation mode error is small (N7), (perhaps because it is in the early stage of development, the breast) symmetry (temporarily) does not appear (C8), (but) the posture (whether) is abnormal (N9), data changes (lifetime of chest posture) can be accumulated (N10).

5. Innovation Characteristics Analysis

Based on the three elements of patent examination (novelty, progress and industrial utilization), this paper analyzes the main innovative characteristics of problems solved by self-thinking technology.

In novelty, the above demonstration operation cases propose that the proposed model is an innovative design model using Chinese logic to operate mathematical problem-solving strategies, adopting strategic thinking of problem-cooperation, using problems, transforming thinking framework, generating solutions beyond expectations, and systematically and automatically generating many solutions. Although there may be incremental solutions or virtual solutions with relatively low industrial value, or ideal solutions that may not be accessible by existing technologies, it completely points out all the solutions for development, and each solution specifically represents the connotation of user experience connected with the market, which is a specific practice of consumer-oriented design technology and method concept and a systematic creative project to provide a complete solution. The creative spectrum formed by all solutions can also be used as a “guide map for technological innovation and development” [30], as a thinking tool with aesthetic, engineering and business significance, academic research value, and industrial application potential.

For progress, the relative advantages of the proposed model can be clearly distinguished by comparison with relevant creative technology methods. For efficacy, the proposed model can explore issues such as experience innovation or emotional design difficult to be involved in TRIZ method. Although the brain concussion method often used in design thinking can diffuse thinking and produce a large number of creative ideas, it is easy to vary from person to person or encounter inspiration with the unstable quality of creative process and output [31]. Morphological analysis, called pattern matrix method, is a creative thinking technique systematically analyzes the elements of product form and structure, deconstructs the characteristics, and then recombines them [32]. It is similar to the proposed model in the process technology of “structure, deconstruction and reconstruction” and in the combination form of mass production creative ideas. However, the type analysis method mostly takes the spatial type and structural elements as the creative derivation framework through comparative analysis with competitive products or similar products. The significance in the creativity quantity production is much greater than or higher than the improvement in the creativity quality. The creative content is mostly incremental rather than radical innovation, and it does not involve the strategic thinking of cooperation with problems and the cognitive feeling and experience connotation of product service system.

Compared with another Mandala Chart, winning by quantity, it takes a group of participants to fill up the complete four rounds with a total of 585 ($=8^5$, $n=0\sim3$) to produce 4680 ($=8^6$, $n=1\sim4$) creative components to explore the way to solve the problem [33]. Creative components only produce the constituent components of the idea, not enough to become an idea with conceptual components. Compared with the creative concept productivity of the proposed model above, the negative complaint program composed of eight experience contents only needs one or a few people to operate, which can easily produce the number

of 6561 ($=3^8$) concepts in a short time, beyond the sum of the four rounds of datura thinking. Moreover, each concept has its own logical order, representing a relatively complete measurement experience content and converting the customer measurement experience expectation value, with the concept content statement of “quality, quantity.” According to current literature analysis, the creative capacity of the proposed model is comparable to that of any existing creative thinking technology or design method using manpower, except that information technology can surpass in quantity in certain fields through artificial intelligence and big data algorithms. However, the proposal of this model provides a new technical framework and theoretical basis for digital creative computing or the so-called robot creative ability.

In terms of practicability, the thinking technique of letting problems solved by self can be applied to life or industry, and the innovative ideas produced by it have the possibility of being put into practice. The industrial significance of developing new products or service systems is nothing more than production, attack, defense, and cooperation. Production refers to the creation of intellectual property and subsequent industrial application. Attack and defense can be divided into two aspects to capture new market opportunities or greater market share, and prevent competitors from entering or following to protect their own niche. The basis of cooperation is that the resources of both parties (or multiple parties) need to complement each other, and intellectual property is the core technical resources. The proposed model can make specific contributions to the above three aspects.

The thinking technique of letting problems solved by self can produce huge “solutions” under the condition of saving the most manpower, which is far more than the number of “solution” that can be produced by simply relying on team manpower to carry out brainstorming or other creative technologies. As far as the degree of creativity is concerned, “conception” is only a preliminary “solution.” Because of the large number of solutions, it is necessary to use an efficient solution quality evaluation and screening mechanism, conducive to point out solutions with value or potential. In terms of attack, defense, and cooperation, the quality of solutions produced is both progressive and radical. Each solution pays attention to the customer experience process or innovative service process, takes the guiding significance of operation and consumer demand into account, and is systematically scattered on the innovation concept space, regarded as a “technological innovation development guide,” so as to master competitors, partners, and strategic layout as a reference for the study and judgment of attack, defense, and cooperation. For business strategy, we can examine all ideal solutions; difficult to realize by our own resources, protect, and utilize patent potential; generate intellectual property rights and turn them into technical commodities or asset leverage for cooperation; authorize others to implement or set up patent mines to become offensive and defensive weapons; or an incentive to attract the alliance of partners.

6. Conclusion

Based on the structure of thinking dilemma composition, this study develops three types of nine strategic approaches, producing solutions, points out the innovative thinking of problems solved by self, summarizing eight operational essentials from the strategic thinking of solving mathematical problems, and putting forward thinking technologies that can break through the thinking framework.

Problems solved by self is an innovative thinking technology using word logic to operate mathematical strategies. The problem-solving framework from the existing problem materials is inferred, replace numbers with words, and use rational logical thinking to guide the development of perceptual concepts, and systematically and automatically generate many solutions. Each solution concept has its logical order, representing a relatively complete set of user experience content, and has both qualitative and quantitative concept statements.

Through the application of demonstration cases and comparative analysis with the effectiveness of relevant creative technology methods, the feasibility, novelty, progress, and practicability of the proposed model are verified to help model users think outside the existing framework, expand their thinking space, create “unknown needs” of consumer users, and make design as “a purposeful creative behavior,” with more stability and predictability, which are the important basis of science. The proposed thinking technology and problem-solving mode takes the thinking mode of natural science and social science into account and takes the essence of innovation (seeking innovation and change) and human nature standard (perceptual rationality) as the development characteristics, so as to help to shape the systematic view and discipline paradigm of design as a science (design science).

Since the content and quality of the solution of the output will be greatly affected by the language tools of the mode operation, it focuses on Chinese language logic and context as the development and test vehicle currently. In order to expand the effectiveness and international influence of the proposed mode, the research focus in the next stage will be on the research and development of English language logic and context as the operation tools to compare the characteristics of Chinese and English tools and the main differences between them in process and output efficiency. In addition, the utility comparison of different attribute cases and the quantitative analysis involving weight calculation and complex screening mechanism will be studied in future.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Discrete Dynamic Modeling Analysis Based on English Learning Motivation

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With the popularization of the Internet, various online learning platforms have developed rapidly, providing users with abundant learning resources, and realizing personalized resource recommendation has become the development trend of online learning platforms. In this paper, a personalized learning recommendation model based on improved collaborative filtering is proposed. Firstly, a multilayer interest model of learners is established to accurately describe learners' interest in knowledge topics, courses, and knowledge areas; then, in view of the sparse scoring matrix and cold-start problems of traditional collaborative filtering recommendation algorithms, an improved collaborative filtering-based personality is proposed. The personalized learning recommendation model is used to improve the similarity calculation of users by introducing user initialization tags and solve the cold-start problem of new users. Finally, the effectiveness of the algorithm is proved by experimental comparison, and the improved algorithm improves the recommendation effect of personalized learning.

1. Introduction

In recent years, consumers' interest in mass-produced undifferentiated commodities has gradually decreased, and they have pursued personalized and customized products that can reflect their own interests and preferences. However, full customization will consume a lot of time, manpower, material resources, etc., and the cost is high [1–4]. How to effectively solve the contradiction between the high cost of complete customization and the pursuit of personalized and differentiated products by consumers has become a difficult problem for many companies, especially manufacturing companies [5, 6]. In this context, mass customization emerges as the times require [7]. The basic idea of mass customization is to better meet the needs of consumers by providing users with ever-increasing product categories and personalized products, and to meet their personalized characteristics, while retaining the efficiency and cost of the original mass production [8–11]. Whether in business or academia, the research on mass customization is increasing, but most of them focus on the definition, characteristics, customization mode, acquisition of customer

needs, supply chain management, and marketing of mass customization. How to help users quickly and efficiently find their own product solutions from massive data. There are not many research studies on recommendation algorithms. At present, people have entered the era of big data. One of the important features of the era of big data is the huge amount of data, and information overload has become an objective phenomenon that has to be faced. For customers who want to customize products to meet their own interests and preferences and face for a large amount of product configuration information, how to quickly form one's own personalized customization plan has become a top priority, and the emergence of the recommendation system has effectively solved this problem [12–14].

With the continuous increase of online education applications, online education platforms have become an important platform and space for multiple learners to jointly create, share, and acquire knowledge. There are many different learners involved in an online education platform, each with different interests and hobbies, and it is dynamic. In order to label and manage learners' interests, online education platforms usually provide learners with a way to

customize their interests by labeling topics. However, it is difficult for learners to describe their interests in detail, and the interest labels are not necessarily updated with the change of interests. In addition, there are many learners who do not actively mark their interests. Therefore, how to automatically discover the learning interests of learners in an open learning environment is a problem worthy of research.

The user-based collaborative filtering algorithm is user-centric, which is more suitable for the field of personalized learning recommendation [15, 16]. In the face of massive learning resources, how to implement personalized resource recommendation according to users' learning interests, habits, and abilities is the development trend of online learning platforms. Personalized recommendation is widely used in the field of e-commerce, and scholars at home and abroad have carried out relevant researches on the recommendation of personalized online learning resources [17]. Chen Jiemin summarized the current personalized recommendation algorithms for learning resources and concluded that there are mainly content-based filtering, association-rule-based, collaborative filtering, and hybrid-based models. Liang Tingting established a learning resource filtering model through content vector space filtering; multidimensional correlation analysis is carried out on learners, resources, situations, etc., to achieve personality matching between resources and learners; Shen Miao designs a collaborative filtering algorithm based on student attribute classification to realize the intelligence and personality of the student course selection system [18]. Resource recommendation: Lei W first obtains association rules through data mining to establish preference matrix and then mixes it with collaborative filtering algorithm for personalized recommendation [19].

In this paper, a personalized learning recommendation model based on collaborative filtering algorithm is proposed. Through knowledge modeling of learning users and learning resources, collaborative filtering algorithm is used to introduce users' learning behavior logs [20–23]. Sharing, collection, browsing, downloading: Potential features such as educational background and interests can alleviate the user's cold-start problem. The improved collaborative filtering algorithm can achieve more accurate personalized network learning resource recommendation and effectively alleviate the data sparseness and cold-start problems existing in traditional recommendation technology [24, 25].

2. Multidimensional Learner Model Construction

The learner is the main body of online learning and has static and dynamic personalized characteristics. The learner model is used to describe the characteristics of the learner. The construction of this model is the core of improving the recommendation performance of online learning resources, optimizing the recommendation accuracy, and realizing personalized recommendation. When constructing a learner model, the first choice is to determine the individual characteristics of the learner. Based on the CELTS-11 learner information model specification, this paper divides the

learner characteristics into static characteristics and dynamic characteristics under the guidance of learning style theory and educational goal classification theory. There are two parts, in which the static features include the learner's basic information, learning style, and static interest preferences, and the dynamic features include cognitive level and dynamic interest preferences. Static features are the initial features of learners, which cannot change with the deepening of learning during the entire learning process and cannot represent the degree of individualized features of learners, but as basic features can solve the cold-start problem of initial users in the recommendation process. Dynamic features refer to the gradual emergence of some implicit features of learners with the occurrence of learning behavior, such as learning cognitive status and learning evaluation of certain resources, which will change over time. Therefore, dynamic features are to build a learner model. The static and dynamic data of learners are collected through the acquisition layer, and the information is classified in the data layer. The data analysis layer will further data mine the classified information, which is the learning style, cognitive level, and static and dynamic of the presentation layer. Interest preference features provide a data basis. The learner model building process is shown in Figure 1.

2.1. Data Collection. The learner's initial static data and dynamic behavior data are the data basis for constructing the learner model. The basic information, learning style, static interests and preferences, and other characteristic information of the learner model can be obtained through the questionnaires and scales filled in by the learners during registration and obtain the learner's cognitive level and dynamic interest preference characteristics. The acquisition and collection of basic data are realized through the data collection layer, which lays the foundation for the next step of classification, analysis, mining, and feature representation.

2.2. Feature Representations for Learning Styles. The concept of learning style was first proposed by Salem in 1954. It is a concept that reflects the needs of learners' physical and psychological needs. The study of learning style provides a basis for the individual requirements of the learner model. Based on the Felder–Silverman-style model and using the Solomon Learning Style Questionnaire (ILSQ) as a means, the learners' learning style is quantified from four dimensions of perception, input, processing, and understanding. Each learner has to fill in the learning style questionnaire, send the obtained ILSQ scale results to the data layer and analysis layer, and construct learning style features in the presentation layer.

The specific process of learning style feature quantization is as follows:

- (1) The learning style quantization result is represented in the form of a quadruple $\langle L_i, V_i \rangle$ ($i = \{1, 2, 3, 4\}$), L_i represents the four dimensions of ILSQ, and V_i

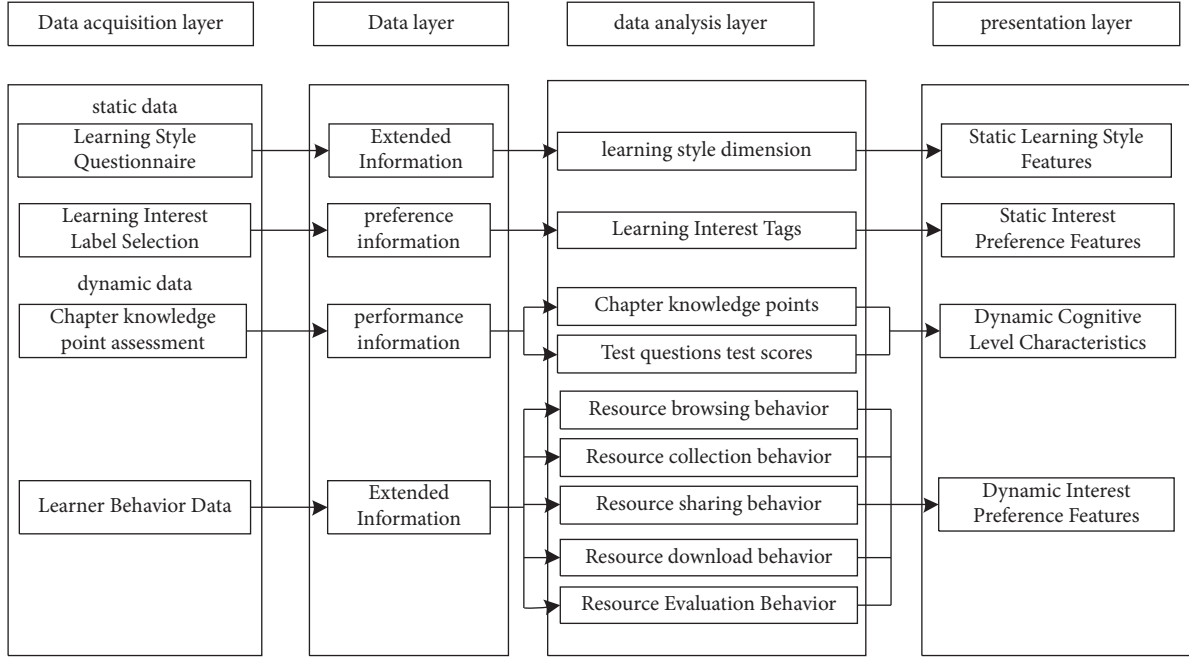


FIGURE 1: The process of building the learner model.

represents the learning style in the L_i dimension A quantified value of propensity.

- (2) When the learner fills in the ILSQ scale, there are 44 questions in total, each question contains two options A and B, and the value of the answer result is defined as P_j , where j represents the question number.
- (3) Screening and processing according to the results of P_j , classification, and accumulation, and the final accumulation results are represented by a and b .
- (4) Judging the size of a and b values, if $a > b$, then $V_i = (a - b)a$; if $a < b$, then $V_i = (b - a)a$.
- (5) The test result of the learning style feature quadruple L_S is the quantification result of the learner's learning style feature.

2.3. Feature Representation of Interest Preference. The learner's interest preference features are divided into static interest preference features and dynamic interest preference features. Part of the learning resources in the dataset is manually marked, and the remaining resources are automatically marked by similarity calculation, nearest neighbor sorting, etc., and finally checked through the manual query-related feedback mechanism to ensure the accuracy of the feature representation of learning resources. Using the normalized label set composed of learning resource features as an option, construct a static interest and preference questionnaire. In the data collection layer, each learner must fill in the static interest and preference questionnaire, and the obtained results are

sent to the data layer and the analysis layer, and are constructed in the presentation layer. Static interest preference features.

The learning process of a learner is a dynamic changing process. Various operations in the learning process will generate corresponding behavior information, which reflects the current learner's interest preference. In this paper, the interest preference generated over time is called dynamic interest. Preference, the specific quantification process is as follows.

2.3.1. Learner Behavior Classification and Weight Calculation. Learner behaviors are mainly divided into five categories, namely, browsing behavior, collection behavior, sharing behavior, downloading behavior, and evaluation behavior. Different behaviors represent different implicit preferences of learners. Here, weights are introduced to represent different learning behaviors. There are many ways to determine weights. Expert evaluation or empirical weights are subject to a certain degree of subjectivity. In this paper, the entropy weight method is used to determine the weight learner's behavior classification, weight distribution, and the final weight value used in this paper, as shown in Table 1, where w_i indicates the weight distribution occupied by the i th behavior.

2.3.2. Learner-Learning Resource Scoring Matrix Construction. According to the learning behavior and its weight distribution, the learner-learning resource scoring matrix $P_{m \times n}$ is constructed. This matrix can be used as the basis for learners' evaluation of learning resources. $P_{m \times n}$ is

TABLE 1: Learner behavior classification and weight distribution.

Behavior classification	Weight distribution	Numerical value
Browsing behavior	w_i	0.176
Collection behavior	w_i	0.193
Sharing behavior	w_i	0.195
Download behavior	w_i	0.212
Evaluate behavior	w_i	0.224

$$P_{m \times n} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ S_{m1} & S_{m2} & \cdots & S_{mn} \end{bmatrix}. \quad (1)$$

Each value in the $P_{m \times n}$ matrix represents the behavioral weight of the learner u_m to the resource i_n . If $s_{ui} = 0$, it means that the learner u_j does not have any action on i_k . If the matrix elements are all 0, it means that the learner u_j did not start learning.

2.3.3. Learning Resources-Learning Label Matrix Construction. In order to establish a direct relationship between learners and learning resource labels, we first construct a learning resource label matrix to represent the characteristics of learning resources:

$$Q_{n \times l} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1l} \\ r_{21} & r_{22} & \cdots & r_{2l} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{nl} \end{bmatrix}. \quad (2)$$

The element r_{jk} in the $Q_{n \times l}$ matrix indicates whether the resource i_j has the label t_k , $r_{jk} = 1$ indicates that the label t_k labels the resource ij , and $r_{jk} = 0$ indicates that it is not labeled, so the matrix $Q_{n \times l}$ is a matrix composed of 0 and 1.

The learner-label matrix $T_{m \times l}$ is constructed according to the learner-learning resource scoring matrix $P_{m \times n}$ and the learner-learning resource label matrix $Q_{n \times l}$:

$$T_{m \times l} = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1l} \\ g_{21} & g_{22} & \cdots & g_{2l} \\ \cdots & \cdots & \cdots & \cdots \\ g_{m1} & g_{m2} & \cdots & g_{ml} \end{bmatrix}. \quad (3)$$

In the formula, $g_{jk} = \sum_{c=1}^n s_{jc} r_{ck}$, $T_{m \times l}$, the element g_{uk} in the $T_{m \times l}$ matrix represents the behavioral weight of the learner u_j accumulated on the learning resource label t_k , and $T_{m \times l}$ is used to represent the dynamic interest preference matrix after the learner produces behavior.

2.3.4. Representation of Learner's Dynamic Interest Preference Behavior Feature. The accumulation of different behaviors of learners on learning resources can be represented by the dynamic interest preference matrix $T_{m \times l}$. The degree of preference of learners to resources reflects the difference

between learners, which is the characteristic attribute of learner's behavior that is an increasing function, and its calculation formula is

$$F_{ut_k}^{op} = \exp\left(\frac{g_{uk}}{v_{ut_k}} - \lambda\right), 1 \leq k \leq l. \quad (4)$$

In the formula, g_{uk} ($1 \leq k \leq l$) is the cumulative value of the learner's interest preference on the learning resource and is the sum of the continuous accumulation of the learner u 's behavior on the tag t_k of the associated resource; v is the learner's average interest preference value; λ is the minimum value of the cumulative sum of learner behavior, which is used to eliminate the bias of interest and preference among different learners.

2.3.5. Time Factor Adjusts the Offset of Dynamic Interest Preference Features. The learner's interest and preference characteristics will shift with the deepening of learning. The adjustment of dynamic interest and preference characteristics includes the characteristic representation of various behaviors and time factors. The characteristics of the time parameter are calculated using the time decay function. The calculation formula of the learner's dynamic interest preference characteristic time factor is as follows:

$$F_{ut_k}^{\text{time}} = \theta + (1 - \theta)\exp[-(t_{\text{now}} - t_{ut_k})]. \quad (5)$$

In the formula, $1 \leq k \leq l$, t_{now} is the current time; t_{utk} represents the learner, u is labeled, and the latest value in the time set is marked by t_k ; the hyperparameter $\theta \in [0, 1]$ can affect the time factor to dynamic interest features, and the two show a negative correlation.

The behavioral feature and time weight feature are integrated to obtain the learner's dynamic interest preference feature, that is,

$$F_{ut_k} = F_{ut_k}^{op} F_{ut_k}^{\text{time}}, 1 \leq k \leq l. \quad (6)$$

2.4. Feature Representation of Cognitive Level. The characteristics of the learner's cognitive level describe the results of the test after the learner has learned a certain knowledge point.

Based on "Bloom's Educational Objective Classification Theory," the learning objectives of the learning resources corresponding to knowledge points are divided into 6 levels, as shown in Figure 2, these 6 levels represent the mastery of different learners' core knowledge points, the cognitive level. The chapter knowledge test data of the collection layer represent performance information. By analyzing the chapter knowledge points and test questions, the characteristics of the knowledge level can be obtained. Since this indicator is divided into 6 levels, different learners will have different overall cognitive levels, and the same learner will have different level statuses for different knowledge points in different periods, so the cognitive level reflects the individual characteristics of the learner. The characteristics of learners' cognitive level are expressed as follows:

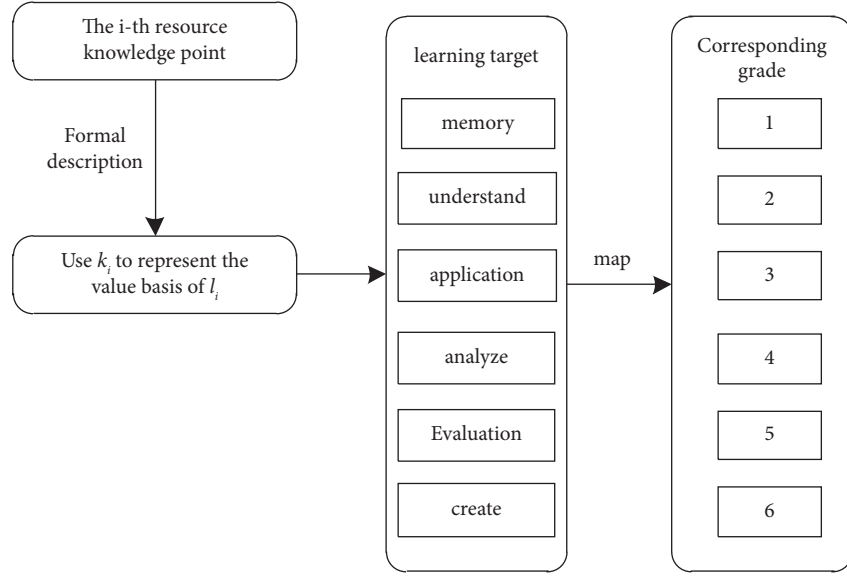


FIGURE 2: The representation method of the mastery degree of learning resource knowledge points.

$$K_L = \{(k_1, l_1), (k_2, l_2), \dots, (k_i, l_i), \dots, (k_n, l_n)\}. \quad (7)$$

In the formula, k_i represents the i th knowledge point; l_i represents the mastery of the i th knowledge point, that is, the cognitive level; and n is the number of knowledge points that have been learned.

3. Improved User Collaborative Filtering Recommendation Algorithm

The user-based collaborative filtering algorithm establishes a user similarity model according to the user's historical interest in resources and recommends resources with high predicted scores to users through the predicted scores of users with similar interests; item-based CF establishes resources based on users' historical evaluation of resources. The similarity model calculates the similarity between resources and then recommends resources similar to the user's historical preference to the user. In this paper, aiming at the matrix sparsity and cold-start problems of collaborative filtering recommendation algorithm, the learning behavior log and user initialization label are introduced to improve the algorithm. According to the user's ability, major, interest, and education tags, the user initialization tag is generated; the user similarity is calculated according to the user resource matrix and the user initialization tag; finally, the recommendation result is generated.

The specific algorithm model architecture is shown in Figure 3.

3.1. User Resource Evaluation Matrix. The user's historical evaluation of resources is converted into a component value matrix to form an $M \times N$ matrix, as shown in Figure 4.

U_k is the k th user, i_j is the j th resource, and r_{kj} is the rating of resource j by user k . The value ranges from 0 to 10. The default value for resources that have not been evaluated

is 0. There may be only a small part of the resource, so most of the values in the entire matrix are 0, causing the entire matrix to be sparse.

3.2. User Resource Behavior Matrix. The user's operation of network resources is not only the direct acquisition and evaluation, but also learning behaviors such as sharing, collection, browsing, and downloading in the middle. Therefore, by collecting users' learning behavior logs, analyzing their learning behavior trajectories, and establishing the relationship between behavior trajectories and resource evaluations, mining the similarity of users can improve collaboration to a certain extent. Convert the user's relevant learning behavior to the resource into the corresponding interest score. The score is obtained through the questionnaire. The questionnaire gives 15 learning behaviors. The resource is just clicked and browsed, indicating that the user may not have a high evaluation of the resource, but the user has browsed + saved + downloaded + shared the resource, indicating that the user should have a high evaluation of the resource. A total of 500 questionnaires were distributed to students in school, and 421 copies were effectively recovered. The average score of each behavior was counted and then reduced to a multiple of 0.5. The final score is shown in Table 2.

The user resource behavior matrix is shown in Figure 5.

U_k is the k th user, i_j is the j th resource, and s_{kj} is the learning behavior of user k on resource j . The value range is shown in Table 2.

3.3. User Resource Matrix. If the user has not evaluated a certain resource, analyze whether the resource has performed relevant learning behavior operations, and calculate the corresponding score according to Table 2. After this process, a user resource matrix is obtained, the density of which is significantly higher than that of the user resource evaluation matrix.

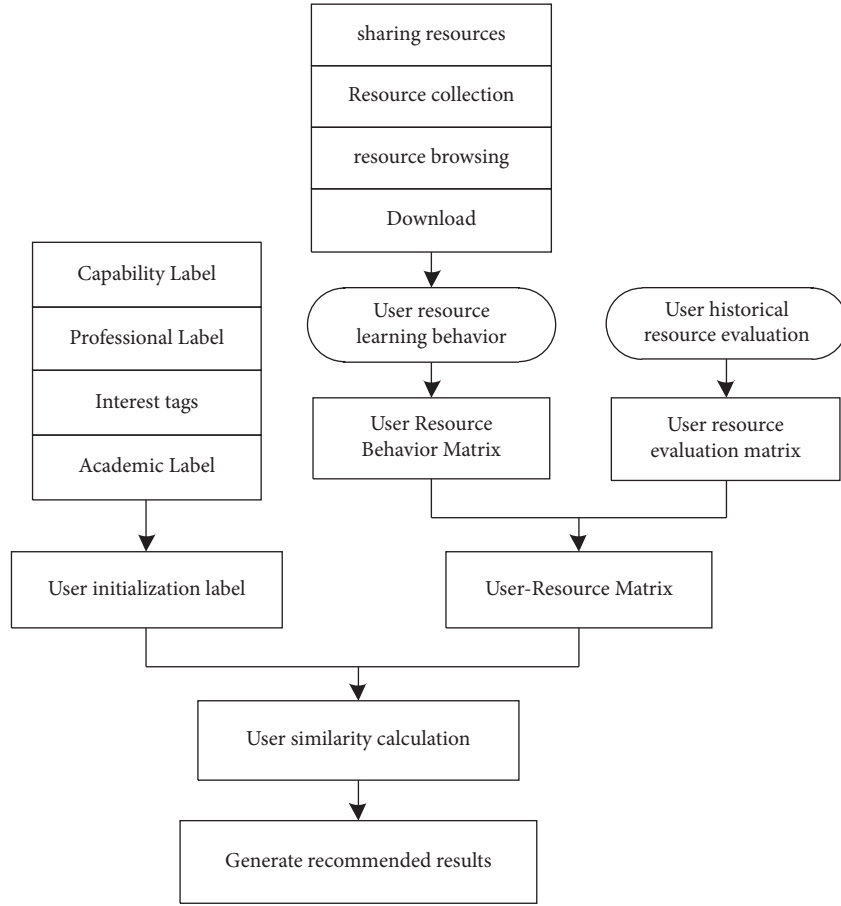


FIGURE 3: Model architecture of the improved user collaborative filtering recommendation algorithm.

user \ resource					
	i_1	i_2	...	i_{n-1}	i_n
u_1	r_{11}	r_{12}	...	r_{1n-1}	r_{1n}
u_2	r_{21}	r_{22}	...	r_{2n-1}	r_{2n}
...
u_{m-1}	r_{m-11}	r_{m-12}		r_{m-1n-1}	r_{m-1n}
u_m	r_{m1}	r_{m2}		r_{mn-1}	r_{mn}

FIGURE 4: User resource evaluation matrix.

3.4. User Initialization Label. The characteristics of the user's learning ability, study major, education background, and interests are the direct description of the user. When a new user joins the system, the user's initial label is used to calculate the similarity of the user. The label representation of the user is shown in

$$T_u = [t_{ua}, t_{um}, t_{ur}, t_{ui}]. \quad (8)$$

t_{ua} , t_{um} , t_{ur} , and t_{ui} represent the learning ability, major, education, and interest of user u , respectively.

TABLE 2: Learning behavior resource ratings.

Type	Learning behavior				Behavior score
	Browse	Collect	Download	Share	
An act	✓				1
		✓			2
			✓		3
				✓	4
Two acts	✓	✓			2.5
	✓		✓		3.5
	✓			✓	4.5
		✓	✓		4
		✓		✓	5
Three acts			✓	✓	5.5
	✓	✓	✓		5
	✓	✓		✓	6
		✓	✓	✓	7
Four acts	✓	✓	✓	✓	8

- (1) Learning ability: It is divided into 4 levels, namely, poor, medium, good, and excellent, represented by 1–4. The similarity calculation of the learning ability of users u and v is shown in

$$\text{sim}(t_{ua}, t_{va}) = 1 - \frac{|t_{ua} - t_{va}|}{3}. \quad (9)$$

user \ resource					
	i_1	i_2	...	i_{n-1}	i_n
u_1	s_{11}	s_{12}	...	s_{1n-1}	s_{1n}
u_2	s_{21}	s_{22}	...	s_{2n-1}	s_{2n}
...
u_{m-1}	s_{m-11}	s_{m-12}	...	s_{m-1n-1}	s_{m-1n}
u_m	s_{m1}	s_{m2}	...	s_{mn-1}	s_{mn}

FIGURE 5: User resource behavior matrix.

- (2) Study majors: According to the professional classification of the Ministry of Education, there are 13 disciplines, 92 professional categories, and 630 majors.

$$\text{sim}(t_{um}, t_{vm}) = \begin{cases} 0, & \text{if different subjects,} \\ 0.5, & \text{if same subject,} \\ 1, & \text{if same major.} \end{cases} \quad (10)$$

- (3) Education: It is divided into secondary and higher education. Secondary education is divided into general technical secondary school and high school, which are, respectively, represented by 1 and 2; the similarity calculation of the educational degrees of users u and v is shown in

$$\text{sim}(t_{ur}, t_{vr}) = 1 - \frac{|t_{ur} - t_{vr}|}{5}. \quad (11)$$

- (4) Interests: Mainly interested in those majors, you can choose more than one, but the limit is no more than 5. The similarity calculation of user interests is shown in

$$\text{sim}(t_{ui}, t_{vi}) = \frac{1}{m * n} \sum_{a \in I_u} \sum_{b \in I_v} \text{sim}(t_{ua}, t_{vb}). \quad (12)$$

where I_u and I_v represent the specialized sets that users u and v are interested in, respectively, and m and n represent the sizes of the two sets, I_u and I_v , respectively. The calculation of $\text{sim}(t_{ua}, t_{vb})$ is shown in formula (11).

The similarity of these four is fused, as shown below.

$$\begin{aligned} \text{sim}_{t(u,v)} = & \alpha \text{sim}(t_{ua}, t_{va}) + \beta \text{sim}(t_{um}, t_{vm}) \\ & + \gamma \text{sim}(t_{ur}, t_{vr}) + \delta \text{sim}(t_{ui}, t_{vi}). \end{aligned} \quad (13)$$

In formula (13), $\alpha + \beta + \gamma + \delta = 1$, respectively, representing the weight of the corresponding similarity.

3.5. User Similarity Calculation. The user similarity uses a linear weighting method to fuse the user resource score similarity and the user initialization label similarity, and its calculation is shown in

$$\text{sim}(u, v) = \varphi \text{sim}_{i(u,v)} + (1 - \varphi) \text{sim}_t(u, v). \quad (14)$$

$\text{sim}_{i(u,v)}$ is the similarity of user resource scores, and its user evaluation data come from user resource matrix; $\text{sim}_t(u, v)$ initializes the label similarity for the user, and the calculation is shown in formula (13).

3.6. Output Recommendation Results. After the similarity of users is obtained, they are sorted by size, and the first k neighboring users are selected as the similar user set $S_u = \{s_{u1}, s_{u2}, s_{u3}, \dots, s_{uk}\}$ of the target user u . Find all the resources that the target user u has not evaluated in the similar user set S_u , and predict the target user u 's score for the resource. The specific calculation formula is as follows:

$$\hat{r}_{ui} = \bar{r}_u + \frac{\sum_{v \in S_u} \text{sim}(u, v) (r_{vi} - \bar{r}_v)}{\sum_{v \in S_u} \text{sim}(u, v)}. \quad (15)$$

4. Experiment Analysis

4.1. Experimental Data. The experimental data come from the school's high-quality resource online course learning platform. The platform includes 1,015 courses and 38,578 student users. 2,000 users and 400 courses are randomly selected as experimental data. The experimental data include the students' scores on the course and the behavior records of browsing, collection, download, sharing, etc., as well as the comments and forwarding records between students. 200 user data are extracted from the system for experimental testing.

4.2. Evaluation Indicators. The evaluation standard adopts the MAE evaluation index of the recommendation algorithm, and the average absolute error of the MAE is used to accurately predict the score of the learning user to evaluate the effectiveness of the algorithm. The calculation formula is

$$\text{MAE} = \frac{1}{n} \sum_{i=1}^n |y_i - x_i|. \quad (16)$$

Among them, MAE is the mean absolute error, y_i is the predicted rating of the learning resource by the learning user, x_i is the actual rating of the learning resource by the learning user, and n is the number of predicted ratings.

4.3. Experimental Results and Analysis. Set the fusion weight factor φ to 0.7. The value range of the number of adjacent users k is [10, 50], and the experimental results are shown in Figure 6.

As can be seen from the above figure, the RMSE value is the smallest when k is 30.

In order to verify the mitigation effect of the improved algorithm on the user's cold-start problem, a verification experiment of the recommendation effect of new users was carried out, and 200 users were randomly selected as the test data. In order to imitate new users, when finding similar users, the similarity of their resource scores is removed, only

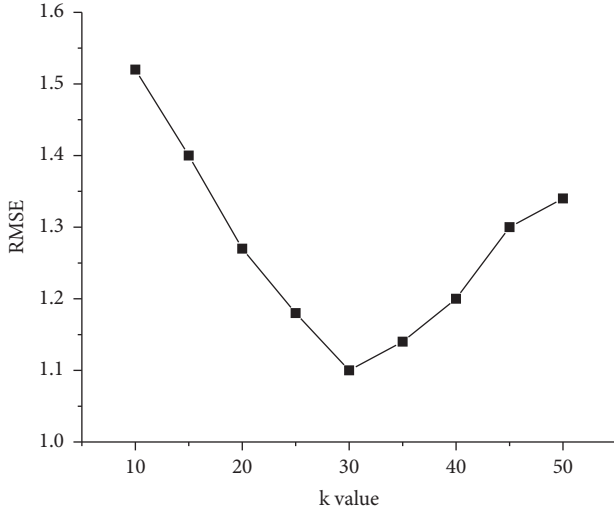


FIGURE 6: RMSE for different k values.

the similarity of user initialization labels is retained, and the experimental parameter φ is taken as 0.7. The recommendation effect is measured using the average precision and recall, which are calculated as shown in

$$\text{precision} = \frac{1}{|T|} \sum_{u \in T} \frac{|P_u \cap R_u|}{|P_u|}, \quad (17)$$

$$\text{recall} = \frac{1}{|T|} \sum_{u \in T} \frac{|P_u \cap R_u|}{|R_u|} \hat{r}_u. \quad (18)$$

In formulae (17) and (18), T denotes the test data, $|T|$ denotes the size of the test dataset, P_u denotes the resource set prerecommended to the user with a predicted score $\hat{r}_u \geq 8$, and R_u denotes the actual user score $r_u \geq 8$ users really like the resource set (in this experiment, the user score ≥ 8 is set as the user's favorite resource). In the case of taking different numbers of adjacent users, the results of the average precision rate and average recall rate are shown in Table 3.

It can be seen from the experiments that the algorithm in this paper also has a good effect on the recommendation of new users, avoiding the problem that the collaborative filtering algorithm cannot be recommended due to the cold start of new users.

In order to verify the performance of the improved algorithm in this paper, the algorithm proposed in this paper is compared with four other types of algorithms. The algorithm proposed in this paper is referred to as IT_UCF, and the collaborative filtering algorithm that only introduces user learning behavior logs is referred to as I_UCF. The filtering algorithm is abbreviated as T_UCF, the traditional user-based collaborative filtering recommendation algorithm is abbreviated as UCF, and the traditional item-based collaborative filtering recommendation algorithm is abbreviated as ICF. Measured using RMSE, the results are shown in Figure 7.

Through comparative experiments, it is found that the RMSE values of I_UCF and T_UCF are small, indicating that the introduction of user learning behavior logs or user initialization label similarity can indeed improve the

TABLE 3: Experimental results of new user recommendation.

Neighboring user k	Precision (%)	Recall (%)
10	22.8	17.9
20	26.5	21.1
30	33.1	23.7
40	34.3	22.5
50	30.9	20.6

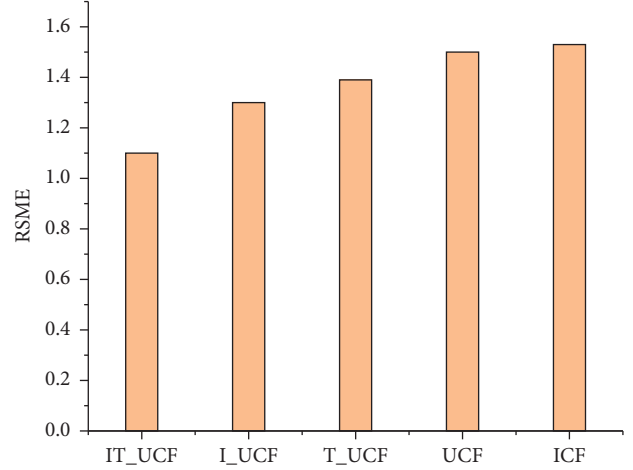


FIGURE 7: Comparison of experimental results with traditional collaborative filtering algorithms.

algorithm; the RMSE value of the IT_UCF algorithm is smaller than that of the I_UCF and T_UCF algorithms, indicating that user learning is introduced at the same time. Behavior logging and user initialization tags are better than introducing just one or the other.

5. Conclusion

With the popularization of the Internet, various online learning platforms have developed rapidly, providing users with rich learning resources, and realizing personalized resource recommendation is the development trend of online learning platforms. Aiming at the typical problems of traditional collaborative filtering-based recommendation algorithms—cold start and matrix sparseness, this paper proposes a personalized learning recommendation model based on improved collaborative filtering. By introducing user initialization tags, the similarity calculation of users is improved, and the cold-start problem of new users is solved. And the effectiveness of the algorithm is proved by experimental comparison, which improves the recommendation effect of personalized learning. However, the algorithm in this paper also has certain shortcomings. On the one hand, the algorithm has certain limitations. In many other application fields, the user's operation log of the resource and the user's initial label are not easy to obtain; on the other hand, over time, the user's learning Interests, habits, and abilities may change, and historical data are time-sensitive. This phenomenon of user interest drift is not considered in the algorithm proposed in this paper. Further research is needed to address these issues.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Evaluation of Competitive Performance Ability of Basketball Players Based on Hybrid Model

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Competitive performance ability is the on-the-spot performance of basketball players' comprehensive use of technical and tactical, physical, and psychological abilities. Because basketball players' competitive performance includes many evaluation contents and influencing factors, it is difficult to comprehensively and objectively use a single qualitative analysis or quantitative statistics for evaluation and measurement. Based on the analytic hierarchy process (AHP) and intelligent fuzzy comprehensive evaluation, this research establishes a hybrid model, which is applied to evaluate the performance of basketball players. Based on the actual needs, this research uses the relevant theories in the discipline of sports training, with abundant empirical data materials, combined with the specific practice of basketball players' training and competition, starting from the concept of clear sports intelligence, to further determine the indicators of the basketball players' sports intelligence evaluation system and weights, construct a set of evaluation system about basketball players, and use this as a standard to evaluate and judge the current situation of basketball players' sports intelligence.

1. Introduction

The competitive ability and athletic level displayed by basketball players in the game are not only an important embodiment of the charm of basketball competition but also the basic guarantee for winning the game. From the analysis of system theory, basketball competition is a complex system with many influencing factors, in which the player's ability to play on the spot is an important part of the system. For athletes' performance in competition, qualitative methods are generally used to evaluate and judge, and the evaluation methods are relatively rough and subjective. At the end of the last century, the United States took the lead in using the technical statistics of athletes as the basis, combined with the actual situation of basketball games, and used a simple method of adding and subtracting weights to reflect the competition performance of athletes [1–3]. With the vigorous development of modern information technology, technical concepts such as big data and cloud computing are

widely used in the analysis of basketball players' technical statistics and behavioral efficiency, providing a feasible technical method for quantitative analysis of basketball players' competitive performance in competitions. The scientific nature of evaluation theories and methods is further strengthened.

Athletes with a high level of sports intelligence have a clear understanding and grasp of the technical characteristics, tactical characteristics, and supporting laws of special projects and have a deeper understanding of the methods and approaches of special training. It can be seen that in the process of training, athletes can accurately and effectively grasp the intention of the coach and can meet the relevant requirements of the coach through their own training or competition practices, which is an intuitive manifestation of good sports intelligence. Athletes achieve an ideal state of sports intelligence, which means that athletes have more ideal training and competition thinking, and the ability to understand techniques and tactics is stronger. Under the

influence of this kind of understanding and thinking ability, athletes will greatly shorten the time for mastering and quantity of techniques and tactics, and at the same time, the accuracy of mastery and understanding of techniques and tactics will also be greatly improved. Under the influence of higher sports intelligence, athletes can more efficiently implement corresponding technical and tactical arrangements in training and competition and can more effectively adjust their competition status, so as to ensure the full play of their high-level special competition ability [4–7].

Basketball is a physical confrontational sport in the form of a team, which requires relatively high technical ability, tactical ability, and thinking ability of athletes. These factors together constitute the special competitive ability of athletes and affect the performance of the game [8–11]. At the same time, basketball is a confrontational project on the same field. How can athletes exert their technical and tactical advantages at a high level under high-intensity confrontation conditions, and how can they ensure the team's competitive advantage through their own competitive ability? An important criterion for measuring the comprehensive ability of athletes is necessary. Therefore, the exercise of basketball players' sports intelligence can ensure the performance of the players' physical skills and tactical literacy, enhance the players' ability to understand game problems and solve game problems, and promote the players to more fully and accurately understand the coach's tactical intentions in the game, so as to effectively implement the game plan and win the game [12]. All in all, sports intelligence has become an important factor affecting the comprehensive competitive ability and competition ability of athletes, which needs to be paid attention to in daily training.

The evaluation of basketball players has become an important issue in the field of basketball training, but the evaluation index system needs to point to the basketball technical and tactical ability of the players, and some evaluation index systems also point to the evaluation of basketball players' special physical fitness. However, the evaluation of basketball players, especially basketball players' thinking ability, innovation ability, control ability, understanding ability, cognitive ability, and other fields of sports intelligence is extremely limited. Through the preliminary field investigation, it was learned that many basketball players did not understand the training tasks assigned by the coaches, and the use of relevant techniques and tactics was extremely rigid, lacking flexible combinations and innovative optimization of existing techniques and tactics. Although many athletes have certain advantages on the basis of physical fitness and techniques and tactics, they are extremely slow in understanding new knowledge and skills and innovating existing knowledge and skills, resulting in the inability to effectively exert their original advantages. According to the relevant theories of sports training, the lack of sports intelligence is an important reason for the above-mentioned bad phenomena in athletes. Based on this problem, this study starts from the perspective of sports intelligence in the field of sports training, trying to construct a basketball player's sports. The intelligent evaluation index

system can more accurately and objectively evaluate the sports intelligence of high-level basketball players in colleges and universities, find out the problems and deficiencies, and further propose targeted improvement and optimization strategies, so as to improve the overall competition of basketball players [13–17].

In evaluation research, both qualitative analysis and quantitative statistics have their own irreplaceable advantages and characteristics [18, 19]. Modern systems science believes that a comprehensive and effective evaluation method is to emphasize the combination of qualitative and quantitative, gather subjective experience and objective information, learn from each other, and promote each other. Finally, the comprehensive evaluation of the evaluation object is completed. The performance ability and level of basketball players are not only components of the open complex system of a basketball game but also a complex system with various levels, complex structure, and rich content. This paper follows the thought of systematic science, according to the working idea of the comprehensive integration method, and builds a hybrid model based on the analytic hierarchy process (AHP) and intelligent fuzzy comprehensive evaluation to comprehensively and objectively evaluate the performance of basketball players.

2. Background

2.1. Sports Intelligence of Basketball Players. To clarify the concept of sports intelligence of basketball players, we should first clarify the concept of sports intelligence. By combining and studying the relevant literature, it is found that domestic and foreign scholars have first conducted a certain degree of research on the concept of "intelligence." American psychologist Howard Gardner analyzed the concept of intelligence, and the research pointed out that intelligence is the ability of social individuals to solve their own problems and create some additional thinking or ideological products under a certain social background. Howard Gardner also regards sports intelligence as an essential part of human intelligence, and he believes that sports intelligence is the ability of human individuals to use body movements to achieve certain goals. Lingbo defined the concept of sports intelligence in combination with water polo and pointed out in his research that sports intelligence is the ability to ensure that level athletes have a correct understanding of level training and competition. The ability to use correct thinking and stable psychological emotions to control one's own physical movement is very important for the improvement of the special competition ability of horizontal events. The ability to process, recognize, and translate information into practical sports behaviors in various training competitions is important for basketball players.

Sports intelligence refers to the athlete's multidisciplinary theoretical knowledge of sports and the comprehensive ability to control the body to complete sports technical movements through thinking consciousness and participate in sports training and sports competitions. The sports intelligence of basketball players refers to the ability of

basketball players to control them to complete sports training and sports competition under specific conditions with the help of various subject knowledge, acceptance ability, ideological concepts, and thinking consciousness that they have mastered. However, it should be noted that there is a big gap between basketball players in terms of cultural literacy, competitive ability, and thinking consciousness as professional or professional athletes. It can be seen that there are obvious differences between the two in terms of special competitive ability, training background, competition environment, and personal characteristics. Sports intelligence is not simply sports intelligence. Intelligence is the ability to use the knowledge learned to recognize and solve problems. Intelligence not only includes intelligence but also manifests itself in the form of an ability. At the same time, there are differences between sports intelligence and sports awareness. In basketball, the choice of techniques and tactics by athletes reflects a kind of sports awareness. How athletes use techniques and tactics reflects their level of basketball awareness. And basketball sports intelligence is improved. The basis of basketball awareness is an expression level of sports intelligence.

Through the definition of the concept of sports intelligence and the identification of a series of related concepts, sports intelligence can be regarded as an organic combination of knowledge and ability. The concept of basketball player's kinesiology proposed in this study is analyzed by comprehensive literature data, and through consultation with many experts and scholars in related fields, the concept is defined as: or in the game, on the basis of combining their own characteristics, they can use their own special knowledge theory and special basketball skills and tactics, and in the combination of mind and body, effectively use their own mental cognitive ability to control the ontology to complete training and competition. The mental and cognitive ability of athletes can be reflected and exerted to the greatest extent in training and competition through the reasonable adjustment of basketball-specific cultural knowledge and skills. Therefore, the improvement of basketball players' special competitive ability largely depends on the mental and cognitive ability of the players. Sports intelligence is another important factor that determines the level of special competitive ability of basketball players in addition to the theory of physical fitness, special skills, tactics, and special knowledge.

2.2. Analytic Hierarchy Process. Analytic hierarchy process (AHP) is an index system construction method that has a wide range of applications in the field of social science research in recent years, especially in the comprehensive evaluation of a social phenomenon or behavior. The evaluation of the basketball player's sports intelligence in this study is to evaluate several goals and attributes contained in the basketball player's sports intelligence. Therefore, the analytic hierarchy process is more suitable for the purpose of this research from the method characteristics. This research uses the analytic hierarchy process to analyze the importance of each index between different levels in the basketball

player's sports intelligence evaluation system, forms a corresponding judgment matrix, and scientifically evaluates the weight of various indicators at all levels in the basketball player's sports intelligence index system. After considering the group characteristics of basketball players and the connotation of sports intelligence, a three-layer target structure model is established. The first layer is the target layer, which is the research goal that this research hopes to achieve basketball players' sports intelligence. The second layer is the criterion layer, which mainly decomposes the sports intelligence of basketball players. The high-level indicators can analyze different levels of sports intelligence and have a certain generality. The third layer is the program layer. The specific evaluation index obtained from the analysis is also an operational test and method for improving the sports intelligence of basketball players.

2.3. Fuzzy Comprehensive Evaluation Method. After using the AHP to construct the basketball player's sports intelligence evaluation index system, it needs to be further verified whether this index system is operable. Therefore, this study uses the fuzzy comprehensive evaluation method to verify the operability of the constructed index system. In the verification, this study selects the athletes of Shanxi University men's basketball team as the verification object of the sports intelligence evaluation index system and uses the fuzzy comprehensive evaluation method to scientifically and reasonably evaluate the sports intelligence of the selected athletes.

3. Competitive Performance Evaluation Index

3.1. Questionnaire Design. According to the needs of this research, on the basis of fully reviewing the relevant literature, combined with the suggestions of some experts and scholars, the first round of expert questionnaires for the primary indicators of basketball players' sports intelligence evaluation was formulated. Questionnaires are distributed to experts in basketball research direction and sports statistics research direction. The main purpose is to determine the relevant components of basketball players' sports intelligence evaluation indicators and the formulation of evaluation indicators.

This study mainly adopts the methods of expert questionnaire survey and interview to determine the indicators of the basketball player's sports intelligence evaluation index system. It is found in the expert's questionnaire that some ideal indicators can directly and clearly reflect the true nature of the evaluation object. However, some indicators are ambiguous and cannot clearly evaluate the evaluation object, so the evaluation effect is relatively limited. At the same time, through the questionnaire data, it is found that there are contradictory relationships, cross-relationships, causal relationships, and other adverse relationships that affect the evaluation effect among some indicators. Therefore, it is necessary to classify and integrate the preliminary proposed three-level indicators and conduct effective and reasonable screening at the same time, so as to achieve the

purpose of objective and accurate evaluation. More importantly, this screening procedure can ensure that we can effectively evaluate each indicator, combined with the purpose of this study and the principle of primary indicator screening, and on the basis of fully considering the role of different indicators and evaluation orientations, we can appropriately evaluate them. The indicators with unsatisfactory evaluation effects in the whole three-level indicators are eliminated, thereby reducing the corresponding workload.

In the first round of expert questionnaires, a total of 100 experts were distributed with questionnaires, 95 points were recovered, and all the recovered questionnaires were valid questionnaires, with an effective recovery rate of 95%. In the expert questionnaire, a total of one first-level indicator, 6 second-level indicators, and 49 third-level indicators were designed, and the total number of candidate indicators was 56. According to the basic principles of index selection and statistical analysis of expert questionnaire data, it was found that there were five tertiary indicators that did not meet the standards required by the study and were therefore eliminated. These five indicators were the level of flexibility, body shape, action stress response ability, ability to solve daily problems, mastery of fake movements, and ability to use them. Although the remaining 51 indicators meet the relevant evaluation requirements, there is also overlap in the meaning of different indicators, so the indicators with similar meanings are also eliminated, and 45 indicators are finally determined as the construction after integration.

3.2. Evaluation of Sports Intelligence Index System by AHP. After constructing the basketball player's sports intelligence index evaluation model, in order to further clarify the importance of different indicators in the evaluation process, it is necessary to compare the indicators at different levels in the model, so as to more clearly understand the role of each index in basketball players' sports. To express importance of intelligent evaluation, the scheme establish a comparison matrix of basketball players' sports intelligence evaluation index system.

$$R = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix}. \quad (1)$$

The element r_{ij} in the i -th row and the j -th column in the membership relationship matrix R represents the membership of the evaluation object from the fuzzy subset of the x_i level corresponding to the evaluation factor (indicator) a_i . The characteristics of an evaluation object or object in the i -th evaluation factor (indicator) a_i are expressed according to the membership relationship matrix R . In this step, this research establishes the expert evaluation questionnaire of the index weight coefficient and uses the calculation formula of the geometric mean to

calculate the importance scores of different indexes in the whole evaluation model, that is, the weight coefficient. The scores of experts are summed and normalized. In the normalization process, the numbers 1–9 and their reciprocals are used as scales, and 1–9 indicates that the importance of indicators is increasing; for example, the indicator basketball training years are 1 pair. The number of entries, that is, the importance level of entry level 2 is 4, it is marked as $A_{12} = 4$, and the reverse importance is $1/5$, that is, $A_{21} = 1/5$.

3.3. Calculating Weight Indicators. According to the criteria of the constructed judgment matrix indicators, the first-level indicators in the basketball player's sports intelligence index system, basketball players' sports intelligence and second-level indicators, basic competition ability, special technical and tactical ability, game confrontation ability, cognitive characteristics, on-the-spot reaction ability, and ability to solve attack and defense problems are compared, and the corresponding comparison matrix is established, as shown in Table 1.

The comparison data of the secondary indicators of basketball players shown in Table 1 are obtained by the method of obtaining the geometric mean and are calculated by the software of AHP.

As can be seen from the data shown in Table 2, for the basic competition ability, special technical and tactical ability, competition confrontation ability, cognitive characteristics, on-the-spot reaction ability, and ability to solve offensive and defensive problems, there are a total of 6 constructions. The weight coefficients corresponding to the six secondary indicators are 0.1314, 0.2053, 0.1531, 0.1715, 0.1825, and 0.1563, respectively.

4. Fuzzy Comprehensive Evaluation of Basketball Players' Sports Intelligence

For the same basketball player, the difference in the evaluation index system will also lead to different evaluation conclusions. Therefore, how can a scientific and reasonable evaluation system for sports accurately evaluate the athlete, so that the evaluation results conform to the actual situation of high-level basketball players in colleges and universities, and the question of who the evaluation subject has also restricted the construction. In the research, the main objects of investigation are the first-line coaches engaged in basketball training and the research experts and scholars in this field. After two expert questionnaires, the basketball player's sports intelligence was finally formed. Then, according to this evaluation index system, several groups of teammates, coaches, and team managers who have a close relationship with basketball players are investigated. These groups constitute the main body of evaluation of basketball players' sports intelligence. The first subject is teammates. From a professional point of view, the sports intelligence of basketball players is mainly reflected in the daily training and competition of the players. The basic performance of the players in training

TABLE 1: Comparison matrix table.

Name of scale	Basic competition ability	Special technical and tactical ability	Game confrontation ability	Cognitive characteristics	On-the-spot reaction ability	Ability to solve attack and defense problems
Basic competition ability	1	0.6875	0.7439	0.8657	1.2868	2.1523
Special technical and tactical ability	1.5268	1	0.9335	2.1526	0.8696	0.6524
Game confrontation ability	2.1525	1.2458	1	0.9563	1.5365	2.1745
Cognitive characteristics	0.8563	0.6854	1.5684	1	2.8554	2.1452
On-the-spot reaction ability	0.4152	0.3695	0.5695	0.5789	1	1.1223
Ability to solve attack and defense problems	0.3896	0.5684	0.5263	0.2574	1.2888	1

TABLE 2: Metric weights for sports intelligence.

Name of scale	Feature vector	Weights	Largest eigenvalue	CI value
Basic competition ability	0.504	0.1314	4.051	0.017
Special technical and tactical ability	1.445	0.2053		
Game confrontation ability	1.740	0.1531		
Cognitive characteristics	0.311	0.1715		
On-the-spot reaction ability	1.375	0.1824		
Ability to solve attack and defense problems	0.628	0.1563		

and the abilities and characteristics they have in the game are best known by the same ball. As far as the game is concerned, the basketball project requires five players to cooperate with each other, so most of the techniques and tactics of basketball players need to be completed through the cooperation of teammates. The second subject is the coach. Coaches are the coaches of basketball players' training and competition, and they are the most authoritative party to evaluate the training and competition level of players. With the continuous improvement of the current basketball players' comprehensive competitive ability and the improvement of the CUBA competition level, most teams have higher requirements for the employment of coaches. From this point of view, the current basketball team coaches are generally those who have many years of front-line training experience and good basketball knowledge and skills. Therefore, this group's evaluation of athletes' sports intelligence is not only objective but also scientific. The third subject is team managers. In each basketball team, its managers often have rich team management experience or sports training management experience. The managers are mainly responsible for various affairs except training, so they have more problems with the team or players. Moreover, as a manager, he is also the coordinator between coaches and athletes, so he has a deep understanding of the individual characteristics of each athlete, which creates ideal conditions for team managers to evaluate the sports intelligence of basketball players. Make a comprehensive evaluation on the evaluation of the three subsystems of teammates, coaches, and managers, and set the result set of the comprehensive evaluation as R total, which is composed of B_x , B_y , and B_z , namely,

TABLE 3: The weight relationship of the evaluation of the three types of evaluation subjects.

Evaluation subjects	Coach	Teammate	Manager
Weight	0.6	0.25	0.15

$$R_{\text{total}} = \begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix}, \quad (2)$$

$$= \begin{pmatrix} 0.573 & 0.564 & 0.311 & 0.084 \\ 0.585 & 0.574 & 0.324 & 0 \\ 0.537 & 0.523 & 0.384 & 0 \end{pmatrix}.$$

In the evaluation scale for basketball players' sports intelligence issued by experts, the statistical analysis shows that the weight relationship of the evaluation of the three types of evaluation subjects of coaches, managers, and teammates is shown in Table 3. It can be seen from the data in Table 3 that the weight relationship of the evaluation subsystem formed by the three types of evaluation subjects is $A = (0.6, 0.25, 0.15)$.

5. Conclusion

The training of basketball players' sports intelligence is a long-term and lasting process, and the basics of sports intelligence of different athletes are also quite different. Therefore, coaches should adopt the principle of step-by-step and individualized teaching in the training process. According to the age characteristics of different athletes,

educational background characteristics, personality characteristics, technical and tactical characteristics, the scheme carries out targeted training and improvement. In the training process, in addition to the indicators with relatively high weight values in the indicator system, coaches should also pay enough attention to indicators with low weight coefficients. These indicators often play a crucial role in the competition process. In a word, the training of basketball players' sports intelligence needs to be systematic, and on the basis of realizing the optimization of various indicators, the sports intelligence level of athletes should be maximized.

Data Availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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Research Article

Preparation of Ag@AgCl/GO Material with Efficient Visible-Light Photocatalytic Performance

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Ag@AgCl/GO was prepared by chemical coupling, in-situ deposition of supported AgCl, and photoreduction. The morphology, structure, and surface area of the prepared Ag@AgCl/GO were characterized by SEM, TEM, FT-IR, Raman spectra, and BET. The optical properties of the photocatalyst were analyzed by PL and UV-Vis DRS, respectively. The surface electrical properties and degradation stability were evaluated by zeta potential measurement and cyclic catalytic degradation experiments, and the photocatalytic mechanism was proposed in detail based on the ESR test and trapping experiment. The results showed that Ag@AgCl nanoparticles were spherical and cluster distributed on the folded structure of GO. The prepared Ag@AgCl/GO had good adsorption performance and photocatalytic degradation stability. The material showed good visible light catalytic performance; especially, the degradation rates of cationic dyes RhB and MB were significantly higher than those of anionic dyes MO and CR, and their degradation processes were in line with the quasi-first-order reaction kinetics. Holes (h^+) and superoxide radicals ($\cdot O_2^-$) were the main active species for the degradation of RhB.

1. Introduction

Wang et al. [1] first discovered the excellent visible light degradation performance of Ag@AgCl for methyl orange. In recent years, Ag@AgCl plasma photocatalyst has attracted extensive attention [2–4]. Ag@AgCl refers to the simple state of Ag^0 decomposed by AgCl under light conditions, which is loaded on the surface of AgCl. Therefore, Ag@AgCl photocatalyst is a new visible photocatalytic material based on the nanometal surface plasma effect and semiconductor photocatalysis effect. The surface plasma resonance (SPR) effect is an important reason for the good performance of silver halide photocatalyst [5]. Although Ag@AgCl has good photocatalytic activity, AgCl has poor photochemical stability, easy agglomeration, and high recombination rate of photogenerated electrons and holes [6]. Therefore, its application in photocatalytic research is limited. Through the construction of AgCl and g-C₃N₄ [7, 8], AgBr [9], V₂O₅ [10], B₄Ti₃O₁₂ [11], WO₃ [12], MIL-88A [13], and polyaniline [14]

composite photocatalysts, the problem of easy agglomeration of AgCl nanoparticles is solved, and the photo-corrosivity of the material is reduced, so as to improve its photochemical stability and photocatalytic activity [15].

Graphene oxide (GO) is a novel carbon-based material, which is a derivative of graphene. It is a monolayer graphene sheet composed of carboxyl, hydroxyl, epoxy, and other oxygen-containing functional groups. The surface of GO is wrinkled, with excellent hydrophilicity, large specific surface area, and low toxicity. The composites formed with photocatalysts have attracted great attention in the fields of photocatalysis, such as GO and TiO₂ [16, 17], Ag₃PO₄ [18, 19], BiOI [20], BiVO₄ [21], and Zn(OH)₂ [22]. At present, in the research of GO and AgCl composite photocatalyst materials, Wang Shuang et al. successfully prepared AgCl/GO composite visible light catalyst by microemulsion method. The degradation rate of methyl orange (MO) reached more than 91% after 100 min visible light irradiation [23]. Chao Xu et al. successfully prepared

graphene oxide-supported uniform Ag@AgCl core-shell nanoparticle composites by a facile two-step synthetic process, and these nanoparticle composites display effective photodegradation of methylene orange dye under visible light irradiation, which indicates their potential applications in environmental areas [24].

This study aims at the problems of poor photochemical stability, easy agglomeration, insufficient adsorption capacity, and difficult recycling of AgCl. By introducing GO and using the property of sodium alginate (SA) aqueous solution and divalent cation (such as Ca^{2+}) to form a stable gel, AgCl was successfully loaded on GO by chemical coupling and in-situ deposition, and Ag@AgCl/GO was prepared by photoinduced reduction. The photocatalytic material can be used for the degradation of actual organic pollution wastewater with the advantages of strong adsorption capacity, short photocatalytic degradation time, high catalytic efficiency, wide visible light response range, and easy recycling.

2. Materials and Methods

2.1. Preparation of Photocatalytic Materials

2.1.1. Preparation of GO. First, 92 mL concentrated sulfuric acid was cooled to 0°C in an ice bath, and 2 g flake graphite and 2 g NaNO_3 were added to the concentrated sulfuric acid under magnetic stirring. Then, 12 g KMnO_4 was slowly put into the above-mixed solution, and the reaction system was kept below 5°C for 2 h, heated up to 40°C for 2 h, diluted with 60 mL deionized water, and stirred for 1 h. Finally, 15 mL 30% H_2O_2 solution was used to remove unreacted KMnO_4 . After standing overnight, GO was obtained by ultrasonic, centrifugation, and washing to neutralize with deionized water in succession, and the prepared sample was dried at 60°C for 2 h.

2.1.2. Preparation of Ag@AgCl/GO. Preparation principle: in the first step, when GO dispersion is mixed with the mixed solution of sodium alginate (SA) and cetyltrimethylammonium bromide (CTAB), alginate ions will be adsorbed on the GO layer due to the action of hydrogen bond and the surfactant of CTAB. In the second step, after adding silver nitrate, due to the electrostatic attraction, the positively charged silver ion (Ag^+) will attract the negatively charged alginate ion and the carboxylate group ($-\text{COO}^-$) on GO, so that the silver ion is closely surrounded in GO.

Specific preparation method: 3 mL 4 g/L SA solution was added to 60 mL 1 g/L GO dispersion solution, stirred, and ultrasound for 15 min to mix fully. 1.5 mL 10 g/L CTAB surfactant was put into the mixture and dispersed by ultrasonic for 30 min. Under magnetic stirring, 9 mL 50 g/L AgNO_3 solution was slowly dropped into the mixture. After continued stirring for 15 min, 9 mL 20 g/L CaCl_2 solution was slowly added to the above-mixed system to form insoluble particles by using the crosslinking effect of Ca^{2+} and AgCl precipitation. It is allowed to stand for 24 h after magnetic stirring for 30 min. The particle precipitate was obtained by filtering through double-layer gauze and washed

with deionized water for 5 times. The filtrate was retained. Then, the precipitate was added to a 250 mL flask containing 50 mL deionized water and irradiated for 1 h by using a 350 W xenon lamp under magnetic stirring. Ag@AgCl/GO (denoted as GO+) was obtained through double-layer gauze filtration and vacuum freeze-dried. Meanwhile, the above-mentioned filtrate was centrifuged, and the obtained Ag@AgCl precipitate was treated according to the same method.

2.2. Characterizations of Photocatalytic Materials. The morphologies were collected with a field emission scanning electron microscope (SEM) (Quattro S, FEI, USA). The microstructures were examined by a transmission electron microscope (TEM) (JEM-2100, Japan Electronics Co., Ltd). The chemical bonding status of the samples was analyzed on an FT-IR spectrometer (IRtracer-100, Shimadzu, Japan), with a resolution of 4 cm^{-1} and a scanning range of $400\text{--}4000\text{ cm}^{-1}$. The Raman spectra of the samples were measured with a laser confocal Raman spectrometer (LabRAM HR Evolution, HORIBA, France). The specific surface area of the samples was calculated by using an automatic-specific surface area analyzer (BELSORP-max, MicrotracBEL, Japan). The zeta potential of the samples was measured by a zeta potentiometer (ZEN3600, Malvern, UK). The UV-visible absorbance spectra of the samples were obtained by means of a UV-visible spectrophotometer (lambda750, PerkinElmer, America). The photoluminescence (PL) spectra were measured under 315 nm excitation wavelength by a fluorescence spectrophotometer (FluoroMax-4, Horiba, France). UV-visible absorbance spectra of the degradation solution were obtained by means of a UV-visible spectrophotometer (UV-2600, Shimadzu, Japan). The electron spin resonance (ESR) spectra in the solution were detected under dark or visible light ($\lambda > 420\text{ nm}$) with an electron paramagnetic resonance spectrometer (JES-FA200, Japan Electronics Co., Ltd).

2.3. Photocatalytic Test

2.3.1. Degradation Dynamics Analyses. In order to study the kinetic relationship of photocatalytic degradation of pollutants by the prepared GO+, the Langmuir-Hinshelwood model was used to obtain the first-order photocatalytic reaction rate equation: $\ln(C_0/C_t) = kt + A$, where k is the apparent rate constant (min^{-1}), and C_0 and C_t are the pollutant concentration (mg/L) at reaction time 0 and t , respectively.

2.3.2. Photocatalytic Activity Analyses. 0.2 g of the prepared GO+ was added into a 100 mL triangular flask, and then, 60 mL 10 mg/L RhB (or another dye) solution was added. After mixing, the initial pH value was adjusted to 6.5, and the temperature was controlled at 40°C . After magnetic stirring for 30 min in dark, the triangular flask was placed under a 300 W xenon lamp ($\lambda > 420\text{ nm}$), and the distance between the light source and the liquid level was about 5 cm. The time was started under magnetic stirring, and 3 mL of the upper

reaction solution was taken out every 2 min as the test solution. The absorbance change was measured to evaluate the degradation activity of the catalytic material. The relationship curve between the C_t/C_0 of the dye solution and the degradation time t in the degradation process is the photodegradation curve, where C_0 and C_t are the dye concentration (mg/L) at reaction times 0 and t , respectively.

3. Results and Discussion

3.1. Morphology and Elemental Composition. Figures 1 and 2 show the SEM image and TEM image of the GO + composites, respectively. The folded structure of the catalytic material is loaded with a large number of irregular AgCl and Ag@AgCl nanoparticles, which are overlapped and stacked in clusters. AgCl particles are spherical, with uneven particle size of 50 ~ 100 nm. It can be seen that Ag@AgCl particles are successfully loaded on Ca^{2+} cross-linked GO/SA folds. The fold structure can act as a partition to effectively divide the clustered Ag@AgCl particles, which is conducive to the adsorption and rapid degradation of dyes by the composite to a certain extent, and effectively improve the photocatalytic performance of the composite. From the electron diffraction pattern of the composite (Figure 3), it can be seen that the catalytic material shows an obvious polycrystalline diffraction ring.

Figures 4 and 5 show the EDS spectra and the surface scan distribution of the main elements of the GO + composites, respectively. The sample contains Ag, Cl, C, O, N, Ca, Br, and other elements. The mass concentration of Ag element was higher than that of C element, and the concentration of Ag atom was also higher than that of C and O, while the content of silver atom is about four times that of chlorine atom, namely, Ag: AgCl = 4:1, indicating that each AgCl particle surface was roughly adhered by Ag nanoparticles (AgNPs). In addition, the composites also contain a small amount of AgBr particles and CTAB cations, and a small amount of AgBr particles can also cooperate with Ag@AgCl for the catalytic degradation of pollutants.

3.2. FT-IR Analysis. For the GO and SA, the absorption peaks of GO at 1040 and 1220 cm^{-1} (Figure 6) derive from the C–O and C–OH, respectively. At 1415, 1622, and 1730 cm^{-1} , respectively, there are vibration absorption peaks of carboxyl C–O, “benzene ring” C=C, and carboxyl C=O [25]. The characteristic peaks of hydroxyl (–OH) appear at 3370 cm^{-1} (GO) and 3320 cm^{-1} (SA). The absorption peaks of SA at 1596 cm^{-1} and 1405 cm^{-1} belong to the antisymmetric and symmetrical stretching vibration of –COO–, respectively, and the absorption peak at 1028 cm^{-1} is attributed to the C–O–C.

For the GO+, the characteristic peak of AgCl appears at 610 cm^{-1} of the fingerprint area [23], and the absorption peak at 1040 cm^{-1} is attributed to the vibration of the C–O–C. Compared with pure GO, the peak intensity of the C–O–C is significantly weakened. The peak at 1411 cm^{-1} may be caused by the C–O vibration of the –COO– groups.

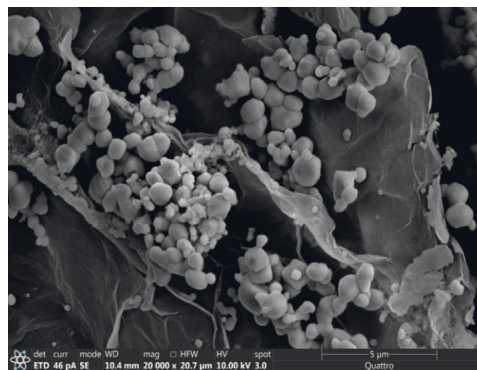


FIGURE 1: The SEM of the sample (SEM).

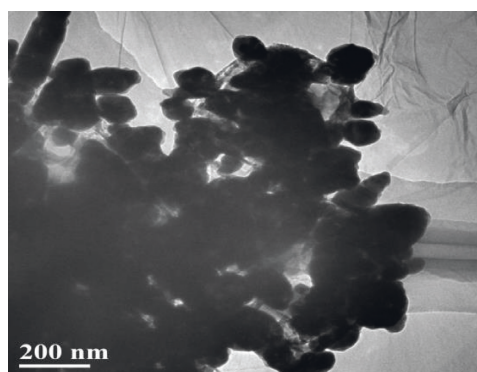


FIGURE 2: The TEM of the sample (TEM).

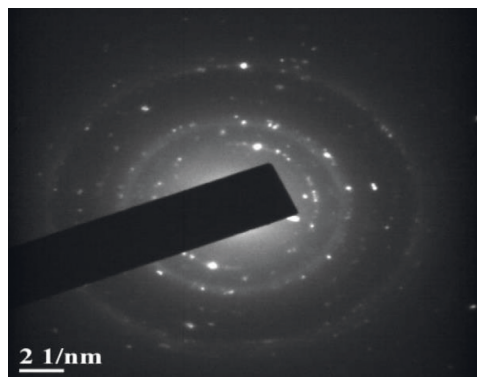


FIGURE 3: Electron diffraction pattern of the sample.

The peak at 1609 cm^{-1} is mainly attributed to the deformation vibration of adsorbed water molecules (bending vibration peak of water molecules). The stretching vibration peaks of C–OH and carboxyl C=O at 1220 cm^{-1} and 1730 cm^{-1} (GO) disappeared in the GO+. The absorption peaks at 2925 cm^{-1} and 2850 cm^{-1} are the manifestation of symmetric and asymmetric stretching vibrations of methylene (–CH₂–) of CTAB [26]. It is known that the vibration peak of free hydroxyl is located in 3640 ~ 3610 cm^{-1} , while the stretching vibration peak of associated hydroxyl exists in 3400 ~ 3200 cm^{-1} . The wide absorption band at 3380 cm^{-1} is

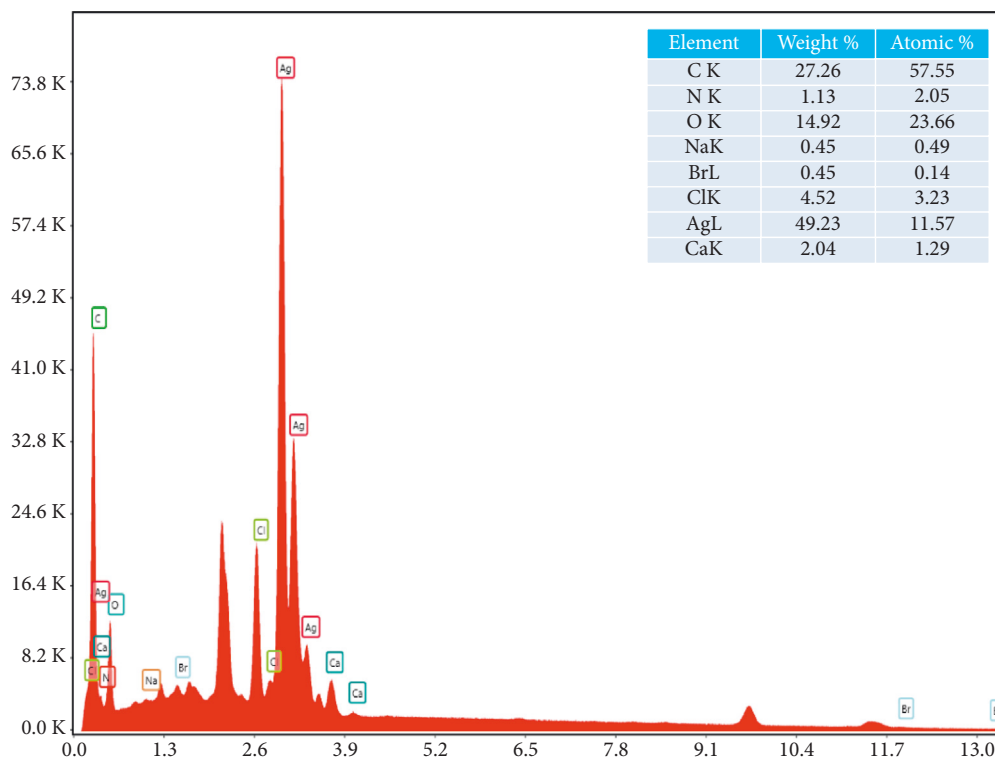


FIGURE 4: The EDS profiles of the sample.

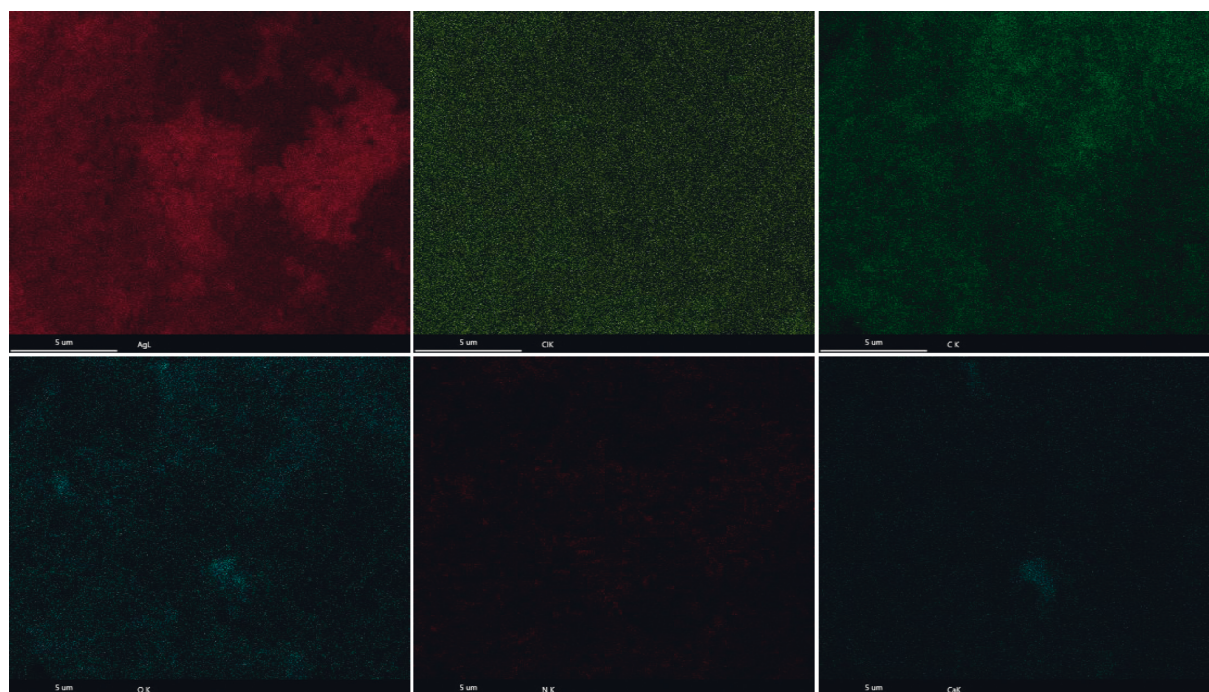


FIGURE 5: Elemental analysis of the sample.

attributed to the stretching vibration of the O–H bond of the oxygen-containing functional group [27]. Compared with pure GO, the intensity of the characteristic peak is significantly reduced, indicating that the –OH content in the GO+ is greatly reduced compared with GO and SA. This is because

most –OH groups participate in the crosslinking reaction, resulting in the reduction of intramolecular hydrogen bonds and intermolecular hydrogen bonds. Therefore, the infrared band of the –OH peak is widened and slightly red-shifted [28].

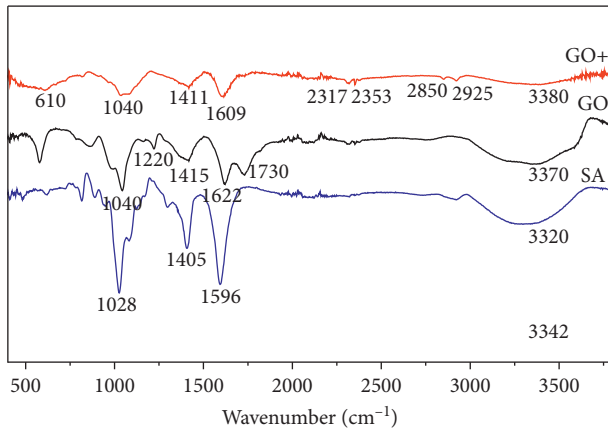


FIGURE 6: FT-IR spectra of the GO+, GO, and SA.

The characteristic peak of the oxygen-containing functional groups on the surface of the GO+ is significantly reduced, and the intensity of the characteristic peak is significantly weakened at $1500\sim 1750\text{ cm}^{-1}$, indicating that a stable coordination crosslinking is formed between the oxygen-containing groups on the surface of GO and the divalent cations (Ca^{2+}), and some oxygen-containing functions are lost in the process of crosslinking and recombination [23].

3.3. Raman Spectra Analysis. The D peak in Raman spectra represents the edge defect and amorphous structure of graphene, and the G peak means the ordered SP² bond structure [29]. Figure 7 shows the Raman spectra of the GO+ and pure GO. The GO+ has two characteristic peaks of GO at 1350 cm^{-1} (D peak) and 1581 cm^{-1} (G peak) [30], indicating that the GO+ has the composition and structure of GO. The weakening of the two characteristic peaks of the GO+ is due to the strong interaction between GO and AgCl and the crosslinking with Ca^{2+} . The integral intensity ratio (I_D/I_G) of D peak and G peak increased from 0.90 to 0.93, which is due to the increase in structural defects and disorders caused by crosslinking reaction and the loss of some oxygen-containing functional groups [31].

3.4. Adsorption Property Analysis. Generally, the larger the specific surface area of the material is, the stronger the adsorption performance of the material is [32]. The BET-specific surface area can be calculated from the N_2 adsorption-desorption isotherm of the GO+. Taking the sample prepared with equal mass SA instead of GO (denoted as SA+) as the control, Figure 8 shows that the isotherm of the GO+ conforms to the class IV isotherm, indicating that the composite has mesoporous structure, which is conducive to the absorption of visible light and reduces the recombination of e^- and h^+ [33]. The adsorption hysteresis loop of the GO+ is not obvious compared with SA+, indicating that the GO+ has no significant capillary condensation in the hole, and the adsorption performance is relatively strong. The specific surface area and average pore size of the material are $1.2645\text{ m}^2/\text{g}$ and 18.021 nm , respectively, and the pore

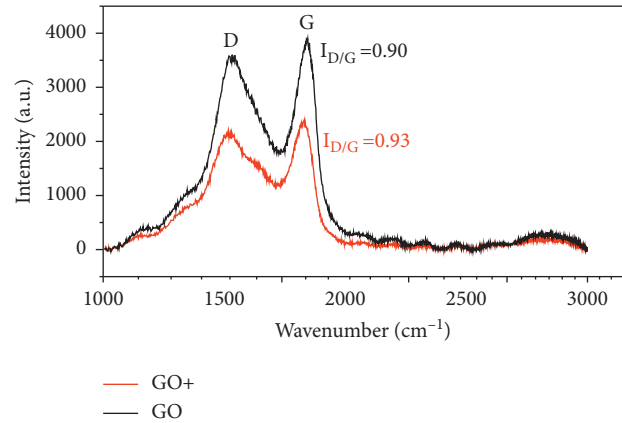


FIGURE 7: Raman spectra of the GO+ and GO.

size distribution is between 2 and 100 nm. According to the photocatalytic oxidation mechanism, the recombination of photogenerated electrons and holes on the catalyst surface is completed within 10^{-9} s , but the carrier capture rate is relatively slow, which usually takes $10^{-8}\sim 10^{-7}\text{ s}$. Therefore, only the pollutants adsorbed on the catalyst surface are likely to obtain highly active electrons and holes for reaction. Because GO has a large specific surface area and strong adsorption capacity of carbon-based materials, dispersing and depositing Ag@AgCl on GO can effectively enhance the adsorption performance of the GO+ to pollutants and the ability of the photocatalytic degradation of pollutants.

3.5. Fluorescence Property. PL spectroscopy is an effective method to study the recombination efficiency of photogenerated carriers. The fluorescence intensity reflects the recombination efficiency of electron-hole pairs. Generally, the lower the intensity of PL, the lower the recombination rate of photogenerated electrons and holes. Figure 9 shows the PL spectra of the prepared GO+ and Ag@AgCl. Both samples had fluorescence peaks at 430 nm, but the intensity of the emission peak of the GO+ was much weaker than that of Ag@AgCl, indicating that the probability of photogenerated charge recombination of the GO+ is low. Thus, the addition of the GO can reduce the recombination of photogenerated electrons and holes to enhance the photocatalytic activity.

3.6. UV-Vis DRS Characterization. It is reported that the indirect energy band gap of AgCl is about 3.25 eV. Except for the absorption band in the UV region, AgCl has almost no absorption performance in $400\sim 800\text{ nm}$ [34]. Therefore, the strong absorption performance of Ag@AgCl in the visible light region should be the resonance absorption band generated by the SPR effect of Ag nanoparticles [35]. It can be seen from Figure 10 that the GO+ still has strong absorption in the UV-vis region, and the absorption in the visible light region is still in a wide wavelength range. It indicated that GO played a synergistic effect on the visible light absorption of Ag@AgCl to some extent.

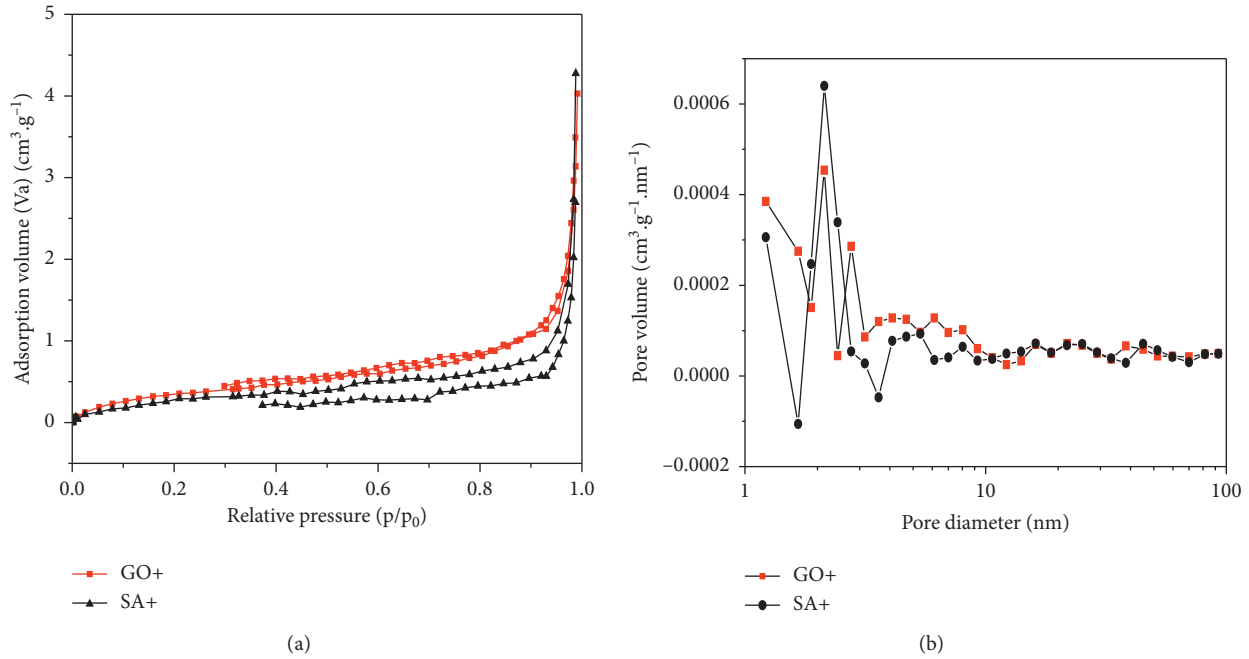


FIGURE 8: (a) Adsorption-desorption isotherms and (b) pore size distribution of GO+ and SA+.

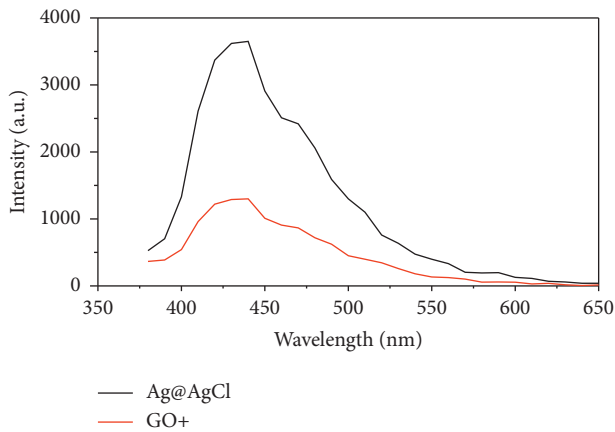


FIGURE 9: Photoluminescence (PL) spectra of the GO+ and Ag@AgCl.

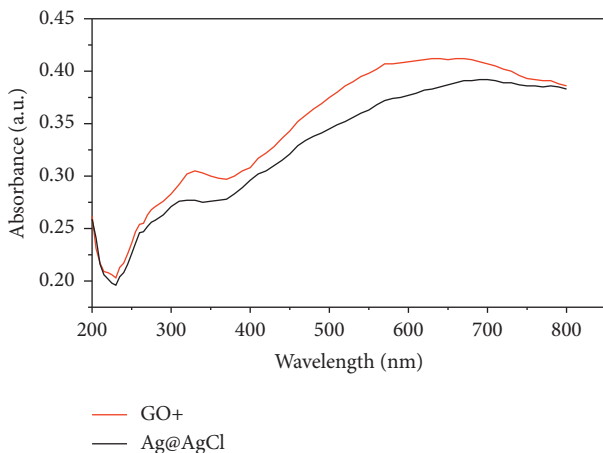


FIGURE 10: UV-vis DRS of the GO+ and Ag@AgCl.

3.7. Photocatalytic Degradation Performance. Figure 11 shows the degradation curves of rhodamine (RhB), methylene blue (MB), methyl orange (MO), and carmine red (CR) by the GO+ under visible light irradiation. The characteristic absorption of RhB at 554 nm in the visible region ($n \rightarrow \pi^*$ electron transition on C=O, C=N) and 270 nm in the UV region ($\pi \rightarrow \pi^*$ electron transition on benzene ring) decreased rapidly with the extension of reaction time, indicating that the main structural substances of RhB were completely decomposed. MB has characteristic absorption peaks at 664, 609, 291.8, and 246.4 nm, of which 664 nm and 291 nm correspond to the absorption peaks produced by the super-conjugated structure and the $\pi \rightarrow \pi^*$ transition of benzene ring, respectively. These characteristic absorption peaks disappeared after the reaction, indicating that MB had been degraded after the reaction. The characteristic peaks of MO at 465.2, 271.6 nm were produced by the $-N=N-$ azo and benzene ring conjugate system, respectively. After 12 min, there were no obvious absorption peaks in the UV-vis region, indicating that MO was completely catalytic degraded. The typical absorption peaks of CR appeared at 514.5 nm and 280 nm. After 12 min, the structure at 514.5 nm was effectively degraded, but the characteristic peaks at 280 nm were still obvious, indicating that the characteristic groups still existed.

Figure 12 shows that the photocatalytic degradation of the four dyes all follows the quasi-first-order kinetics reaction. The degradation rate constants (k) of RhB and MB are 0.5381 min^{-1} and 0.4989 min^{-1} respectively, which are higher than those of anionic dyes MO (0.2573 min^{-1}) and CR (0.2573 min^{-1}). The results showed that the GO+ has a stronger ability to degrade cationic dyes RhB and MB, a weaker ability to degrade anionic dye MO, and the worst

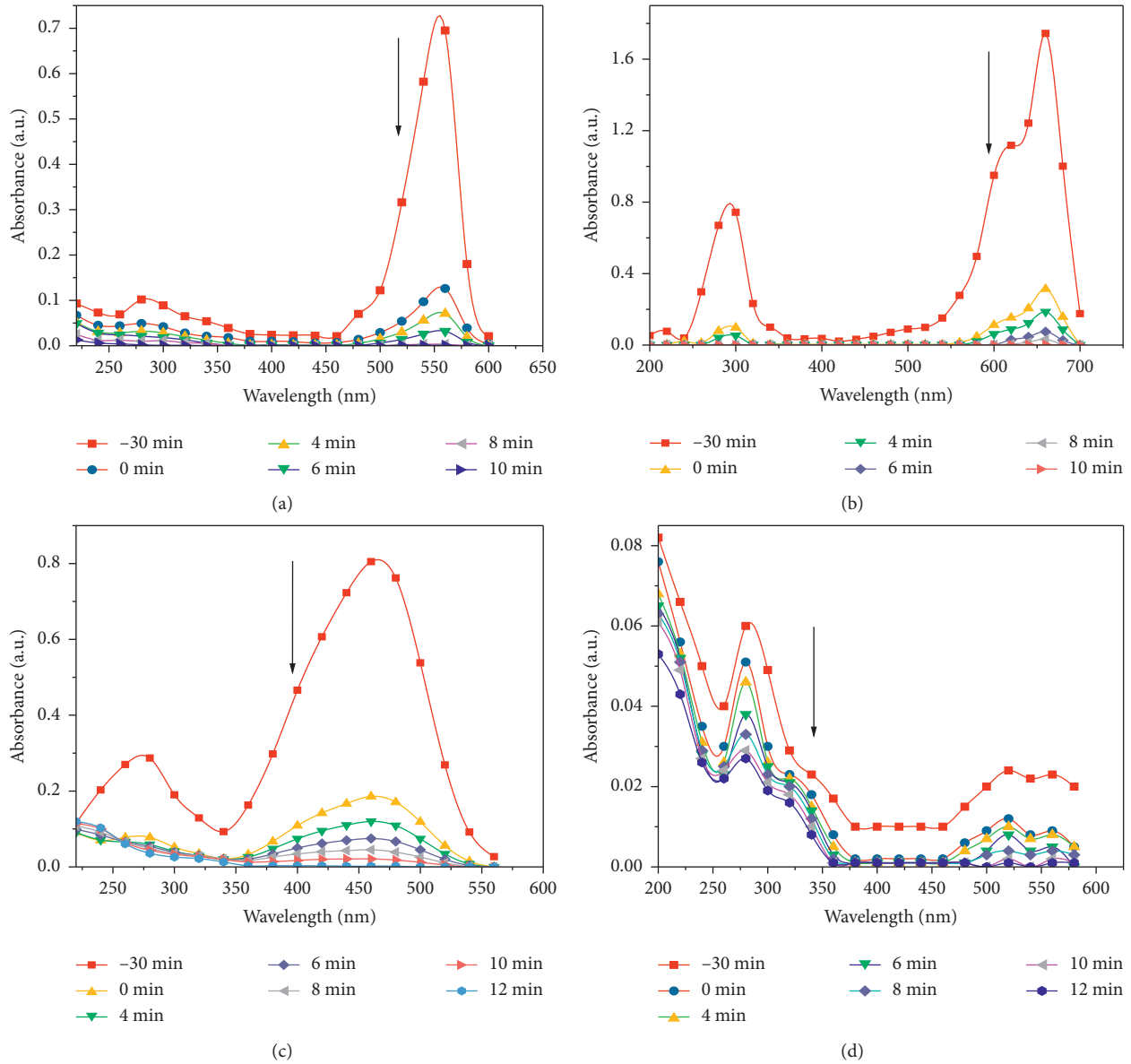


FIGURE 11: Absorption spectra of visible light irradiation by the GO+: RhB (a), MB (b), MO (c), CR (d).

ability to degrade CR. This may be related to the negative charge of the GO + itself in pH 6.5 solution. The negatively charged material surface would adsorb more RhB and MB molecules, so more photogenerated holes can contact RhB and MB molecules to participate in the degradation process, thus inhibiting the recombination of photogenerated holes and electrons.

3.8. Electrical Property and Stability. Zeta potential is a measure of the strength of mutual repulsion or attraction between particles. The zeta potential results of the GO + are shown in Figure 13. When pH is less than 4.5 and pH is greater than 6.5, the surface of the GO+ is negatively charged. At this time, there is repulsion between catalytic materials, resulting in the steric effect of catalytic material particles, indicating that the GO + has strong stability. In

practical application, the reusability of photocatalyst is particularly important [36]. The activity of the photocatalytic material had not changed significantly after 5 times of recycling (Figure 14), and the degradation rate of RhB was still more than 90.0%, indicating that the GO + has good photocatalytic stability and reusability. As a visible light catalyst, it has great potential in practical production.

3.9. Free Radical Detection and Capture Test. In order to intuitively understand the generation of O_2^- and OH during light irradiation of the GO+, the active substances under visible light irradiation were determined by ESR technology with deionized water as solvent. With deionized water as solvent, the active substances under visible light irradiation were determined by ESR technology. As shown in Figure 15, the signals of DMPO- OH and DMPO- O_2^- were not detected

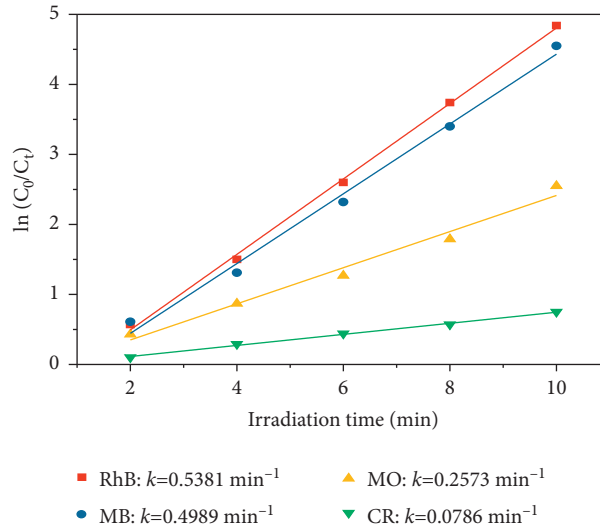


FIGURE 12: The first-order kinetics rate constant of photodegradation.

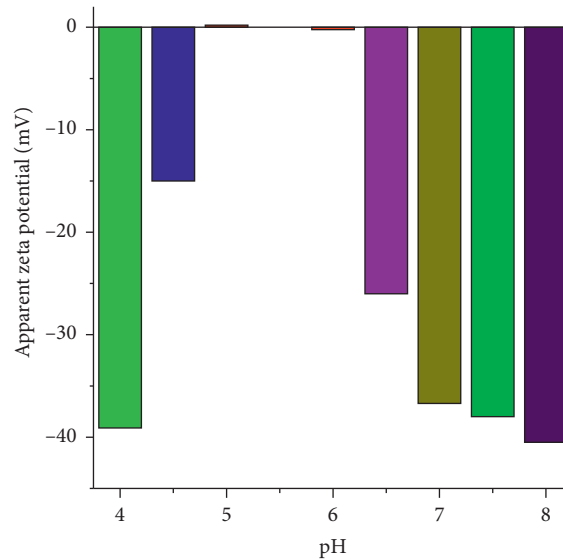


FIGURE 13: Potential distribution.

in dark conditions. However, the characteristic quadruple peaks of DMPO-O_2^- and DMPO-OH could be clearly observed after 5 and 10 min of visible light ($\lambda > 420 \text{ nm}$). Figure 15(a) shows that the signal peak intensity ratio is about 1:1:1:1, with the hyperfine splitting constant values: $\alpha_N = 1.319 \text{ mT}$, $\alpha_H^\beta = 1.038 \text{ mT}$, and $g = 2.00073$. Therefore, it can be judged that the peak is the characteristic signal peak of the DMPO-O_2^- [37]. Figure 15(b) shows that the peak intensity ratio of spectral signal is 1:2:2:1, with the hyperfine splitting constant values: $\alpha_N = \alpha_H^\beta = 1.500 \text{ mT}$, $g = 2.00087$, which is an important sign for ESR technology to distinguish -OH [38]. With the increase in irradiation time, the peaks intensity of DMPO-OH and DMPO-O_2^- increased gradually. The results show that OH and O_2^- appear under light conditions, and light irradiation is a necessary condition to stimulate active substances.

In order to better understand the active substances that play a major role in the photocatalytic degradation of RhB by the GO^+ , the free radical quench experiments were carried out. Tert butyl alcohol (TBA, 5 mL), disodium EDTA (EDTA-2Na , 0.2 g), and p-benzoquinone (p-BQ, 0.2 g) were used as scavengers for $\cdot\text{OH}$, h^+ , and $\cdot\text{O}_2^-$, respectively.

Figure 16 shows the photocatalytic degradation rate and fitting kinetics of RhB with and without different scavengers. With no scavenger, the degradation rate of RhB in 12 min is 99%, and the k is 0.3069 min^{-1} . As a $\cdot\text{O}_2^-$ scavenger, the addition of p-BQ greatly reduced the degradation rate, and only 9.23% of RhB was degraded, which signifies that a large amount of $\cdot\text{O}_2^-$ was produced, and $\cdot\text{O}_2^-$ was a main reactive active species. The addition of EDTA-2Na greatly delayed the degradation process, with the k

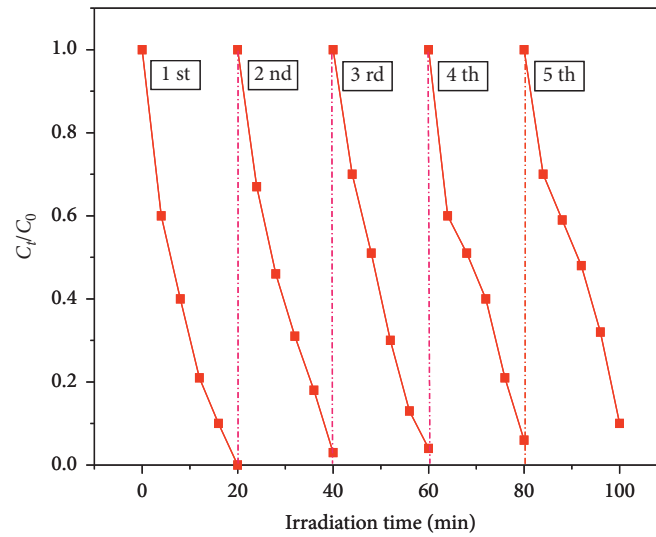
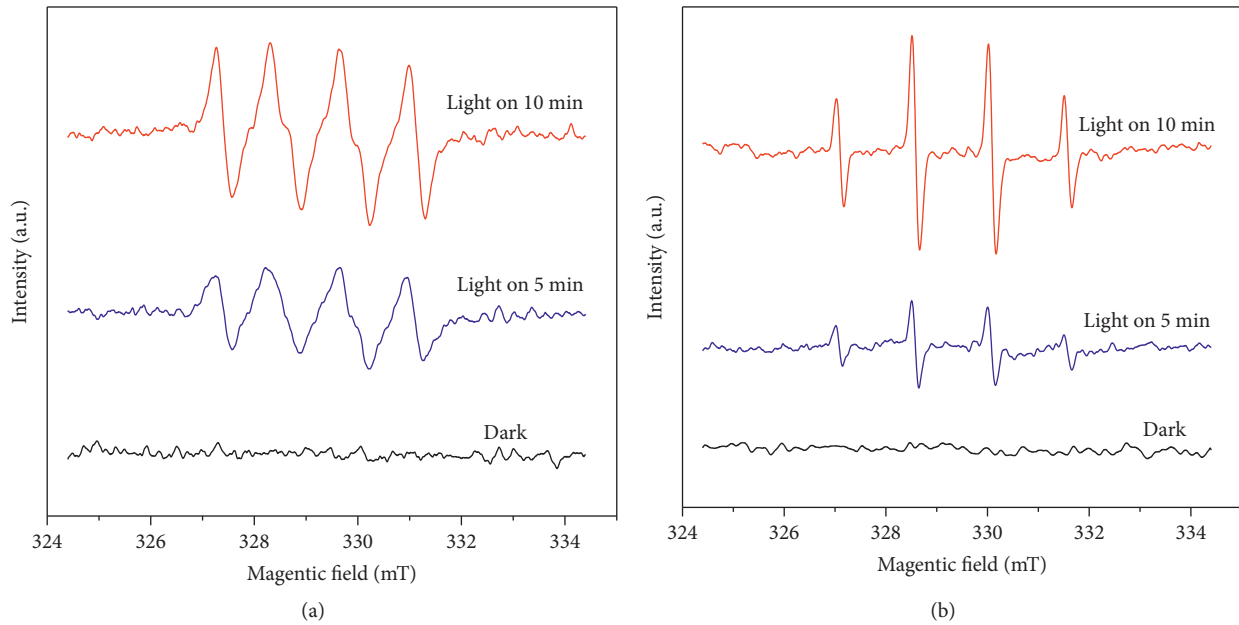


FIGURE 14: Stability test of GO+.

FIGURE 15: ESR spectra of superoxide radical and hydroxyl radical: (a)- $\text{O}_2^{\cdot-}$, (b)- OH^{\cdot} .

about 0.1267 min^{-1} , which means that h^+ was also a main reactive active species. The addition of TBA had little effect on photocatalytic degradation, indicating that $\cdot\text{OH}$ was not the main active substance. The above results show that in the photocatalytic degradation of RhB, $\text{O}_2^{\cdot-}$ plays a leading role, followed by h^+ , while $\cdot\text{OH}$ does not play a major role [39].

3.10. Photocatalytic Mechanism Analysis. Under visible light irradiation, Ag nanoparticles (AgNPs) on the surface of the GO+ were excited by the SPR to form electron-hole pairs (Figure 17) [40]. Because the Fermi level of AgNPs is relatively low compared with the conduction band phase of AgCl, and the existence of Cl^- on the surface of AgCl makes

the surface of AgCl negatively charged, resulting in a polarization effect, the generated e^- quickly moved from AgCl to the surface of AgNPs. Because the conduction band edge potential (-0.75 eV) formed by the antibond π^* orbit of GO is lower than that of hydrogen (-0.046 eV), GO can be used as the acceptor of photoexcited electrons due to its small band gap width [41], so that the electrons on the surface of AgNPs could be quickly transferred to the GO surface, and then captured by O_2 in the solution to form $\cdot\text{O}_2^-$, and then decompose RhB, realizing the effective separation of photogenerated electron-hole pairs [42]. In the meantime, the photogenerated h^+ was transferred to the AgCl surface. The h^+ itself had strong oxidation and could effectively remove pollutants. The h^+ of AgCl surface could also interact with Cl^- to form Cl^0 . Cl^0 had strong oxidation ability to oxidize

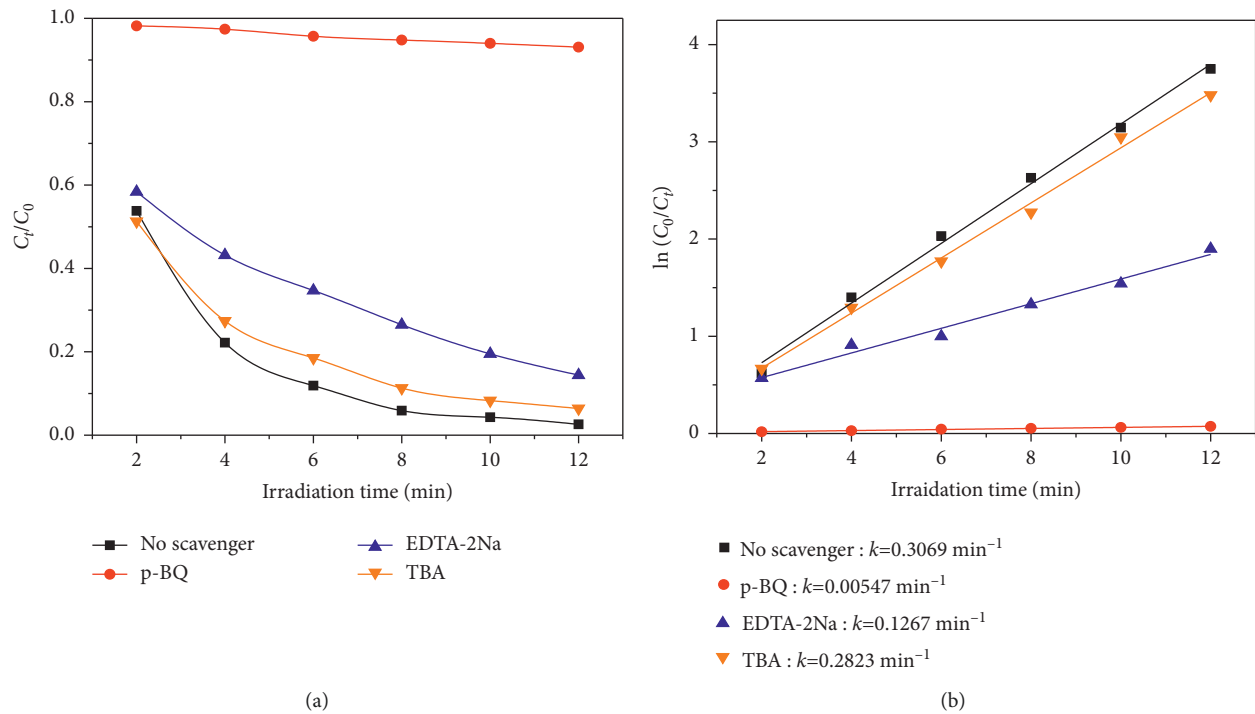


FIGURE 16: (a) Degradation rate of RhB with different scavengers by the GO+, and (b) the k of photodegradation.

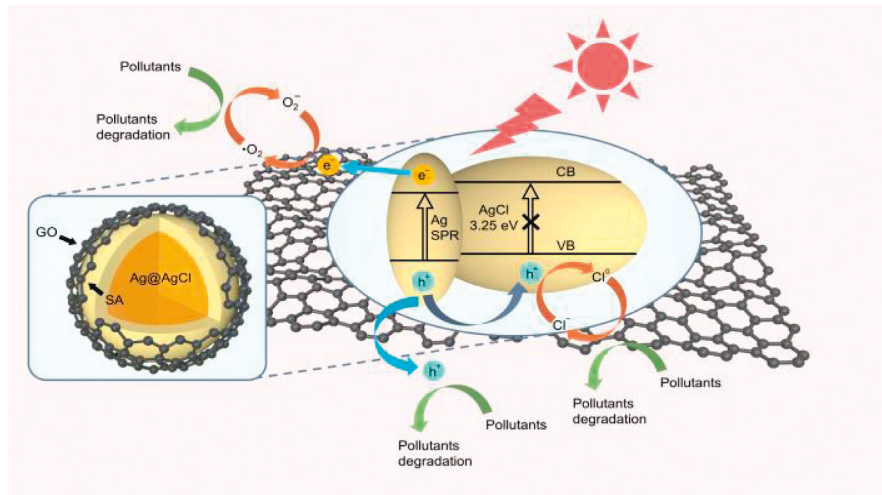


FIGURE 17: Reaction mechanism of degradation by the GO+ under visible light irradiation.

the organic molecules adsorbed on the catalyst surface. Meanwhile, Cl^0 was reduced to Cl^- , which effectively ensured the stability of the catalytic system [1]. The addition of GO in GO+ material could effectively capture e^- on the surface of AgNPs, inhibit the recombination of photo-generated electrons and holes, and improve the charge separation efficiency and the photocatalytic performance of the composites.

4. Conclusion

The GO+ prepared by chemical coupling, in-situ deposition, and photoreduction has the advantages of simple

preparation, high loading rate, response to both UV and visible light, especially the wide absorption band under visible light. Large specific surface area is conducive to adsorb more dye molecules and effectively improve the visible light catalytic activity.

The GO+ has good degradation effect on RhB, MB, MO, and other simulated dye wastewater, with high catalytic efficiency and short catalytic time. Their degradation processes were in line with the quasi-first-order reaction kinetics. Holes (h^+) and superoxide radical ($\cdot O_2^-$) were the main active species for the degradation of RhB.

The catalytic material is small granular, has good photocatalytic stability and reusability, and is easy to recycle. As

a visible light catalyst, it has great potential in practical production.

Data Availability

The experimental 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 to report regarding the present study.

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Research Article

The Influence of Demographic Factors on Urban Medical Insurance Expenditure under Big Data

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As the urban basic medical insurance with the most widespread area and age coverage, a series of research is conducive to the optimization and better promotion of policies. As the main receptor of medical insurance, people analyze the impact of population factors on the expenditure of urban basic medical insurance, which is conducive to the improvement and implementation of the medical insurance system. In this paper, birth rate, total dependency ratio, urban population proportion, and educational population proportion were selected as independent variables, urban basic medical insurance expenditure was selected as dependent variables, and a regression model was established after data processing and analysis. The results show that the birth rate, the proportion of the urban population, and the expenditure of the urban basic medical insurance fund will change in the opposite direction; the expenditure of the urban basic medical insurance fund, the total dependency ratio, and the illiteracy rate will change in the same direction.

1. Introduction

1.1. Research Background of the Article. In recent years, medical difficulties often appear. Especially in big cities, there are often cases of queuing up to hang expert numbers, and the level of experts is also uneven [1]. The left-behind elderly and children in towns and rural areas are blocked, the only labor force works in other places, and the medical level of the township is too low, so it is difficult to get effective treatment for the disease. This is also the reason why the country vigorously promotes urbanization, which can allow more people to enjoy medical insurance. In our country, the concept of urban basic medical insurance belongs to the content of social medical insurance, which is composed of two parts: urban worker medical insurance and urban resident medical insurance. We adopt the medical insurance system with the government and the accordance with the principle of the payment standard and the general consistency of the treatment level [2, 3]. Urban basic medical insurance is the earliest development part of the social medical insurance system and also the most mature part of the operation mechanism of social insurance. By the end of

2018, the number of people participating in urban basic medical insurance was 1344.52 million, an increase of 167.706 million compared with 117.6814 million at the end of 2017, with the characteristics of wide coverage, low threshold, and high acceptance [4–6].

1.2. The Research Purpose of the Article. Compared with rural areas, cities and towns belong to frequent accidents, so the expenditure of urban basic medical insurance funds can better depict the welfare level of urban workers and residents [7, 8]. Compared with the “old” insurance form of rural medical insurance, the research on urban basic medical insurance has more significance for humanization and future development. Urban basic medical insurance fund, as the largest insurance coverage of social insurance, can effectively alleviate the problem of “difficult medical treatment” in the society, let residents have less financial pressure and concerns about medical treatment and greatly improve the psychological effect of social welfare. But changes in its spending are also vulnerable to all aspects of society. In recent years, the consumption level of residents has

gradually increased, and the population change is more obvious. Especially in modern urban areas, urban basic medical insurance has been unable to meet people's needs. With the current aging population, the two-child policy, and the acceleration of urbanization, as people are the main body of medical insurance for urban residents, the impact of demographic factors on urban medical insurance is particularly important. Therefore, it is very necessary to study the influence of the changing population factors on the basic medical insurance expenditure of urban workers.

1.3. Source Analysis of the Data. The data for this paper were taken from the China Statistical Yearbook for 17 years from 2002 to 2018. The expenditure of urban basic medical insurance fund, birth rate, total dependency ratio, urban population, total population, total population aged 6 years old and above, and population aged 6 years and above were selected as the basic indicators. The comparison between urban population and total population is the proportion of urban population; another research variable is the illiteracy rate of the total population aged 6 and over. The illiteracy ratio can better reflect the depth of contemporary education under the condition of excluding people under 6 years old without a strong sense of autonomy [9]. In recent years, with the expansion of urban basic medical insurance fund expenditure with its influence, the expenditure trend of urban basic medical insurance funds is shown in Figure 1.

1.4. The Survey Methodology Used in the Article. Therefore, the expenditure of urban basic medical insurance fund is taken as the dependent variable, and the birth rate, total dependency ratio, urban population proportion, and illiteracy rate are taken as the independent variables. The research methods used in this paper mainly include the EG two-step cointegration test and the Granger causality test. EG two-step cointegration test is a regression method for nonoriginal stationary variables, which can better express the internal relationship between variables. The Granger causal test is a statistical method for hypothesis testing whether one set of time series x is the reason for another series y . It is based on the autoregressive model in the regression analysis. However, it should be noted that the conclusion of the Granger causality test is only a statistical estimate, not a causality in the real sense, and cannot be used as the basis for affirming or denying causality, and the actual causality should be judged according to experience. In this paper, we determine the stationary order of the data, construct a regression equation, determine the corresponding residual sequence, and check the cointegration relationship by checking the stationarity of the residual sequence [10–13]. If there is a cointegration relationship, then the corresponding error revision model is established to estimate the relationship between the variables. Later, the respective variables and dependent variables were tested by Granger, combined with reality, not only to determine the statistical causal relationship but also to find the causal relationship in real life [14].

2. Literature Review and Scholar's Ideas

In recent years, due to the acceleration of China's modernization process, the development of all aspects of society is in a new period of vigorous development. As the urban basic medical insurance is the most accepted social insurance project among the people, the expenditure of urban basic medical insurance after excluding the price factor can indicate whether the degree of social insurance is appropriate to some extent. Therefore, domestic scholars have made some research on the development status and development trend of the basic resident medical insurance or the basic worker medical insurance under the urban basic medical insurance system. On the current situation, problems and countermeasures of medical security for urban residents were studied.

A part of some scholars pointed out that there are mainly the following problems in the basic medical insurance for urban residents [15, 16].

Part 1: It is impossible to effectively distinguish whether residents are employed, when they are in employment, and when they are unemployed, resulting in the inability to clearly distinguish the objects of basic medical insurance for urban residents from those of basic medical insurance for urban workers [17].

Part 2: Due to the limited number of people suffering from serious diseases, only a small number of residents can enjoy basic medical insurance for urban residents, and the actual benefit rate is not high [18].

Part 3: As the actual benefit ratio of the insured is not high, the resulting sustainability of the insured is reduced. Ginseng in the medical insurance final settlement link can get part of the basic medical insurance compensation, but due to the actual process, some doctors did not put themselves according to patient family conditions, often open too high imported drugs, but go to this part of the insurance ego cost may be compared to the insurance way cost more high. So it is uncertain whether residents will continue to participate in the insurance in the future [19].

Part 4: The basic social insurance existing now mainly consists of three parts: basic medical insurance for urban residents, basic medical insurance for urban workers, and the new rural cooperative medical care system. Each part has a relatively mature and comprehensive operation mode. But there is no complete seamless connection between the three parts. With the gradual increase of population mobility, people move more frequently around the country, and the identity of the insured changes with the flow. People cannot decide which form of insurance to protect their rights and interests, which also affects the sustainability of the insured to a certain extent [20].

Part 5: Although the popularization of the basic medical insurance system for basic urban residents is high, most of the insured people do not understand the policy itself

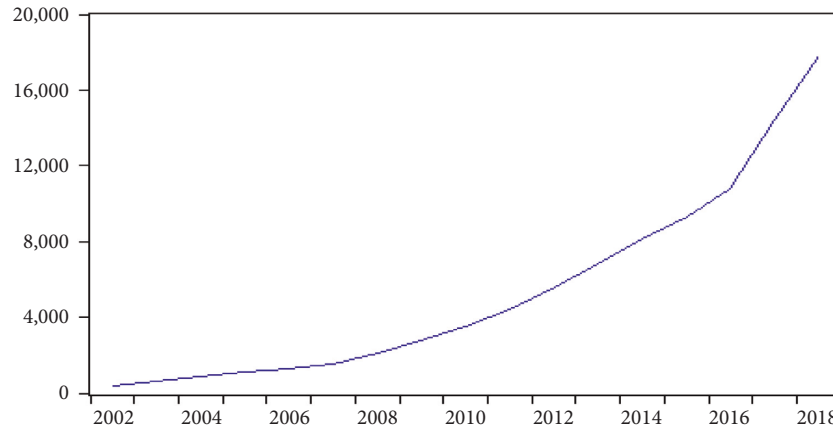


FIGURE 1: Expenditure trend of urban basic medical insurance funds.

thoroughly and do not realize the necessity of participation, so the lack of participation is not high [21].

For the contents of the above five parts, it is believed that the above five problems should be solved pertinently. First of all, the definition standard of the guarantee object should be made clear, and the types of insured should be divided according to the definition standard, so as to avoid the phenomenon of “kicking each other” due to inaccurate definition. Secondly, compulsory participation insurance policies can be appropriately adopted to ensure its continuity. Optimizing the structure of the guarantee and increasing the amount of guarantee are also effective means to ensure the actual proportion of benefits. Thirdly, the basic medical insurance for urban residents, the basic medical insurance for urban workers, and the new rural cooperative medical care system should strengthen the cooperation relationship, determine the guarantee method according to each standard, and ensure the initiative and effectiveness of the policy implementation. Finally, the policy publicity should be strengthened to let the residents realize the importance of participating in the basic medical insurance for urban residents. This study comprehensively analyzes the common problems existing in the basic medical insurance for urban residents today but ignores the loopholes existing in the hospital. For example, prescribing high-priced drugs in hospitals and arranging too many unnecessary examinations virtually increase the cost of medical treatment and reduce the benefit ratio to a certain extent.

The other scholars gave defensive strategic suggestions on this problem in the SWOT study of medical insurance for urban residents in Shanghai.

Part 1: We will strengthen the management of medical insurance contributions. We will strengthen the supervision of medical expenses and medical treatment, draw lessons from the concept of similar foreign private doctors, and handle them at different levels according to their conditions. That is, the small disease grass-roots small clinics and serious diseases go to the big hospital [22].

Part 2: We will improve the operation and management system. A comprehensive regulatory system should be established, and the government should set up a separate regulatory agency for effective management and check. In addition, a special social supervision system should be added, such as complaints and suggestions channels for the operation mechanism to be more transparent.

Part 3: We will improve medical ethics, avoid the occurrence of medical treatment such as expensive drugs and unnecessary examination items, and implement the assessment mechanism for hospitals, so as to improve the utilization rate of medical resources [23].

The above are some studies on the current development status of the basic medical insurance for urban residents [24, 25]. However, the above studies have made some analyses and suggestions on the most prominent problems of the basic medical insurance for urban residents and did not pay attention to the impact of the characteristics of population factors on the urban basic medical insurance system. With the gradual development of the economy and society, the characteristics of the population itself have gradually become an important factor affecting the development of all aspects. As the main body of consumption and enjoyment of urban basic medical insurance, the change of demographic factors in this system cannot be underestimated. In addition, with the increasing aging problem of the population in recent years, the opening of the two-child policy and the acceleration of the urbanization process, the parenting pressure of the younger generation increases sharply, and the characteristics of the demographic factors themselves are also changing. Therefore, studying the impact of demographic factors on the basic endowment insurance system for urban residents and predicting the future population structure has a certain reference significance for the development of the future residents' medical insurance system.

3. Data Processing Is the Model Construction

3.1. Data Processing and Model Setting. In the process of research, in order to simplify each index, the dependent variable is the urban basic medical insurance expenditure, y representative is used, and the birth rate, total dependency ratio, urban population proportion, and illiterate rate are the independent variables x_1, x_2, x_3, x_4 , respectively. ADF stationarity test was conducted for each variable, and the results show that the different orders are required for each variable to be stable. In Table 1, the results are not ideal. The independent variables y and the independent variables x_1 are treated logarithmically and treated differently.

Table 1 shows that the logarithm form, $\ln y$, of the dependent variable and the logarithm form, $\ln x_1, x_2, x_3$, and x_4 , of the independent variable, x_1 , all meet the I(1) criteria. The JJ consolidation test was tried to be used, but because the data year of each variable is short and the observation value is insufficient, the corresponding conditions are not met. Therefore, the EG two-step method was used to cointegrate the test, and the error revision model was established to test whether there is a long-term cointegration relationship among the variables [26].

3.2. Model Setting and Calculation. First, the regression analysis [27–35] was performed on $\ln y, \ln x_1, x_2, x_3, x_4$, the residual sequence of the equation, named E , was tested for unit root stationarity for E , and the results are shown in Figure 2.

According to the results, the T statistic value of residue sequence E is -4.786 , less than -3.830 at the 5% significance level, rejecting the null hypothesis, so $\ln y$ has a long-term equilibrium relationship with $\ln x_1, x_2, x_3$, and x_4 . The test form is $(c, t, 0)$. Later, the error revision model was established. The revision model is rebuilt as follows:

$$\Delta \ln Y = \beta_1 \Delta \ln x_1 + \beta_2 \Delta x_2 + \beta_3 \Delta x_3 + \beta_4 \Delta x_4 + c + E(-1). \quad (1)$$

Each variable was treated using E views, and the following equation was obtained after the final regression:

$$\Delta \ln y = 0.279 - 1.257E(-1) - 1.068 \Delta \ln x_1 + 0.046 \Delta x_2 - 0.039 \Delta x_3 + 0.021 \Delta x_4, \quad (2)$$

$$\begin{aligned} & (2.162381)(-5.145341)(-3.286293)(-3.189868) \\ & (-0.379910)(0.881231) \end{aligned} \quad (3)$$

$$R^2 = 0.760790,$$

$$DW = 1.95,$$

where Δ indicates the first-order differential treatment of the variables, reflecting the state of influence on the equilibrium in the short term.

A Granger's causal test was performed between the respective variables and the dependent variables. The results are obtained as shown in Table 2.

From a statistical perspective, the previous change of $\Delta \ln x_1, \Delta \ln x_3$, and $\Delta \ln x_4$ variables can effectively explain the change of $\Delta \ln y$ while the previous change of $\Delta \ln y$ can effectively explain the change of Δx_2 . However, according to practice, urban basic medical insurance, as a voluntary insured project, the demographic factor is a nonartificially controllable variable, so, in fact, the change of Δx_2 itself should affect the growth of $\Delta \ln y$.

3.3. Results Analysis. According to the regression equation, the equation fits well and can well reflect the impact of demographic factors on the insurance fund expenditure in a short period of time. The increase in urban basic medical insurance fund expenditure was negatively associated with the birth rate. The more the birth rate falls, the more the corresponding urban basic medical insurance fund spending increases. In the implementation of the two-child policy, the birth rate should increase year by year, but in addition, the impact of the aging population has exceeded the two-child policy, and there are other more realistic factors leading to the decline in the birth rate. In today's society, the cost of raising children is too high for many low-class people to afford. Moreover, many workers are busy and have too little leisure time to support their children, once the children have the cost of living. So the birth rate is still on a slow decline. This suggests that the faster the birth rate falls, the more the urban basic medical insurance fund spending increases accordingly. That is, because the elderly population is relatively large, individual children not only need to raise parents but also raise parents, in order to avoid unnecessary losses in the future, so choose a wide coverage, authoritative urban medical insurance. The independent variable x_2 , namely the total dependency ratio, is positively correlated with the expenditure of urban basic medical insurance funds. The total dependency ratio can intuitively reflect the proportion of the nonworking population in the working population, that is, to reflect the living pressure of the population with labor force in the whole society. With the aging of the population and the implementation of the second child policy, the demand for the working population in today's society will gradually increase in a short time, so the total dependency ratio will also gradually rise. Therefore, the corresponding social pressure also increases. After ensuring the safety of the elderly and children, social pressure becomes unbearable. Many working people have to pay basic medical insurance for non working people. Because of the age characteristics of nonworking population, it is more prone to accidents, so the expenditure of urban basic medical insurance funds also increases accordingly.

The independent variable x_3 , namely, the proportion of the urban population, is negatively correlated with the expenditure of urban basic medical insurance funds. The proportion of urban population refers to the proportion of the urban population in the total population, directly reflecting the progress of urbanization. With the acceleration of China's modernization process, the pace of township poverty alleviation and prosperity has gradually accelerated the improvement of education level and the rapid

TABLE 1: Unit root test results.

Sequence	Test form	ADF statistics	5% critical value	Whether stationarity
Y	$(c,0,2)$	-3.856234	-3.11991	Stationarity
x_1	$(0,0,2)$	-3.335038	-1.970978	Stationarity
x_2	$(c,t,1)$	-5.205592	-1.96843	Stationarity
x_3	$(c,0,1)$	-3.20079	-3.081002	Stationarity
x_4	$(0,0,1)$	-3.435425	-1.96627	Stationarity
$\ln y$	$(c,0,1)$	-4.688307	-3.081002	Stationarity
$\ln x_1$	$(0,0,1)$	-3.08381	-1.96843	Stationarity

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.785832	0.0117
Test critical values:	1% level	-4.886426
	5% level	-3.828975
	10% level	-3.362984

FIGURE 2: Root of the unit test of E .

TABLE 2: Granger's causal test for the respective and dependent variables.

Null hypothesis	F statistics	Prob
$\Delta \ln x_1$ does not Granger cause $\Delta \ln y$	7.9697	0.0102
$\Delta \ln y$ does not Granger cause Δx_2	3.7839	0.0442
Δx_3 does not Granger cause $\Delta \ln y$	3.85204	0.0319
Δx_4 does not Granger cause $\Delta \ln y$	1.64914	0.0355

development of population urbanization, so the proportion of the urban population is gradually increasing. But the new era of the urban population has made a qualitative leap in consciousness over the last century just like the pursuit of contemporary life from the initial food and clothing to the present pursuit of spiritual and material. At the same time, population urbanization also reflects the rise in people's consumption level, and the awareness of self-safety and prevention in the bud is gradually increasing. For towns with a generally higher income than rural areas, basic medical insurance is no longer enough to meet individual requirements, so it turns to more personalized, more comprehensive insurance types and institutions.

The independent variable x_4 is the decrease of the illiteracy rate and the increase in the expenditure of the urban basic medical insurance fund. With the gradual increase in educational level and educational coverage in recent years, the illiteracy rate has decreased significantly in recent years. The decline in the illiteracy rate means an increase in the education penetration rate, so it shows that with the improvement of the education level of the population, the expenditure of urban basic medical insurance fund is also gradually increased, and the improvement of people's education level is a positive influencing factor on the whole. Therefore, we improve the will of people as insured and realize the importance and necessity of insured. Therefore, the participation rate will rise significantly, and the corresponding urban basic medical insurance fund will spend more.

The $E(-1)$ coefficient is equal to -1.257 , reflecting the strength of adjustment deviation from long-term equilibrium. When short-term fluctuations deviate from long-term equilibrium, the imbalance will turn back to equilibrium with an adjustment strength of -1.257 .

3.4. Discussion. From the perspective of urbanization, in the future urbanization process, in order to cooperate with the rapidly developing economy, humanized medical insurance can be gradually implemented. In the future security system, insurance types and insurance proportions should be refined, and different standards of medical security systems should be implemented for different income groups. However, in the process of rural urbanization, we should pay attention to the connection of rural areas to towns, and the transition should be permeated from all aspects. Research shows that farmers' desire for urbanization is not strong, and the main crux is from land. It is difficult for farmers to obtain the capital to make a living in cities and towns. The expansion of cities and towns is too extensive, and only hardware measures are pursued. There are often no commercial supporting facilities and inconvenient transportation in marginal areas. Farmers cannot afford to buy a house with their savings, even with all their savings. In addition, the innovation ability of the town is not enough, the pursuit of speed and giving up quality, commercial concentration areas have more similar characteristics and no own characteristic industrial chain, so the prosperity is inevitably determined by the location. In view of the above problems, in order to speed up the pace of urbanization, we should take the government as the leading role, connect towns and surrounding farmers, build a characteristic ecological supply chain, tap local advantages, increase the flow of business circles, and enhance farmers' urbanization aspirations. The government should strengthen farmers' own employability, enhance farmers' willingness to work in cities from the source, and provide corresponding employment channels and help for farmers in cities. Let the rural population strengthen their awareness of urbanization itself and their desire for urbanization, so that the rural population can truly recognize the changes and benefits brought about by urbanization from the heart. The real realization of "urbanization" in the consciousness is the embodiment of the improvement of the quality of life.

From the perspective of education level, the higher the education level, the larger the amount of urban basic medical insurance fund expenditure, which is also a positive influencing factor for medical security. Therefore, in order to expand the level of education, we should improve the "software" and "hardware" as the auxiliary idea. Based on the existing requirements of volunteer teaching in mountainous areas, one-to-one local support agencies and regulatory agencies should also be set up to ensure that the required donations are implemented to key recipients to avoid corruption. In terms of teaching, teachers teaching methods are old, which do not combine the characteristics of the youth of the times and cannot combine practice with theory well, which leads to too low interest in the teaching process and

low students' acceptance of knowledge. Therefore, we should follow the trend of the times, and teachers of all ages should regularly learn novel teaching methods, so that it is easier for students to receive knowledge, so as to deal with the prominent situation of "more water" and give up some of the students with weak self-control. In addition, literacy classes are indispensable for "waiting" people. However, the popularity of literacy classes is not high, the main reason is attributed to the low culture people's desire for knowledge and life change, and there is no corresponding mandatory measure, resulting in the low popularity of literacy classes. In addition, most of the literacy classes existing on the market are civil enterprises, charging, and teaching.

4. Conclusion

The phenomenon that the expenditure of urban basic medical insurance funds increases year by year is fundamentally the manifestation of the gradual improvement of the social security system, which shows that the people's awareness of participating in the insurance payment increases, the quality of the people improves as a whole, and the citizens have the initiative and enthusiasm to participate in the national medical security. Therefore, in order to fundamentally solve the problem that some poor people have difficulty in getting medical treatment and no money for medical treatment, we should strengthen the intensity and depth of targeted poverty alleviation. Only the poor people have savings, which can spare money on a "rainy day" to pay for basic medical insurance. Therefore, grassroots cadres should take responsibility, door to door to understand the situation, and truly achieve targeted poverty alleviation and targeted to help families who lack labor force. In addition, for the poor families with farming labor force but suffering from product sales, we should actively help the people to open up the sales, create the farmers' own characteristics, and drive the development of the industrial chain. With the improvement of consumption level, the sales of agricultural products will naturally improve.

In view of the demographic influencing factors studied in this paper, from the perspective of fertility, the two-child policy can be improved to promote the growth of the birth rate. Since the cost of raising children is too high in today's society, some families choose to drink or give up one child to avoid unbearable expenses. Therefore, appropriate encouraging policies can be adopted to promote the idea of the family raising a second child. For example, appropriate subsidies are given during pregnancy. A series of criteria were set up for eligible families to receive appropriate subsidies during their children's growth, aiming to reduce the burden on low-income families to increase the birth rate, increase the scope of urban medical insurance, and improve the level of welfare. From the perspective of dependency ratio, as the total dependency ratio and the expenditure of basic medical insurance fund for urban residents rise in recent years, the increase of insurance fund expenditure caused by the increase of total dependency ratio increases, this increase is the increase of "negative effect," because excessive aging itself is a negative phenomenon. So the

solution is mainly from the perspective of birth rate. In addition, the reimbursement ratio can be appropriately differentiated according to the number of elderly people and their illness. For the elderly with serious illness, huge expenses, and general family conditions, the reimbursement proportion should be increased according to the actual situation when they go to the hospital for settlement; for the elderly with mild illness and good family conditions, the normal reimbursement proportion should be adopted. However, it is important to note that the growth of the birth rate should not be excessively stimulated; otherwise, a more serious aging trend will appear in more than a decade.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Pantograph Catenary Performance Detection of Energy High-Speed Train Based on Machine Vision

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With the rapid development of high-speed rail in China, addressing the issue of safety assurance during the operation of the train is very important. A very important part of a train's power supply system is the pantograph and catenary system, which consists of a pantograph and a catenary. Failure of the pantograph-catenary system can cause significant damage to the normal operation of the train. The dynamic performance of the pantograph-catheter system must be detected in real time during the operation of the train. This paper is based on the study and analysis of pantograph-catheter dynamic performance parameters and developed a system for real-time detection of pantograph-catheter dynamic performance parameters based on a car visual system. The results are as follows: based on this detection method, the visual error is low and the accuracy is high. The machine-based directional height detection module developed in this paper has a good detection effect and high test accuracy; the arcing detection module designed in this paper can effectively detect the arcing and store the arcing pictures and can display the duration of single arcing and the arcing rate of the section in real-time. The practical application effect is good. The results show that the focal length of the camera lens is 16 mm, and the error of the machine vision system is low. The system designed in this paper may make a great contribution to the operation condition monitoring and fault diagnosis of the pantograph-catenary system of a high-speed train in the future.

1. Introduction

Railways have long been an important part of China's transportation system, which is important for the development of the region's economy and people's livelihoods. The rapid development of railways is critical to China's current sustainable development strategy [1]. The high-speed locomotive power supply system consists of a locomotive substation and a catenary system. The catenary system consists mainly of pantographs and catheters. The high-speed train receives electricity through a pantograph on the roof and the locomotive runs [2, 3]. During the train operation, the upper surface of the pantograph sliding plate directly contacts the catenary conductor. Under the action of internal lifting force, the pantograph will change the height of the sliding plate according to the change of the catenary

conductor height, so as to ensure good pantograph catenary contact [4]. At the same time, in order to ensure that the catenary conductor will not be separated from the pantograph sliding plate and increase the service life of the pantograph sliding plate, it is required that there is a certain distance between the contact line and the center of the train pantograph carbon sliding plate, which is called the "zigzag" value in the straight line section and the pull-out value in the curve section. The height of the catenary conductor also needs to be set according to certain standards. If the height of the wire is too high, the pantograph and catenary will break instantly, resulting in a pantograph and catenary arc, interrupting the current flow, and greatly affecting the quality of the pantograph and catenary current reception. The height of the wire is too low, which increases the wear of the catenary wire and reduces its service life [5]. Whether the

pantograph and catenary can work normally determines the current collection quality of the train, the normal service life of the equipment, and the operation safety of the train. Therefore, it is of practical importance to continuously improve the ability to test the dynamics of high-speed rail pantograph-catenary, to improve the safety and reliability of high-speed railway power supply systems, and to meet the operational and management needs of high-speed rail for the intensive development of high-speed railways and high-speed railways [6].

2. Literature Review

In the 1970s, the Academy of Sciences of the Ministry of Railways developed the first catenary detection vehicle, which can only detect the parameters of catenary conductor height and off-line phenomenon of signal network [7]. In the 1980s, China developed testing equipment for operating lines with a speed of 80 km/h. The equipment can detect parameters such as pull-out value, conduction height, and off-line spark [8]. In the 1990s, Zhengzhou Railway Bureau installed an angular displacement sensor to detect the height of the conductor. In this method, the angular displacement sensor is installed to obtain the angular displacement data on the pantograph main shaft to detect the height of catenary conductor. This method is a kind of contact detection, which can effectively detect the height of catenary conductor, and the measuring point is relatively single [9]. In the late 1990s, Southwest Jiaotong University successfully developed JJC-1 catenary inspection car field. The parameters that can be detected by the detection vehicle include pull-out value, catenary conductor height, pantograph catenary contact force, and hard points. It is suitable for operation lines with a speed of 160 km/h, which greatly improves the detection level for pantograph catenary relationship. At the beginning of the 21st century, the staff of the Shanghai Railway Bureau proposed using CCD camera to detect the dynamic performance parameters of pantograph and catenary. The system uses two cameras to obtain the pantograph catenary image and uses the image processing method to detect the relevant parameters. Lu et al. proposed a method based on image processing, using the high-definition camera installed on the roof to obtain the pantograph catenary image and calculate the relevant parameters. This method only uses one camera, and the detection structure is relatively simple, but the accuracy needs to be improved. Based on the principle of laser ranging, Shandong Laser Research Institute has developed catenary detection equipment, which is fixed on the rail and has high measurement accuracy. However, the changes of relevant parameters cannot be measured in real time [10]. Tang et al. proposed an image processing method to detect arcing. This method detects arcing through the processing of offline video. The detection effect is good, but it cannot achieve the effect of real-time detection [11]. Aiming at the problems of arc detection, Li et al. designed an image real-time processing system based on DM642. The system uses image processing technology to analyze and recognize the arc of pantograph and catenary [12]. Alrabaiah et al. developed a portable catenary detection equipment, which can detect the pull-out value and conductivity parameters. It is temporarily

in the trial stage and has not been widely promoted [13]. The pantograph system, which consists of catenary-related devices and pantographs, is an important part of the high-speed train traction system. The quality of the traction current received by a high-speed train depends on whether the receiving signal is able to collect the current from the catenary wire evenly and steadily. Therefore, it is important to study the dynamic performance parameters of the pantograph and catenary systems. The pantograph is installed on a high-speed train and collects current through contact with catenary. It is the main component of a high-speed train to obtain energy. In the process of sliding, the clue along the pantograph is called catenary conductor, which transmits current through sliding contact. The contact line not only provides the sliding path of the pantograph, and then the electric number is transmitted to the traction power equipment [14]. The position relationship between the train pantograph and catenary conductor is shown in Figure 1.

The dynamic performance parameters of pantograph catenary of high-speed train mainly include conductor height, pull-out value, and arcing. Conductor height refers to the height of catenary conductor, which refers to the vertical distance of catenary conductor relative to the plane connection of steel rail. If the contact wire height is too high, the pantograph skateboard will deviate from contact with the contact line, due to the presence of instantaneous high pressure, produce combustion arc, and damage the contact line and the pantograph skateboard. If the height of the contact wire is too low, it will endanger the safety of the train. In addition, arcs formed when large changes in the height of the contact wire over short distances can directly endanger the current reception quality of the pantograph and catenary system, affecting the normal operation of the train and causing significant damage to the pantograph sliding plates and contact wires. If the pull-out value is set too small, the pantograph sliding plate will be abnormally worn in some areas and deep grooves will appear. If the pull-out value is adjusted too much, it will aggravate the generation of arcing, and in serious cases, there will be accidents such as scraping and threading [15]. Arcing phenomenon refers to the discharge phenomenon caused by poor contact between the pantograph sliding plate of the train and the conductor of the catenary. During the operation of the train, the pantograph sliding plate makes sliding friction with respect to the catenary conductor. The operation speed of the high-speed train has been greatly improved, which intensifies the vibration. The contact between the pantograph sliding plate and the catenary conductor is becoming more and more unstable, and the occurrence frequency of the arcing phenomenon increases immediately [16, 17]. There are many reasons for arcing phenomenon, such as too small pantograph catenary contact pressure, too large amplitude of vertical vibration of pantograph sliding plate, and poor smoothness and hard points of catenary line. Machine vision is also known as computer vision or image-based analysis and processing. The main means for human beings to perceive the world and obtain information are vision, hearing, smell, and touch. Among them, most of the information is obtained through vision. In essence, machine

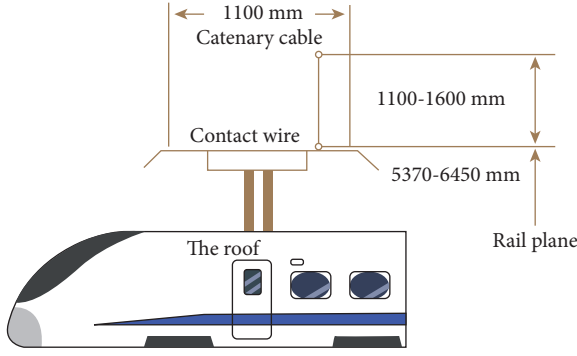


FIGURE 1: Position relationship between pantograph and catenary.

vision is to use machines to replace human eyes, simulate human visual system, measure, understand, and judge, so as to obtain relevant information [18]. The car's visual system mainly consists of modules such as a visual sensor, a high-speed imaging system, and a special image processing system. A block diagram of the car's visual system is shown in Figure 2.

Based on the principle of machine vision, two industrial cameras need to be installed on the train roof to measure the guide height and pull-out value. The field of view covers the entire pantograph and catenary system, and the contact points of the pantograph and catenary wires can be found in the video images taken by the left and right cameras. Taking the contact point as the research object, the coordinates of the point can be obtained through image processing technology, and then the values of guide height and pull-out value can be calculated [19]. The measurement principle is shown in Figure 3.

As can be seen from Figure 3, the connecting line between the centers of the cameras on both sides is their common axis. The line connecting the centers of the two sides of the camera is their common axis, the axis is perpendicular to the surface of the paper, and the axis is parallel.

The origin of the coordinates is their center, the focal length, and the distance between the center points of the two sides of the camera. If a global coordinate system is chosen, the origin of the coordinate system is the midpoint of the line connecting the center points of the two sides of the camera.

When the cameras on both sides are placed as shown in Figure 3, the relationship [20] between the coordinates (X_0, Y_0, Z_0) of a point in the space and its coordinates (x_1, y_1) and (x_2, y_2) in the imaging plane of the left and right cameras is shown in formulae (1)–(3).

$$\begin{cases} \frac{x_1}{f} = \frac{x_0 + L/2}{Z_0} \\ \frac{x_2}{f} = \frac{x_0 - L/2}{Z_0} \\ \frac{y_2}{f} = \frac{y_2}{f} = \frac{Y_0}{Z_0} \end{cases} \quad (1)$$

From (1), we have

$$Z_0 = \frac{Lf}{x_1 - x_2}. \quad (2)$$

Equations (3) and (4) can be obtained from equations (1) and (2):

$$X_0 = \frac{L(x_1 + x_2)}{2(x_1 - x_2)}, \quad (3)$$

$$Y_0 = \frac{L(y_1 + y_2)}{2(x_1 - x_2)}. \quad (4)$$

It can be seen from the above formula that the test result of this point coordinate is only related to the installation position and focal length of the camera, which is less disturbed by the outside world and has high test accuracy.

3. Research Methods

3.1. Camera Selection. The industrial camera mentioned in the pull-out value and guide height detection subsystem is the digital camera [21, 22]. Compared with civilian cameras, industrial cameras have high image stability, better image quality, strong anti-interference, and data transmission ability. Therefore, in this paper, in order to meet the test requirements, industrial camera is selected.

At present, the sensors used by industrial cameras are mainly divided into two categories: CMOS (additional metal oxide semiconductor) and CCD (combined charging device). CMOS sensor adopts photodiode as photoelectric detector, and CCD sensor adopts photodiode or grating transistor. Compared with the two, the CCD transmitter is more sensitive to light, the signal-to-noise ratio of image is higher, and it is used more in low contrast occasions. CMOS sensor has a higher transmission speed to obtain images, so it is widely used in occasions requiring high-speed acquisition. In this paper, two CCD industrial cameras with the same model parameters are selected for the detection of pull-out value and guide height. According to the detection characteristics and requirements of guide height and pull-out value, this paper adopts the high-performance industrial camera el-2800c of Jai Company [23]. The relevant parameters are shown in Table 1. The spectral curve is shown in Figure 4.

3.2. Pantograph-Catenary Dynamic Performance Test Device. To test the effectiveness of the high-speed train pantograph-catenary performance detection system, the system effectiveness shall be tested on a high-speed train pantograph-catheter performance test bench in the state key laboratory of the train. The test bench is mainly composed of two parts: one is pantograph device and the other is reciprocating device. The reciprocating motion device of the test-bed can move laterally on the pantograph sliding plate, during which dynamic contact force can be applied. The movement of the device can be regarded as the movement of the catenary conductor during operation. The reciprocating device contacts the sliding plate of the pantograph through two fixed components, so the pull-out value during

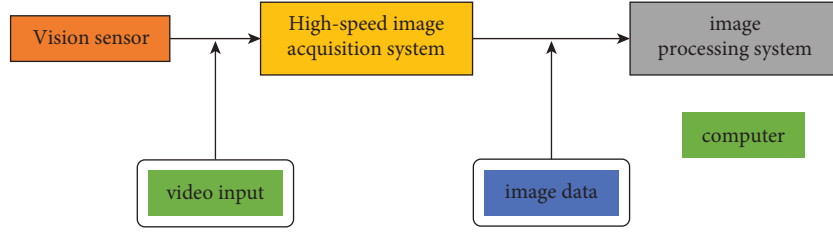


FIGURE 2: Composition block diagram of the machine vision system.

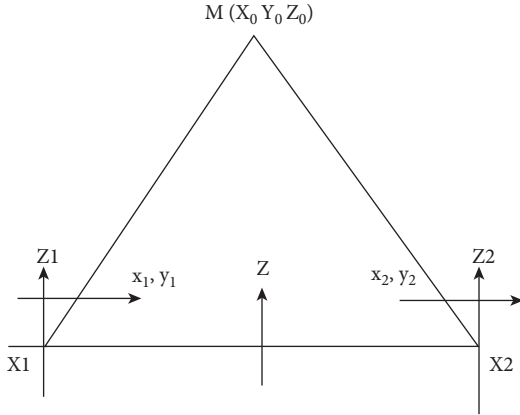


FIGURE 3: Schematic diagram of machine vision measurement.

TABLE 1: Main parameters of el-2800c industrial camera.

Name	High-resolution industrial camera
Imaging device	CCD
Exposure time range	10 μ s to 8 s
Resolving power	1920 \times 1440
Frame rate	50 fps
Data interface	Camera link

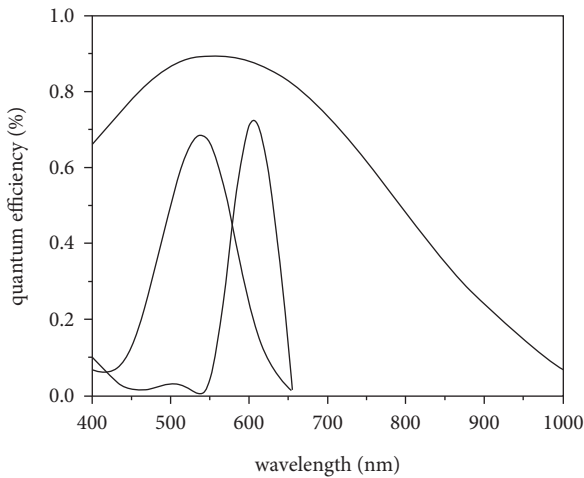


FIGURE 4: Spectrum curve of the industrial camera.

operation can be detected through the work of the reciprocating device. Since the dynamic contact force can be applied during the operation of the reciprocating device, the vertical height of the pantograph sliding plate will change

under the action of the lifting force inside the pantograph, so the change of the conductor height can also be detected [24].

4. Result Analysis

4.1. Analysis of Pull-Out Value Test Results. During this test, the frame rate of the camera is 50 fps; that is, 50 images are collected per second. In the test, the total length of the carbon sliding plate of the pantograph is 1060MM, the distance between the center of the sliding plate and both sides of the sliding plate is 530 mm, and the transverse movement range of the reciprocating device is ± 500 mm. During the test, the transverse motion range of the reciprocating device is concentrated near the center of the carbon sliding plate [25]. In order to better compare the test results with other methods, select the test results of a certain test under the condition of static debugging, use the monocular CCD camera [26–29] to detect the pull-out value, and analyze the accuracy of the machine vision system [30–33] by comparing the relative errors between them. The comparison results are shown in Table 2.

It can be seen from Table 2 that the detection method based on machine vision has small error and high precision.

4.2. Analysis of Test Results of Catenary Conductor Height. In this experiment, the detection of guide height is also based on machine vision technology. The reciprocating motion device of the test bench used in this test can not only move laterally but also exert a certain force in the vertical direction, so the pantograph sliding plate will also move up and down in the vertical direction. The reciprocating motion device of the test-bed simulates the catenary conductor, which is fixed. However, due to the contact force of the pantograph and the catenary, the pantograph slide plate will change in height in the vertical direction. Therefore, this test uses machine vision technology to detect the height change of pantograph sliding plate to detect the height change of catenary conductor. In the static state, the maximum pantograph lifting height of the pantograph of the test-bed is 1400 mm, and the minimum height from the installation base is 550 mm. In order to calculate the accuracy of the conductor height test results, the pantograph of the test bench is slowly reduced from the maximum pantograph lifting height of 1400 mm to 1200 mm, the height of each reduction is 50 mm, and it stays for 1–2 s after each reduction. The test height of the pantograph sliding plate is calculated by the system and then compared with the actual height. The results of the method based on machine vision and other methods described in

TABLE 2: Error comparison of two test results.

Machine vision measurement error (mm)	Measurement error of monocular camera (mm)	Machine vision measurement error (mm)	Measurement error of monocular camera (mm)
-2.1	-3.57	-1.57	2.63
1.21	-4.11	1.58	3.38
-2.05	3.35	-2.33	-3.33
1.72	-1.61	3.37	5.07
-1.75	-5.27	-1.36	5.42
1.31	3.71	2.133	-3.15
-2.54	-4.2	3.04	8.37
2.25	2.45	-2.11	-5.56
0.48	0.86	3.51	-3.70

this paper were selected to compare and contrast the skate height data obtained by the laser displacement distance meter for analysis and comparison. For better explanation, the error comparison between the two results is shown in Table 3.

Through experimental analysis, the machine vision-based directional height detection module developed in this document has a good detection effect and high test accuracy. In addition, the hardware visual measurement method based on hardware is not very expensive, but it has better test effect than ordinary laser displacement range-finder and will be used on a large scale in engineering practice.

4.3. Analysis of Arcing Test Results. Pantograph-catenary arcing detection is based on the photosensitive characteristics of arcing. An ultraviolet camera is installed on a subway line to detect the arcing phenomenon during operation. During the test, in order to improve the detection accuracy, set the frame rate of the UV camera to 500fps to detect the arc burning phenomenon within the time range of 2 ms and above.

In order to verify the arc detection module designed in this paper, we open the original arc video stored in the test process for manual retrieval. The comparison between the manual retrieval results and the system test results is shown in Table 4.

It can be seen from the Table 4 that there is a certain difference between the arcing detection module designed in this paper and the manual detection results. There are two reasons for the difference: (1) the UV camera sets a high frame rate, so there are many arc burning pictures detected. In addition, since the quantum efficiency of the UV camera in the UV band is not 100%, there will be misjudgment under the interference of light; (2) the identification degree of manual detection is relatively low, and the retrieved arc burning pictures will have deviation. In addition, the manual determination of the maximum duration of a single arc burning is not accurate. Through this test, it is proved that the arc detection module designed in this paper can effectively detect the arc and store the arc picture and can display the duration of single arc and the arc rate of the section in real time. The practical application effect is good.

TABLE 3: Error comparison of two test results.

Machine vision measurement error (mm)	Measurement error of laser ranging method (mm)
0	-6.57
1.78	4.36
2.35	5.54
-2.52	5.11
2.14	-6.68

TABLE 4: Comparison between judgment of the arcing detection system and manual search results.

Object	System judgment	Manual retrieval
Arcing times	30	24
Maximum single time (MS)	47	60
Arcing rate	0.24%	0.16%

4.4. Error Analysis of Machine Vision System. The car's visual system uses two cameras to mimic human eye function. The car's visual system uses the coordinates of the point to depict the perspective of the space point in the plane of the image of the two cameras to obtain the three-dimensional coordinates of the space point. The left and right cameras are placed in a horizontal position, and the coordinate source of the visual system is the center of projection of one of the cameras. The focal length of the camera is set as f_1 and f_2 , respectively, the included angle between the optical axis and the axis as α_1 and α_2 , respectively, and the projection angle as ω_1 and ω_2 , respectively. The error analysis model of machine vision system is established, as shown in Figure 5.

As shown in Figure 5, the coordinates of any point in space are shown in the following equation:

$$\begin{cases} x = \frac{B \cot(\omega_1 + \alpha_1)}{\cot(\omega_1 + \alpha_1) + \cot(\omega_2 + \alpha_2)} \\ y = Y_1 \frac{z \cdot \sin \omega_1}{f_1 \sin(\omega_1 + \alpha_1)} = Y_2 \frac{z \cdot \sin \omega_2}{f_2 \sin(\omega_2 + \alpha_2)} \\ z = \frac{B}{\cot(\omega_1 + \alpha_1) + \cot(\omega_2 + \alpha_2)} \end{cases} \quad (5)$$

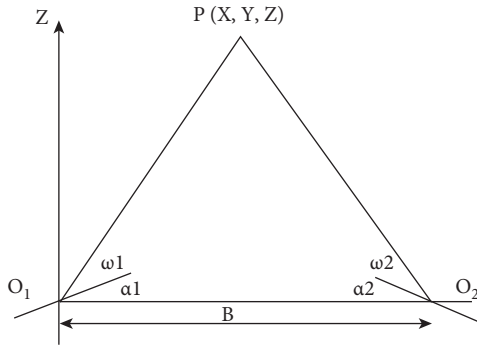


FIGURE 5: Error analysis diagram of the machine vision system.

Assuming that the errors of the two cameras in the X direction are δX_1 and δX_2 , respectively, and the errors in the

Y direction are δY_1 and δY_2 respectively, the errors of the P point in the x -axis direction in the space are shown in the following equation:

$$\Delta x = \sqrt{\left(\frac{\partial x}{\partial X_1} \delta X_1\right)^2 + \left(\frac{\partial x}{\partial X_2} \delta X_2\right)^2}. \quad (6)$$

The error of point P in the y -axis direction is shown in the following equation:

$$\Delta y = \sqrt{\left(\frac{\partial x}{\partial X_1} \delta X_1\right)^2 + \left(\frac{\partial x}{\partial X_2} \delta X_2\right)^2 + \left(\frac{\partial y}{\partial Y_1} \delta Y_1\right)^2 + \left(\frac{\partial y}{\partial Y_2} \delta Y_2\right)^2}. \quad (7)$$

The error of point P in the z -axis direction is shown in the following equation:

$$\Delta z = \sqrt{\left(\frac{\partial z}{\partial X_1} \delta X_1\right)^2 + \left(\frac{\partial z}{\partial X_2} \delta X_2\right)^2}. \quad (8)$$

The overall measurement error of point P is shown in the following equation:

$$\Delta xyz = \sqrt{(\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2}. \quad (9)$$

Analysis known from equation (9), once the camera installation angle is determined, the larger the focal length and of the two cameras selected, the lower the comprehensive error of the system. The focal length of the camera lens selected in this paper is 16 mm. After the test, the error of the machine vision system is low.

5. Conclusion

With the rapid development of China's high-speed rail and the need to detect the dynamic performance of the pantograph-catenary in order to ensure the security of power supply. Based on current technology research and analysis, this paper proposes a method for detecting pantograph and catenary dynamic performance parameters based on machine vision and implements real-time online testing, which has a certain engineering application. This paper designs a detection system for pantograph-catenary dynamic performance parameters. Including the complete overall detection scheme, the hardware equipment is selected according to the detection characteristics of different parameters, and the relevant programs are written. The expected results are achieved

through the test. The pantograph-catenary dynamic performance parameter detection system based on machine vision proposed in this paper has the following characteristics:

- (1) Based on the principle of machine vision, two high-resolution industrial cameras are selected to detect the pull-out value and guide height, which not only realizes the noncontact detection but also improves the detection accuracy.
- (2) According to the photosensitive characteristics of arc burning, the ultraviolet camera equipped with ultraviolet bandpass lens is used for arc burning detection, which improves the accuracy of arc burning detection and avoids the interference of visible light to a great extent.
- (3) The real-time online test is realized, and the test results of relevant parameters can be clearly obtained in the program user operation interface, which is helpful to the monitoring and fault diagnosis of pantograph catenary state during train operation.
- (4) The combination of video image processing and kilometer marker detection is conducive to the location and fault analysis of fault points or over standard points.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Application of Response Surface Methodology in Dance Health and Training Safety

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In order to analyze and optimize the influencing factors of dance health and training safety, response surface methodology is applied to dance health and training safety in this study. Response surface methodology is an optimization method that integrates experimental design and mathematical modeling. It can effectively reduce the number of experiments, provide visual contour maps and three-dimensional diagrams, and investigate the interaction between influencing factors. This paper introduces the basic definition, model construction principle, and characteristics of the response surface method and expounds the test scheme design, model establishment, model inspection, model optimization, and other aspects of the response surface method combined with an example of analysis of influencing factors of dance health and training safety. The results show that the response surface method is an optimization method of comprehensive experiment design and mathematical modeling, which can effectively reduce the number of experiments for the analysis of influencing factors of dance health and training safety and can investigate the interaction between influencing factors.

1. Introduction

Dance sport is a highly artistic sport in which paired male and female athletes play music on a flat and smooth ground, which is arranged according to a certain level, with the help of human body movements to express emotional skills and show the beauty of the unity of the mind and body [1–5]. Dance is a new sports genre that combines sports and art and has the functions of exercise, competition, and aesthetics. It has a strong sports nature and is prone to accidental injury in the process of sports, which will affect further training and competition [6–11]. Therefore, it is necessary for us to study the dance health and training safety in teaching and competition.

Nowadays, dance is developing towards higher competitiveness and performance, and the requirements for dancers' ability, physical quality, and psychological quality are also higher [12–14]. The occurrence of sports injury increases with the increasing high-intensity training, and the injury is difficult to avoid, which directly affects the performance of dancers [15–17].

The nature and characteristics of sports injuries of dancers are summarized and analyzed, including the following points. (1) Male athletes' actions are loud and powerful, with clear movement and stillness; the free and changeable dance posture of female athletes is mainly reflected in the waist, abdomen, and upper limbs. The movement range is large, and the frequency is fast, which makes the sports injury rate of female athletes higher than that of male athletes. (2) Latin dancers bear more intense exercise intensity than modern dancers, and their action frequency and range are also required to be higher. Therefore, the proportion of injuries of Latin dancers is slightly higher than that of modern dancers. The incidence of acute injuries of dancers is higher than that of chronic injuries. (3) Most of Latin dances experience acute injuries, while most of chronic injuries occur in modern dances. (4) Due to the inherent characteristics of dance, the amount of exercise of the lower limbs is much greater than that of the upper limbs, and the requirements for flexibility, strength, speed, and other qualities are higher than those of the upper limbs. Therefore, the incidence of injury in the lower limbs is

higher than that in the upper limbs, mainly sports injuries of knee joints, ankles, and ligaments of the lower limbs.

In recent years, the progress of computer and information technology [18–23] has also provided a powerful tool for the dance health and training safety analysis of this study. In order to promote the safety of dance teaching and competition, this study adopts response surface methodology [22] to study the accidental injuries and characteristics in dance teaching and competition, analyzes the causes, and puts forward corresponding safety precautions to reduce the incidence of injuries in safety measures. Combined with the causes and nature of accidental injuries caused by inadequate safety precautions in dance teaching and training, this paper puts forward safety precautions suitable for dance sports teaching and competition, which have certain guiding significance for dance athletes to avoid accidental injuries, enhance their awareness of prevention, and prevent injuries in teaching and competition.

2. Analysis on the Main Causes of Dance Health and Training Safety

2.1. Analysis Object. The analysis object is the accidents and safety precautions in dance teaching and competition. It can be summarized as the following main factors: poor physical quality (strength and flexibility), poor training or pre-competition preparation activities, incorrect technical essentials, improper cooperation between dance partners, excessive fatigue, unclear music, and dance rhythm, and the dancers' lack of attention to sports prevention.

2.2. Analysis Methods. The analysis methods mainly include the following five types:

- (1) *Documentation Method.* Through the university libraries and CNKI, we can access the materials related to dance sports injuries and safety precautions.
- (2) *Expert Interview Method.* We interviewed experts who have been engaged in dance teaching in universities for a long time to understand the characteristics of injuries caused by various emergencies in dance sports.
- (3) *Questionnaire Method.* We used the previous research questionnaire, modified the content, prepared the questionnaire, and randomly surveyed the 2012 dance students in the Art Department of the University. A total of 50 questionnaires were distributed, and 48 valid questionnaires (23 men and 25 women) were recovered. The recovery efficiency was 96%.
- (4) *Mathematical Statistics Method.* We conducted statistical routine analysis and processing on the collected data and summarized the frequency of different accidental injury accidents so as to provide data basis for this study.
- (5) *Logical Analysis Method.* Combined with the injuries caused by accidents in dance, we analyze and discuss the awareness of safety precautions in dance and refine it into the conclusion of this study.

2.3. Analysis Results. Through the above analysis, we found that the main contributing factors of dance health and training safety are the following aspects.

2.3.1. Poor Physical Fitness. Poor physical fitness is one of the most important factors causing sports injury, ranking first among the injury factors. In fact, strength quality is one of the most important foundations of sports. How to smoothly, stably, and substantially complete the complete set of dance movements with changeable rhythms and diverse movements has put forward higher requirements for the strength quality of dancers. Strengthening strength quality training can reduce the occurrence of sports injuries of dancers, reduce the severity of sports injuries, and achieve self-protection.

2.3.2. Poor Preparation before Training or Competition. The incidence of sports injuries caused by poor preparation of dancers is very high. Inadequate preparation activities will reduce muscle viscosity, inhibit muscle working ability, make it unable to adapt and coordinate with muscle work, and increase the occurrence of muscle sports injury. At the same time, it cannot effectively improve the working state of the heart and internal organs, affecting the role of protecting the heart and internal organs. The amount of preparatory activities is too large. When athletes enter the formal training competition, their physical function has decreased, or they are tired. In this case, they are prone to muscle and ligament strains and sprains.

2.3.3. Incorrect Technical Essentials. Dancers need high accuracy to complete difficult movements. If they are careless, they will deviate from the correct technology, resulting in technical errors and sports injuries. Correct technical movements can not only finish the difficult movements gracefully and lightly but also prevent sports injuries.

2.3.4. Improper Coordination between Partners. Dance is a sport for men and women to cooperate. Male and female dance partners must have a tacit understanding. The strength coordination is inconsistent, and the movement rhythm is not similar. The male leads the female heel and focuses on the lead of the male partner. It is very important to complete each movement and the alternation of dance steps. In the process of dancing, if the male partner does not give the female partner hints and guidance, or the female partner is too active or changes the dance steps at will, it is easy to collide with each other and lead to disconnection, resulting in unnecessary sports injury.

2.3.5. Excessive Fatigue. Dance is a skill-oriented performance, and it takes a long time and a large amount of exercise training to master the relevant technologies. Moreover, the players often participate in multiple rounds of dance competitions and a large number of performances,

which makes the dancers consume a lot of physical strength, and it is very easy to cause excessive fatigue or tension in the body and psychology of male and female players, resulting in sports injury.

2.3.6. Lack of Ideological Attention. Dancers do not pay enough attention to sports injuries in ideology and lack knowledge about the generation and prevention of sports injuries, which often leads to unnecessary injuries in the process of sports. The uninjured dancers should learn more and pay more attention to the sports injury and prevention of dance so as to minimize the incidence of sports injury; dance injured people should look for the most timely and effective treatment to reduce the harm caused by the injury in the event of injury. After rehabilitation, we should pay attention to its prevention, understand the most effective means to prevent sports injury, and achieve self-protection.

3. Response Surface Methodology and Its Application in Dance Health and Training Safety

Response surface methodology (RSM) is a test design method proposed by Box et al. It is an optimization method that integrates test design and mathematical modeling [22–27]. By performing tests on representative local points, the functional relationship between factors and results in the global scope is regressed and fitted, and the optimal level value of each element is obtained. Initially used for the fitting of physical experiments, in recent years, it has become a newly developed optimization theory method in the world and is widely used in the fields of the chemical industry, agriculture, pharmacy, environment, and mechanical engineering. Many scholars and researchers at home and abroad have carried out lots of research [27]. Compared with the currently widely used orthogonal test design method, orthogonal experiments cannot obtain a clear functional expression between the test factors and the response target over the specified area, so the optimal combination of design variables and the optimal value of the response target cannot be obtained. Moreover, when the test factor has more numbers of levels, using the orthogonal design method still needs to do many tests, and it is not easy to implement. The response surface method has the advantages of fewer tests, short test periods, high precision, high accuracy of the regression equation, good prediction performance, and the ability to study the interaction between several factors. It has been widely used in many fields.

3.1. Principle. The response surface methodology uses a limited test design for a set of sample points within a specified design space. It fits a global approximation of the output variable (system response) in place of the actual response surface. In the engineering optimization design, the application of the response surface method can not only obtain the changing relationship between the response target and the design variables but also obtain the optimization

scheme, that is, the optimal combination of the design variables so that the objective function can be optimized.

Before building an approximate response surface model, the relationship between the design variables and the analysis objectives should be clearly defined. Choose an appropriate functional form to describe the relationship between the current design variables and the analysis objectives. At present, the methods of constructing the response surface mainly include polynomial, exponential function, logarithmic function fitting, and approximate methods such as a neural network. According to the Weierstrass polynomial best approximation theorem, many types of functions can be approximated by polynomials, and the polynomial approximation model can handle a wide range of nonlinear problems. Therefore, in practical applications, a polynomial approximation model can always be used for analysis regardless of the relationship between the design variables and the objective function.

The regression model uses polynomials of different orders to approximate the relationship between the represented target and the design variables. It has the characteristics of a simple mathematical representation, small calculation amount, and fast convergence speed and can be represented explicitly. It is the most in-depth research study at present and the most widely used method.

Generally, the system response Y and the design variable x satisfy

$$Y = \tilde{y}(x) + \delta. \quad (1)$$

Here, $\tilde{y}(x)$ is the approximate function of the unknown function, and $x = [x_1, x_2, \dots, x_n]$ is the n -dimensional independent design variable; δ is the total error, including the random error, modeling error, and systematic errors.

If a polynomial response surface is used to approximate the relationship between the system input and the response target, then

$$\tilde{y}(x) = \beta_0 + \sum_{i=1}^k \beta_i \varphi_i(x). \quad (2)$$

Here, $\varphi_i(x)$ is the basis function; β_i is the basis function coefficient; and k is the number of $\varphi_i(x)$.

In practical applications, the form of the polynomial response surface model can be determined according to engineering experience. Usually, a low-order polynomial approximation is used within a certain range of design variables, such as fitting with a linear function or a second-order model. The basis functions of the first-order and second-order polynomial approximation models are

$$\begin{aligned} Y &= \beta_0 + \sum_{i=1}^k \beta_i x_i, \\ Y &= \beta_0 + \sum_{i=1}^k \beta_i x_i + \sum_{i=1}^k \beta_{ii} x_i^2 + \sum_{i=1}^k \sum_{i < j} \beta_{ij} x_i x_j. \end{aligned} \quad (3)$$

Almost all RSM problems can be solved by one or both of the above two models. Of course, a polynomial model cannot be a reasonable approximation of the real functional

relationship in the whole space of independent variables, but it usually does well in a relatively small area.

The least square method can be used to estimate the parameters of the approximate polynomial and then do response surface analysis on the fitting surface. If the fitting surface is a reasonable approximation of the real response function, the analysis of the fitting surface is approximately equivalent to the analysis of the actual system. If the experimental design can be properly used to collect data, the model parameters can be estimated most effectively.

3.2. Test Design. By taking response surface methodology optimization of dance training design as an example, the application of response surface methodology in test design and optimization using Design-Expert software is introduced to improve the level of dance health and training safety.

3.2.1. Selection of Test Factors and Determination of the Optimal Range of Single Factors. There are many methods to determine the design factors and levels of response surface experiments, and the commonly used methods include using the results of the existing literature, single-factor tests, climbing tests, and two-level factorial design tests. Through relevant literature results and single-factor experiments, it was determined that the influencing factors of the improvement of dance health and training safety level mainly depend on the physical fitness, correctness of technical movements, and site facilities. The fuzzy evaluation method [18–21] is used to assign values to them. Their value ranges are 0–1.0, 0–1.0, and 0–1.0, respectively.

3.2.2. Response Surface Experimental Design. There are many response surface test design methods; and the more commonly used are Box–Behnken design (BBD) and central composite design (CCD). The test design divides the experimental points into central, cubic, and axial points, as shown in Figure 1.

BBD is a commonly used test design method for response surface optimization, which is suitable for optimization experiments with 2 to 5 factors. Box–Behnken design with 3 levels for each factor were coded as $(-1, 0, 1)$. The design table is arranged with 0 as the center point, and $+1, -1$ are the cubic points corresponding high and low values. The distribution of experimental points in the BBD design is shown in Figure 2 (taking three factors as an example).

CCD are also sometimes referred to as star point designs. The design table comprises the cubic points of the two-level factorial design plus the axial point and the center point. The CCD method takes 5 levels for each factor and is coded by $(0, \pm 1, \pm \alpha)$, and 0 is the center point, while α is the extreme value corresponding to the axial point ($\alpha = 2^{(k/4)}$ (k is the number of factors)) .

When the factors are the same, because there is no axial point, the number of tests of the Box–Behnken design is less and more economical. The optimal process-level value

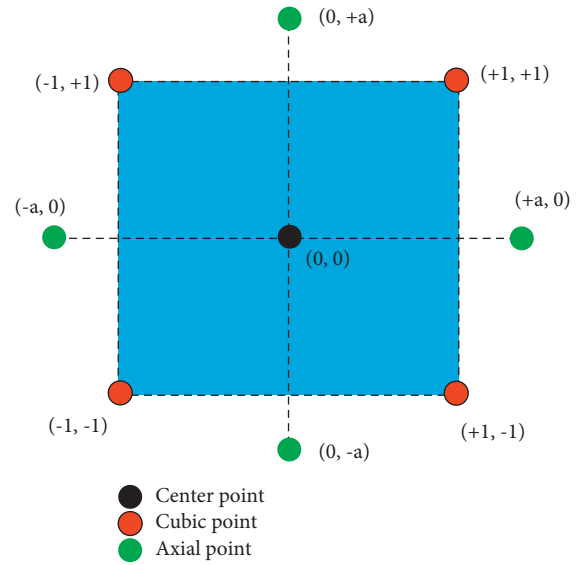


FIGURE 1: Cubic point, axial point, and center point in test design.

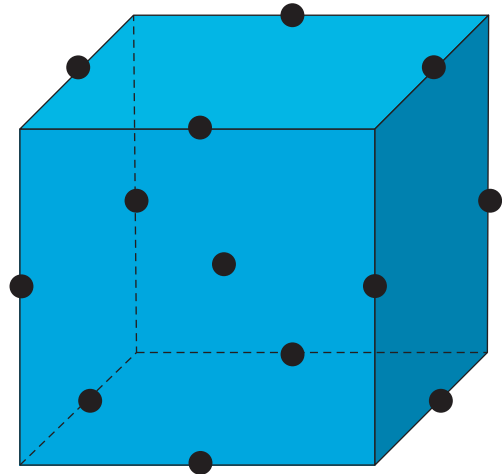


FIGURE 2: Distribution of experimental points in BBD test design.

solved by optimization will not exceed the highest value range. It is especially suitable for some tests with special needs or safety requirements. According to the determined test factors and levels, the Box–Behnken combinatorial design method in Design-Expert software was used to determine the experimental design of the MAP method. Taking the optimal value point of each single test factor as the center, one level value in the upper and lower regions is taken as the design level of the response surface test. The corresponding design factor level values and coding values are shown in Table 1.

Then, we input each factor and its level value into the system, in turn, to generate the test plan table (Table 2). We carry out the test according to this scheme, record the test results of each factor combination, and fill in the test results in the corresponding columns. The degree of improvement of dance health and the training safety level ($Y\%$) of each test is shown in Figure 3.

TABLE 1: Design factor codes and levels.

Factor	Variable	Level		
		-1	0	+1
Physical fitness	X_1	0.0000	0.5000	1.0000
Correctness of technical movements	X_2	0.0000	0.5000	1.0000
Site facilities	X_3	0.0000	0.5000	1.0000

TABLE 2: Response surface test design and results.

Id of the test	X_1	X_2	X_3	Degree of improvement of dance health and the training safety level (Y/%)
1	0.0000	0.5000	0.0000	69.0579
2	0.0000	0.5000	1.0000	82.8232
3	0.0000	1.0000	0.5000	90.7185
4	0.0000	0.0000	0.5000	39.5179
5	0.5000	0.5000	0.5000	89.5732
6	0.5000	0.0000	0.0000	52.1185
7	0.5000	0.5000	0.5000	89.8379
8	0.5000	1.0000	1.0000	91.2732
9	0.5000	0.5000	0.5000	88.2785
10	0.5000	0.0000	1.0000	54.1379
11	0.5000	1.0000	0.0000	71.8532
12	1.0000	0.0000	0.5000	64.5285
13	1.0000	1.0000	0.5000	62.2379
14	1.0000	0.5000	1.0000	73.5832
15	1.0000	0.5000	0.0000	67.9185

3.2.3. Model Building and Testing. We use Design-Expert software to analyze the test results. First, click the Analysis button to test the significance of the linear function, 2FI model, second-order model, and third-order model. By comparing the data of the model significance test, the lack of the fit test, and the correlation test, a suitable model is recommended. The results of this test protocol recommend the use of a second-order model. Then (click the ANOVA button), variance analysis and significance tests are performed according to the selected model. In the analysis of variance, the significance of the constant term, a linear term, the quadratic term (interaction term), and the square term (surface effect) affecting the quadratic equation model will be tested, as shown in Table 3.

The fitted regression equation is

$$Y = 88.2315 - 1.7289X_1 + 13.2156X_2 + 5.1206X_3 - 13.3785X_1X_2 - 200312X_1X_3 + 4.3526X_2X_3 - 10.0231X_1X_2X_3. \quad (4)$$

The error statistics of the fitted regression equation were further analyzed, and Design-Expert software calculated the precision, multivariate correlation coefficient, reliability, and accuracy, as shown in Table 4.

Large F values and small P values represent the significance of the correlation coefficient. The $Pr > F$ value < 0.05 of the analysis of the variance model is considered to be significant, the fitting accuracy is good, and the response surface approximate model can be used for subsequent

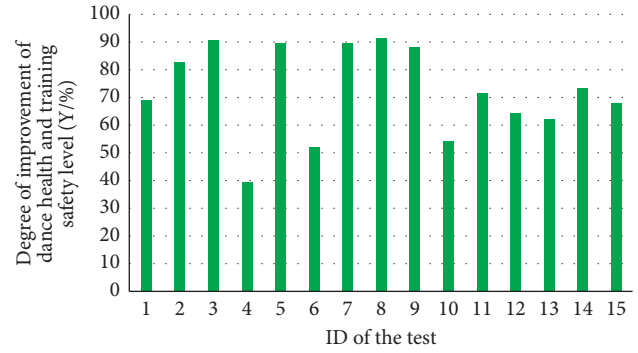


FIGURE 3: The degree of improvement of dance health and the training safety level (Y/%).

optimization design; lack of fit item $Pr > F$ value > 0.05 indicates insignificant; that is, the model fits well in the entire regression area under study; the more significant the multivariate correlation coefficient R^2 , the better the correlation; Adj R-Squared and Pred R-Squared ($R^2_{Adj} - R^2_{Pred} < 0.2$) are high and close to Adj Pred, then the regression model can fully explain the process; if it is not high, it means that the explanation of the process is not sufficient, and it is necessary to consider whether there are other significant influencing factors. CV $< 10\%$ indicates high reliability and precision of the experiment; Adeq Precision is the ratio of effective signal to noise, and it is considered reasonable if it is greater than 4. It can be seen from Table 4 that the fitted regression equation complies with the above test principles and has good adaptability.

4. Measures to Improve Dance Health and Training Safety

In view of the main influencing factors of dance health and training safety, after the analysis by response surface methodology, we put forward the following countermeasures and preventive measures for the health and training safety problems in dance teaching and competition.

4.1. Popularizing the Common Sense of Safety Precautions and Improving the Self-Protection Awareness of Practitioners.

Dance requires great intensity and fast pace, and there are many hidden safety hazards in the process of sports. Teachers should explain and pass on the common sense of safety precautions in dance training and competition to the practitioners so that the practitioners can understand the basic situation of accidents prone in dance sports, improve their awareness of active protection, pay attention to the safety precautions in dance teaching and competition ideologically, and reduce the occurrence of accidental injuries.

4.2. Strengthening Physical Fitness Training and Paying Attention to Recovery after Training.

Teachers should pay attention to the training of the physical quality of the practitioners, focusing on the training of the joints and

TABLE 3: The regression equation analysis of variance.

Type	SS	DF	MS	F	$P_r > F$	
Model	3659.3887	9	406.5987	128.9187	<0.0010	**
X_1	23.9822	1	23.9822	7.6022	0.0004	*
X_2	1398.6115	1	1398.4115	443.4015	<0.0010	**
X_3	208.6873	1	208.6873	66.1673	0.0005	**
X_1X_2	715.2987	1	715.2987	226.7987	<0.0010	**
X_1X_3	16.4022	1	16.4022	5.2022	0.0715	Not significance
X_2X_3	75.6915	1	75.6915	24.0015	0.0045	**
X_1^2	332.4373	1	332.4373	105.4073	0.0002	**
X_2^2	885.7887	1	885.7887	280.8587	<0.0010	**
X_3^2	151.0622	1	151.0622	47.9022	0.0010	**
Residual	15.7715	5	3.1515			
Lack of fit item	14.3773	3	4.7873	6.8973	0.1288	Not significance
Pure error	1.3887	2	0.6987			

Note. SS: the sum of squares of variation, DF: degree of freedom, MS: mean square, and $Pr > F$: the probability of no significant effect; ** represents very significance, and * represents significant.

TABLE 4: Statistical analysis of regression equation errors.

Statistics project	Value
Std. Dev.	2.4287
Mean	73.7722
CV/%	3.2915
PRESS	250.4373
R-squared	0.9928
Adj R-squared	0.9932
Pred R-squared	0.9868
Adeq precision	52.2573

muscle ligaments that are prone to injury so as to improve the strength of the small joints and the activity of the muscle ligaments, form effective support in sports, and improve the safety in sports. After training, appropriate relaxation and recovery work should be carried out in time to reduce the fatigue caused by training, promote physical recovery, and reduce the accident rate caused by decreased attention due to fatigue.

4.3. Reasonably Arranging the Training Load and Carrying Out Adequate Preparation Activities. The training load shall be reasonably arranged to avoid excessive exercise on local areas, such as excessive step training with high intensity, resulting in joint and muscle fatigue. Proper preparation activities can improve muscle excitability and prepare for sports training and competition. Before training and competition, sports dance practitioners should carry out sufficient preparation activities to improve the physical and mental excitement, improve the directivity of attention, and effectively avoid muscle strain caused by insufficient warm-up and inattention caused by low excitement.

4.4. Improving Safety Awareness and Eliminating Potential Safety Hazards. Before training and competition, both teachers and students should inspect the training ground to find and eliminate potential safety hazards. In terms of clothing, avoid wearing inappropriate clothes and high

dancing shoes and avoid wearing jewelry that is easy to cause injury or articles that are easy to cause injury to yourself or others. Practitioners with physical diseases should carry medicines with them, inform their dance partners or coaches of their diseases before training and competition, and prepare for all problems in advance.

5. Conclusions

In order to provide the application of response surface methodology in the experimental design and optimization of the analysis of influencing factors on dance health and training safety, Design-Expert software is used for the experimental design and analysis of response surface methodology, providing intuitive contour maps and three-dimensional diagrams, establishing prediction models, and being able to test the model adaptability, the significance of models and coefficients, and the nonfitting items so as to further carry out variance analysis and model diagnosis. By optimizing the model established by response surface methodology, an experimental optimization scheme can be proposed to solve the problems encountered in the practical application of response surface methodology in experimental design and optimization.

Response surface methodology not only establishes the prediction model but also tests the adaptability of the model, the significance of the model and coefficient, and the mismatch and further carries out variance analysis and model diagnosis. The response surface methodology can effectively guide the optimization of the design of the test scheme in the analysis of dance health and training safety, which is conducive to improving the benefit of the test. However, it is a complex process to construct the response surface approximation model that can meet the optimal design of practical engineering. It also needs to repeatedly collect the test data, fit the approximate model, and test the accuracy of the response surface.

Response surface methodology also has its limitations. The premise of response surface optimization is that the designed experimental points should include the best experimental conditions. If the experimental points are

improperly selected, the response surface optimization method cannot get good optimization results. Therefore, before using the response surface optimization method, we should establish reasonable experimental influencing factors and levels.

Data Availability

The dataset can be accessed upon request to the author.

Conflicts of Interest

The author declares no conflicts of interest.


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Research Article

Dance Action Generation Model Based on Recurrent Neural Network

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In recent years, modeling methods based on Deep Learning and Recurrent Neural Network (RNN) have achieved rapid development in various tasks in the field of computer vision, and video generation technology has also achieved remarkable results on this basis, with boosting effect. This paper analyzes the requirements and system design of the dance generation system based on cyclic neural network and clearly puts forward the specific functional requirements and nonfunctional requirements. Design, test each function of the system, and show the graphs generated by our application during training and testing, and visualize the specific value of the loss function during training. Combining the latest image generation technology and the most effective open source gesture detection project, a dance generation algorithm is completed, which can generate a video of the target person completing the specified dance action.

1. Introduction

The traditional manual drawing of dance scores by observing human movements is very time-consuming. An ordinary dance of about 30 minutes takes a professional dance expert a month to complete. With the development and popularization of deep learning in recent years, artificial neural networks have been successfully applied to the generation of dance movements. A significant advantage of using deep learning for dance generation is their ability to directly extract high-level features from raw data (audio, motion capture data, etc.). In addition, deep neural networks are able to create new dance moves. Recurrent neural networks have been widely used to generate human face images and natural scene images, and there are currently many methods to stabilize the adversarial training process and significantly improve the generated image quality. In order to better solve the general video synthesis problem, we need to understand how the image pixels change in order to generate a complete object action picture with temporal dimension. The precise motion between frames of a moving object in a video has

high uncertainty, but by simulating the uncertainty of the underlying structure of the moving object, the above problem becomes tractable. Assuming that our input data is human pose, from the application's point of view, the user usually considers specific intentions such as changing the background, object's class, color, appearance information, etc. We can express this intent in an appropriate way to explicitly guide the generation process to achieve direct control over the image generation process. Specifically, we believe that it is reasonable to generate images by conditioning on a reference image and specifying poses. The reference image is used as the input condition of the network, and the model has enough information about the appearance of the expected object in advance, while the guidance given by the expected pose skeleton map is both explicit and flexible. So in principle, this method can manipulate any object to accomplish any pose. In this work, we focus on transferring a person from a given pose to a predetermined pose. Many interesting applications derive from this task. For example, in movie production, we can directly manipulate a character's body into a desired pose; or

for human pose estimation, we can generate training data for rare but important poses [1–8]. In this paper, a multilayer joint network model lower limb action recognition algorithm based on long short-term memory neural network (LSTM) and convolutional neural network (CONVNET) is proposed. The generation of lower limb movements in dance needs to consider the dynamic relationship of movements. The self-connected network structure of LSTM makes it have a natural advantage in processing dynamically changing time series data, and CONVNET is very good at learning the spatial information of movements. The LSTM model is fused with the CNN model, so that the two can complement each other and achieve a more accurate recognition effect.

2. Related Works

With the advancement of machine learning technology, various machine learning algorithms have been proposed to generate dance moves in the form of motion capture data. Hidden Markov Models (HMMs) are also used to generate dance moves. As early as 2005, Yi Wang et al. proposed a new model NPHHMM (nonparameter hierarchy Hidden Markov Model), which is a hierarchical Hidden Markov Model with nonparametric output density. They applied it to create a motion engine for learning and reproducible creation of human movements. In their study, they trained NPHHMM on motion capture data containing ballet steps, ballet rolls, disco, and complex disco movements. In 2012, Tape et al., inspired by earlier papers, proposed a new framework for learning many-to-many statistical mappings from musical features to dance graphs. Based on these statistical maps, they defined a discrete Hidden Markov Model and synthesized candidate dance figure sequences using a modified Viterbi algorithm [9]. The model is able to classify music genres based on the Mel-Frequency Cepstrum Coefficients (MFCC) features of the music and generate corresponding dance moves based on the music genres. In 2016, Luka Crnkovic-Friis and Louise Crnkovic-Friis proposed a system called Chor-RNN to generate novel dance material with meticulous dance language and specific styles. It employs a mixed-density long-short-term memory (LSTM) type RNN and is trained with motion-captured modern dance. After 48 hours of training, the model was able to understand and generate choreography grammars and styles well and to some extent semantics. This is the first attempt to apply deep recurrent neural networks to the field of automatic choreography and successfully generate new choreographic sequences. However, the model only considers generating dance moves; it does not provide any way to accompany any music. Inspired by Crnkovic-Friis, in 2017 Omid Alemi et al. introduced an application called GrooveNet, which uses Conditional Restricted Boltzmann Machines (FCRBM) and recurrent neural networks. The network (RNN) generates dance moves. The results show that the application is able to learn and generate dance patterns from a very small training set. However, if the music used is not included in the training set, the effect is not ideal. In 2018, Juheon Lee et al. proposed a neural network-based model that can generate novel and natural dance moves. The

researchers obtained audio-video data pairs from YouTube and used it as a training set. The model extracts the x , y coordinates from the video as motion features and then extracts Mel as audio features. The skeleton sequence is then generated using an autoregressive encoder-decoder network, and the results are compared with the real data using the MSE loss as a cost function. However, if the training dataset is not large enough, the system is not stable enough. A well-designed deep recurrent neural network is proposed by Nelson Yalta et al. The model employs one-dimensional convolutional layers and multiple long short-term memory (LSTM) layers as the encoder part to process the audio power spectrum and then utilizes the LSTM layer as the decoder part to generate dance movements. In the decoder part, the self-encoder module is used to reduce the accumulation of feedback errors. The model has reliable motion generation performance and can be applied in real time. Taoran Tang et al. also proposed a well-designed deep learning model to extract the mapping between sound and motion features. Furthermore, they use temporal indexing and masking methods for better performance. As can be seen from previous literature, in recent years, deep neural networks have been the dominant method in the field of computer choreography [10–15].

3. Related Theories and Technical Methods

3.1. OpenPose Pose Detection Framework. Human posture is a description of a person's posture in the form of coordinates. Essentially, a human pose is a set of coordinate points that can be connected to describe a person's pose. OpenPose is one of the most popular multiperson human pose estimation algorithms. Like many bottom-up methods, OpenPose first detects the keypoint coordinates of all people in the image and then assigns the detected keypoints to each corresponding person. In practice, the OpenPose network first extracts features from images using the first few network layers of VGG-19. Next, these features are passed to two parallel branches of convolutional layers. The first branch is used to predict 18 confidence maps, each representing a joint in the human skeleton. The second branch predicts a set containing 38 joint affine fields (Part Affinity Fields, PAFs) that describe the degree of connectivity between joints. A series of steps are then used to optimize the predicted value of each branch. Using the joint confidence map, a bipartite graph can be formed between each joint pair. Then use the PAF value to remove weaker connections in the bipartite graph. Through the above steps, the key points of the human body posture of all the people in the picture can be detected [16].

3.2. Image Generation. Many researchers utilize adversarial learning for image-to-image transfer, which aims to transform an input image into another domain space as a synthetic image. Compared to $L1$ loss, which usually results in blurry images, adversarial loss has become the mainstream choice for many image generation tasks. The reason is that the loss function that the discriminator can learn is trainable

and can automatically adapt to the difference between the generated and real images in the target domain. For example, the recent Pix2Pix framework using image-conditioned GANs has been applied to applications in different scenarios, such as converting Google Maps to satellite views or generating synthetic images of cats from user-drawn sketches. The Pix2PixHD framework is based on the Pix2Pix infrastructure and proposes a new method to synthesize high-resolution, realistic images using conditional generative adversarial networks using semantic label maps. Conditional generative adversarial networks have been used in a variety of applications but are limited by the fact that their generated results are usually limited to low resolutions and do not look realistic, while in the Pix2PixHD model, the model is able to generate 2048×1024 high-resolution pictures and visually appealing results. The model features a novel adversarial loss, as well as a new multiscale generator and discriminator architecture [17].

The Pix2PixHD framework shows us that, with a new and powerful adversarial learning objective function and a new multiscale generator and discriminator architecture as shown in Figure 1, it is possible to synthesize 2048×1024 resolution and realistic images, which are much smaller than presynthesized images. Images are more visually appealing. The method only needs to achieve the same result with precise training without relying on any human-specified loss or perceptual loss of a pretrained network (e.g., VGGNet).

3.3. Recurrent Neural Network. The inertial data of the action is a time series structure with sequential order, and changing the input order of the data values of the same size will cause the model results to change. The one-dimensional deformed convolutional neural network is used to realize the processing algorithm of serialized structural data, but the CNN model itself cannot provide temporal correlation, so this paper introduces a cyclic neural network (recurrent neural networks, RNN) and Convolutional Neural Networks [18].

The characteristic of the recurrent neural network is that it contains a ring structure as shown in Figure 2, which makes the state information circulate in its own network, thus providing a time dependency. RNN networks can handle general sequence problems well, such as a small continuous speech, a sentence, and a text description. However, for relatively long sequences, such as a speech recording, an English song, or an article, the RNN network cannot handle it well. Or sometimes we only need to view the most recent information to perform the current task and do not want to remember all the previous data.

The essence of the recurrent neural network \vec{x} encodes the input sequence as a fixed-length hidden state sequence \vec{h} , where $\vec{x}_t = (x_1, \dots, x_t)$ and input time series $h_t = (h_1, \dots, h_t)$. The specific meaning refers to the state sequence that changes with time. The update strategy for the hidden state is as follows:

$$h_t = f(x_t, \vec{h}_{t-1}). \quad (1)$$

$f(x, h)$ for calculating the hidden state is a nonlinear equation, usually a logistic function or a tanh function. From the formula, it can be found that the hidden state information h_t at the current moment is not only related to the current input x_t , but also related to the state sequence retained before h_{t-1} .

Expand the network structure shown in Figure 3 on the time axis, and a structure diagram with a clearer dependency relationship can be obtained as shown in Figure 3. Compared with the common neural network, the calculation results are independent of each other. The results are related to the current input and the last calculation result. In this way, the RNN has the characteristics of memorizing the previous calculation results.

4. Design of Dance Movement Generation System Based on Recurrent Neural Network

4.1. System Structure Design. The key to realizing the dance generation application based on generative adversarial network lies in the patch-based pixel generation in the generative network and the multiscale image discrimination in the discriminant network and the final loss function design. The overall structure of this application is shown in Figure 4 [19].

- (1) Interface layer: The interface layer is mainly used for the interaction between the user and the system, and all functions need to be as simple as possible. This application interface mainly includes various controls and view modules, such as selecting video buttons, displaying video views, generating dance buttons, and text prompt views. The application interface will directly display the original dance video and the generated dance video to the user, compare the synthesis effect, and generate corresponding indicator descriptions. Simple and elegant interface design will bring users a good user experience.
- (2) Logic layer: The logic layer is often the core of the entire application system, including the realization of core functions and the connection between the upper and lower layers. The main functions include reading local video or collecting video data from the current camera. Collecting data is an indispensable function for generating models; in addition, the system needs to call other open source projects to extract skeleton information from the data. More importantly, inputting the skeleton diagram into the trained generation model to get the dance generated by the target is the core of the system application; finally, the system will show the generated dance video to the user, letting users experience the thrill of generating dance videos without having to learn to dance by themselves.
- (3) Data layer: The data layer is mainly used to store and read video data and also includes model storage and generation of video storage and reading. Since this

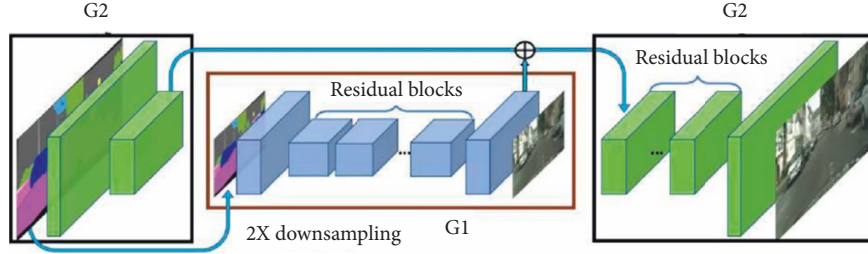


FIGURE 1: Network structure diagram in Pix2PixHD.

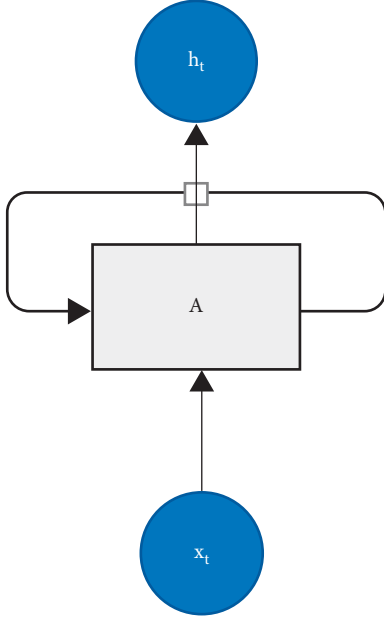


FIGURE 2: Schematic diagram of the ring structure of RNN.

system is an offline system, the model is too large and the training time is long, so online training and generation cannot be realized at present. Therefore, the system must store the pretrained character action model and then generate the dance video of the corresponding character according to the input to the skeleton model. The generated dance video will be stored in the specified directory.

4.2. System Algorithm Design. The task of this application is to simultaneously generate actions between different characters, i.e., transition from a given pose to a desired pose while maintaining important appearance details of the target character. In this application, the system will apply the pose skeleton map (motion representation) to different target subjects to generate new motions. As an intermediate layer, the skeleton map conveys the movement information of the character, and the skeleton map is not restricted by the figure and clothing of the character, so in principle, this application can perform arbitrary actions on any object [9].

4.2.1. Generator Design. In order to improve the user control ability of the generative adversarial network and still improve the resolution and quality of the generated pictures

of the generative adversarial network, we first use paired data for training. As shown in the previous section, the real sample pair is (x, y) . The fake sample pair is $(G(x), y)$. This improvement provides the generation network with the correspondence between the appearance of the character and the skeleton, and this kind of application has a wide range of applications. Similar applications include generating pictures from hand-drawn sketches, coloring grayscale images, and automatic coloring. In order to solve the problem of the quality and resolution of the generated image, we use the Pix2PixHD structure to generate a high-resolution image, as shown in Figure 5. The most important improvement is to use a pyramid method, first output low-resolution pictures, then use the previously output low-resolution pictures as the input of another generation network, and continue to generate better detailed and higher-resolution pictures. What is used in Pix2PixHD is a coarse-to-fine generation network, but this application does not use this structure but only borrows the “coarse” network and uses its fine network. The generator network mainly generates 512×1024 pictures, including a series of self-encoding modules with residuals.

4.2.2. Discriminator Design. In order to be able to distinguish high-resolution real and synthetic images, the discriminator network needs a large receptive field. A deeper network or a larger size convolution kernel can have a larger receptive field, but this is also likely to lead to overfitting of the network and more GPU memory required for too many network parameters. In order to solve this problem in this system, we use the multiscale discriminator proposed in the Pix2PixHD paper. We use 3 discriminators, each of which has the same network structure but operates on different image scales $\{d1, d2, d3\}$. Specifically, we downsample real and synthetic high-resolution images by a factor of 2 and 4 to generate pyramid image data at 3 scales. The discriminators $d1, d2$, and $d3$ are trained to credit real and synthetic images at three different scales. The discriminator has the same structure, but an operation at the coarsest scale has the largest receptive field. It has a global view of the image and guides the generator to generate globally continuous images. On the other hand, the discriminator at the smallest scale encourages the generator to generate finer details. This also makes it simpler to train a coarse-to-fine generator, and scaling a lower-resolution model to meet higher-resolution only requires adding a discriminator at the finest-grained layer, rather than retraining from the skeleton. The input of

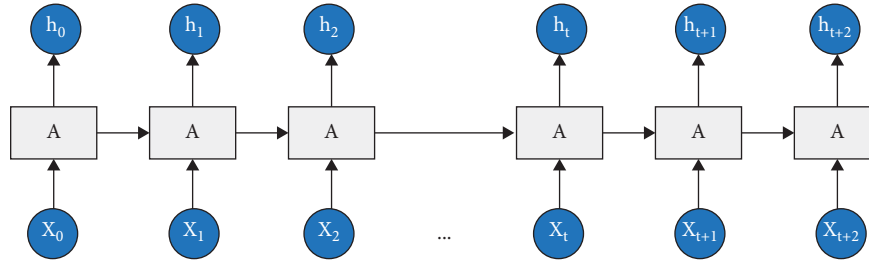


FIGURE 3: Schematic diagram of the time-dependent structure of RNN.

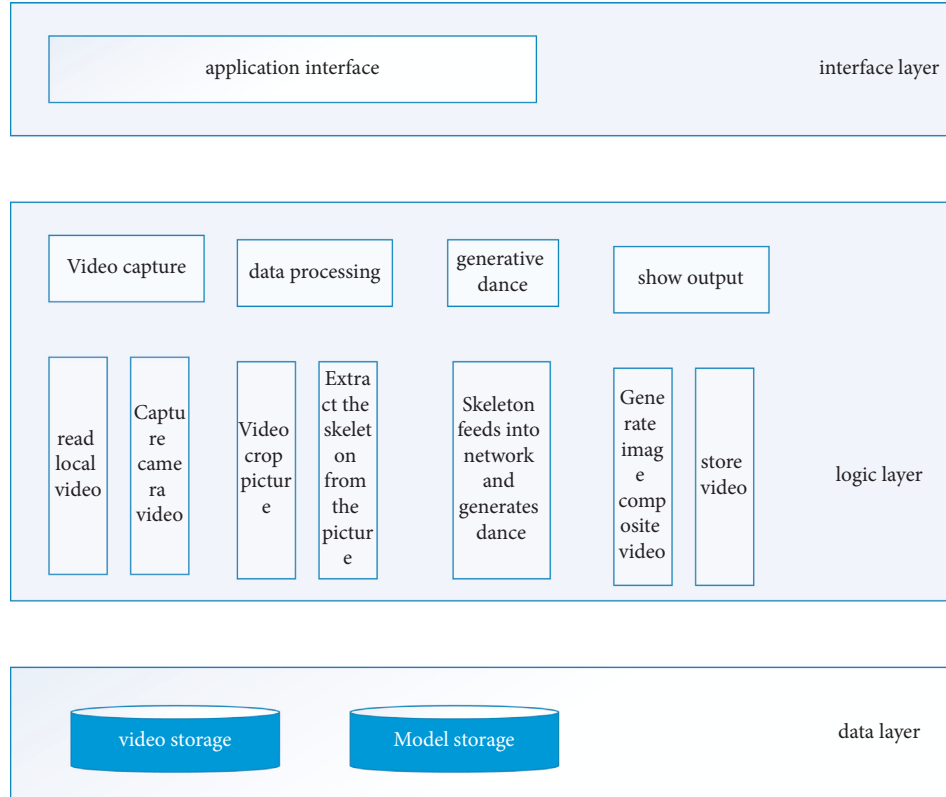


FIGURE 4: Overall system structure.

each discriminative network is images of different scales, and finally the results are fed into a patch-based generative adversarial loss. In this way, the purpose of the discriminator network having a larger receptive field is achieved. The original generative adversarial network has also evolved into a multitask generative adversarial network (see loss function design for details). The multiscale discriminator only has different input image sizes, and other structures are the same, as shown in Figure 6 [20–22].

4.3. System Structure Design. We collect dance source videos as well as target character action videos in different ways. The data structure design of this system is shown in Figure 7, which is divided into training data and test data. In order to learn the appearance of the target character in various poses, we need to capture a sufficient range of actions in the target video, including the character turning around, raising his legs back and forth, hand movements, bending over and

turning his head, etc. And in order to ensure the quality of the video, we need to shoot a video of the target person for about 20 minutes, and the video frame rate is 120 fps.

However, the requirements of the dance source video are not as stringent as that of the training video. We only need to meet the requirements that the source video cannot be shaken during recording and that the distance between the screen and the character is kept reasonable, and the gesture detector can detect the movement information of the character. Training video screenshots and redrawn skeletons are shown in Figure 8.

The key points of the character body mainly include 21 key points of limbs, such as nose, ears, neck, shoulders, arms, hips, knees, and other joints. The key points of the character's hand include 20 key points in each of the left and right hands, mainly including the joints of the five fingers. The key points of the face mainly include 5 key points, mainly the two eyeballs, the nose, the middle, and the chin.

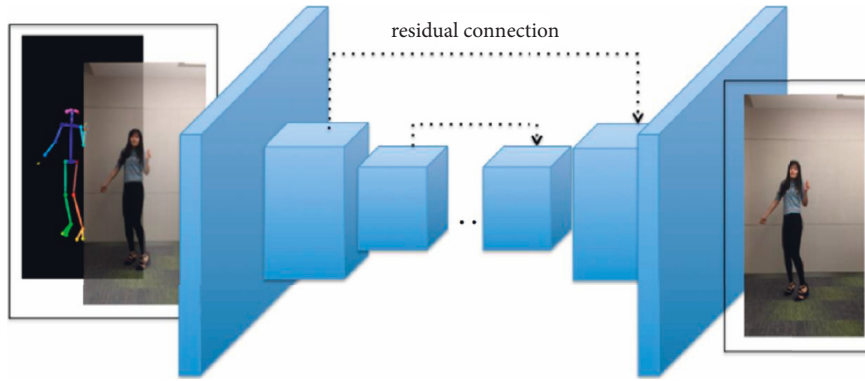


FIGURE 5: Generator network.

5. Implementation and Testing of Dance Movement Generation System Based on Recurrent Neural Network

5.1. System Development Environment. The training and generation of this application are run on the server, and the configuration of the runtime development environment is shown in Table 1. For the core algorithm, a large amount of video memory is required. This time, 8 tesla p100 GPUs are used for training, and the training time is $5 * 24$ hours. Since the system model needs to be trained for a long time, the displayed samples are all models trained in advance.

5.2. Function Realization of Dance Movement Generation System. According to the previous requirement analysis and structural design, this chapter specifically implements the dance generation application based on the recurrent neural network. The core of this article is that the danceTrans algorithm is developed and implemented based on the PyTorch deep learning framework and the open source pose detection OpenPose and image processing open source library OpenCV. According to the system function, it is divided into three parts: data input and output, skeleton extraction, and dance generation.

5.2.1. Implementation of Dance Generation Algorithm. The core algorithm danceTrans of this application mainly designs multiple loss functions to jointly control the output and uses some training techniques to train the model. First, the loss function in the danceTrans algorithm is mainly divided into generator loss and discriminator loss. The generator loss mainly includes adversarial loss, VGG-based perceptual loss, and feature matching loss. Adversarial losses have become a popular choice for many image-to-image tasks because the discriminator can learn a trainable loss function and automatically adapt to the differences between generated and real images in the target domain. The feature matching loss is more important to ensure that the generated model does not oscillate too much. And through specific experiments, it is proved that increasing the VGG perceptual loss can slightly improve the generation results in some cases. The loss of the discriminator mainly includes the loss

of real image pairs and the loss of fake image pairs, that is, the loss caused by discriminating real images as fake and discriminating fake images into real image pairs.

In Figure 9, the loss value saved during the training process is visualized. The content of the figure is the visualized image after the superposition of all generator losses. It can be seen that the generator loss will shake greatly during the training of the generative adversarial network. After several rounds of training, there will be significant relief. However, there is often a sudden jump in a loss value during the training process. We specifically analyze the problem here, mainly because when synthesizing the back image of the character, the distribution of the front image is quite different, so the front and back of the good character are not distinguished when synthesizing, resulting in jitter in the loss value there.

From the discriminator loss graph, which is shown in Figure 10, it can be seen that the discriminator loss has a large loss during the initial training, but after 15 rounds of iterative evolution, the loss value stabilizes within an interval.

5.2.2. Implementation of Dance Data Input and Output Module. The video input of this application can be done in two ways; one is to read the local video, the other is to call the system camera to record the video and store the video locally. Therefore, it is necessary to monitor the data entry button. When the user clicks the record video button, the system will detect the camera device that can be called by the system and activate the device for video recording. When the user's video recording is completed, the user needs to select the video storage address and specify the video name. If the new video file fails, an error message will be returned. When the user chooses to directly read the local video data, the user needs to specify the video file and return the video URL. This application reads the video file according to the URL specified by the user. If the selected video cannot be read or the format of the read video is wrong, an error message will be returned. The video output method of this application is to synthesize the generated image collection into a video file and store it locally. When the dance generation program is completed, the system will generate a new composite image set. The user needs to specify the stored video file and the

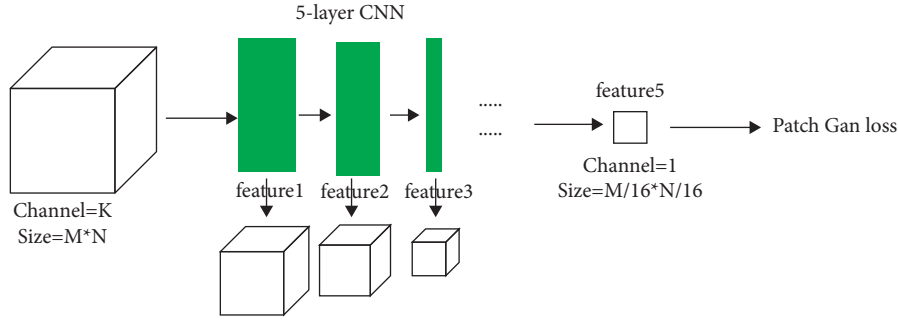


FIGURE 6: Discriminator network.

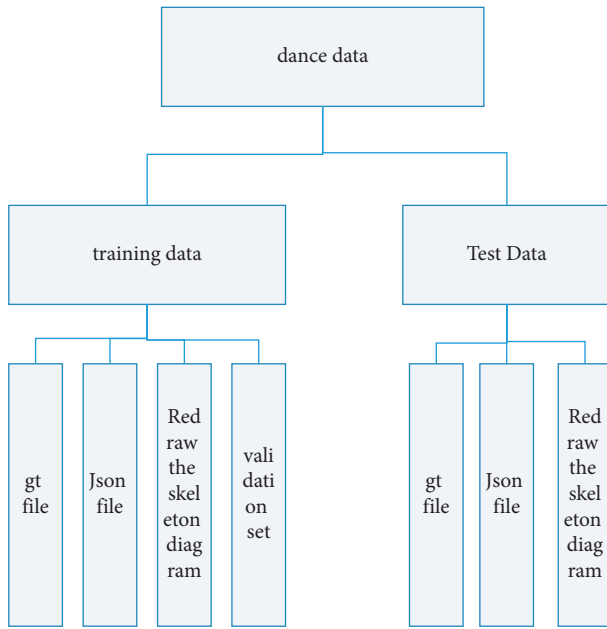


FIGURE 7: Dance data structure diagram.

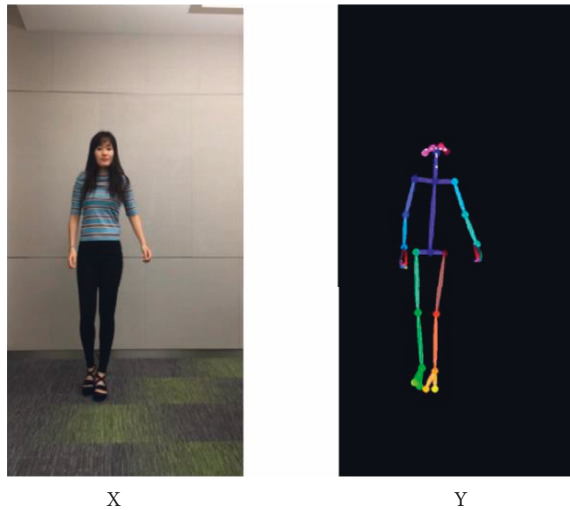


FIGURE 8: Screenshot of training video and redrawn skeleton diagram.

video file name, and the system will create a new video file and store it. If the new file fails, the system will return an error message.

5.2.3. Implementation of Dance Action Skeleton Detection Module. After the video file collection is completed, the application first uses the FFmpeg tool to cut the video file into corresponding frame files and save them as the gt folder; then check the gt folder, including the number of files, file number continuity, and image size; then input all the image files in the gt folder into the OpenPose program component and specify the output path to get the character skeleton JSON file, including 70 face key points, 30 limb key points, and 21 hand key points; then, the application generates the corresponding self-drawn skeleton map set according to the generated JSON folder; for the test, after we get the character skeleton JSON, we use the mean value compensation in the time dimension for the coordinates of each key point (x, y) , full and smooth, and then generate the corresponding skeleton map file.

5.2.4. Implementation of Dance Generation Module. We now detail our complete training pipeline as shown in the training setup in Figure 11. Given a frame y from the original target video, we use a pose detector P to obtain the corresponding pose skeleton map $x = P(y)$. During training, we use the corresponding (x, y) pairs to learn a generator G that maps a given pose skeleton map x to a target person image. By adversarial training with a pretrained VGGNet with a discriminator D and a visual perceptual reconstruction loss, we optimize the generated output $G(x)$ to resemble the real image target subject frame y . The discriminator D tries to distinguish between “real” image pairs (i.e., pose skeleton map x , real person image y) and “fake” image pairs (i.e., pose skeleton map x , generator model output $G(x)$). In the training process, we first spliced the real image of the character and the redrawn skeleton image and spliced according to the color channel of the image. Then the number of channels of the real image of the character is RGB channels, and the skeleton image is also an RGB image, so for the final model of our model the input data is a 6-

TABLE 1: System development and runtime environment.

Host parameters	OS: Centos CPU: Intel E7 system memory: 128 GB GPU: Tesla p100 * 8 GPU memory: 16 GB
Core algorithm development environment	PyTorch version: 0.4 CUDA version: 8.0 IDE: vim development language: Python3
Application test development environment	CPU: Intel E7 PyTorch version: 0.4 GPU: Tesla p100 GPU memory: 16 GB development language: Python3 GUI: PyQt5

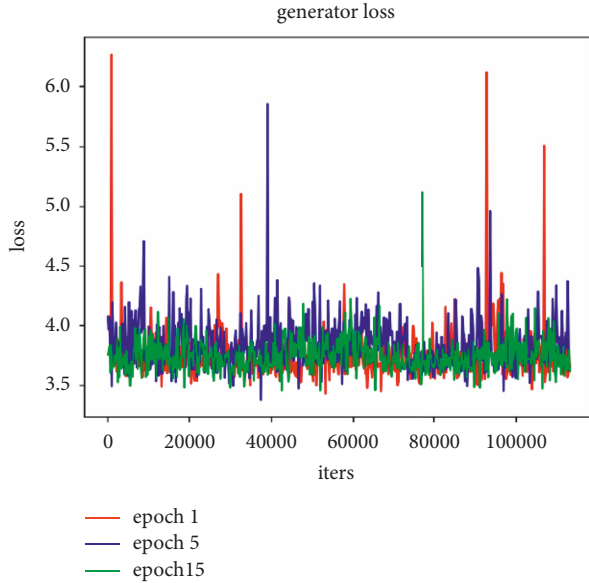


FIGURE 9: Generator loss curves.

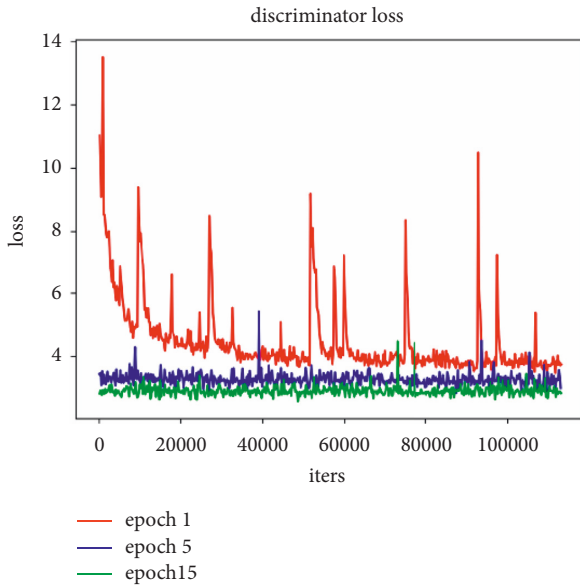


FIGURE 10: Discriminator loss curve.

dimensional $512 * 1024$ combined image. We expect the final model to output a RGB three-channel reconstructed person image. The input of the discriminator is only the RGB real image and the synthesized image of the person. Therefore, the input data format of the discriminator and the

generator will be different, and the discriminator finally outputs only 0 or 1 values to represent real and fake images. Our generative setup is shown in the structural setup in Figure 11. Similar to training, the pose detector P starts from the source frame y' . Generate the extracted pose information, and then input it to the generator to get the final dance generated result image.

To better align the source pose with the target's shooting setup, we generate the source skeleton map to a specified location to make it more consistent with the pose in the target video x . We then pass the pose stick figure x into our trained model G to obtain an image $G(x)$ of our target person corresponding to the original image of the source y' , as shown in Figure 12.

5.2.5. Dance Generation Application Test. According to the requirement analysis and structural design of the dance generation application, this section introduces the testing of each functional module in the testing phase in detail. For each test case, we need to repeat the test for each function multiple times and require all tests to pass to determine that the test case is passed.

Next, we demonstrate how this application performs the effect of dance generation, as shown in Figures 13 and 14; when the user clicks the open button and selects the dance video, the system will cut the video into frame-by-frame images and detect the skeleton information of the characters. After getting the skeleton information, the system will automatically redraw the skeleton of the character and see the redrawn skeleton image passed into the trained model to display the final composite image. It can be seen from this image that when the character generation effect is not good, most of the errors occur in the skeleton extraction, including false detection and missed detection. When the skeleton is relatively clear, the character generation effect is very good. And we do temporal smoothing when compositing the video, which makes our composite video look very coherent.

Finally, the training results of the multiperson model are drawn, and Figure 15 shows the process of generating the same actions for four people from the actions shown in the first row. The first row is the 6 frames of images captured from the source video, the second row is the redrawn character skeleton diagram extracted from the captured images, and the third to sixth rows are the set of action images generated by the target character. The results show that our model can also train well in multiperson (multisample) situations. As can be seen from the figure, our model can synthesize better effects for different character skeletons and has nothing to do with the character's body and background.

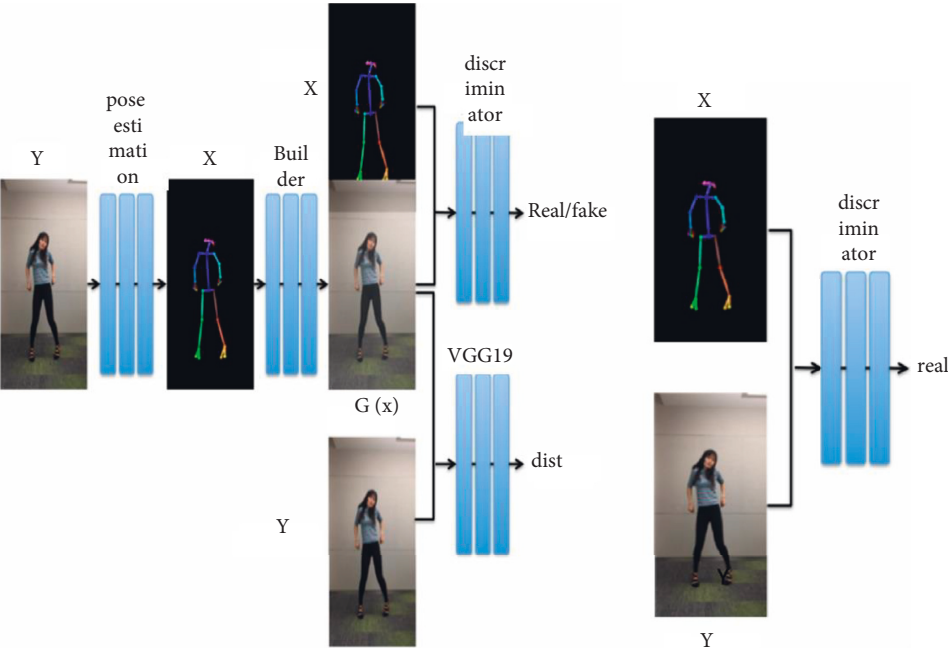


FIGURE 11: Model training flowchart.

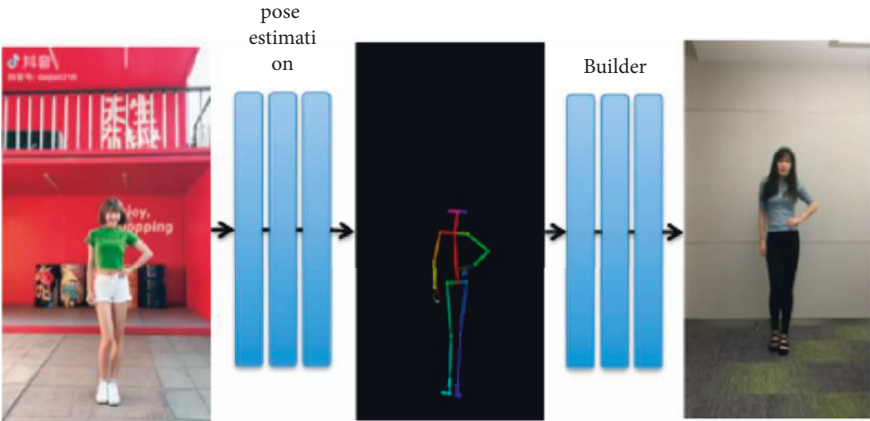


FIGURE 12: Model generation structure diagram.

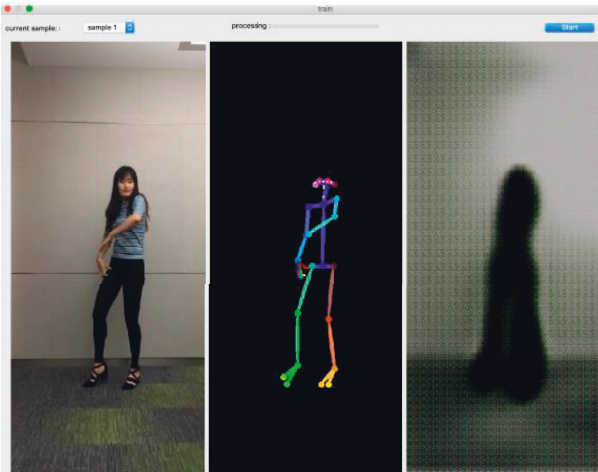


FIGURE 13: Synthesis results of 50 iterations.

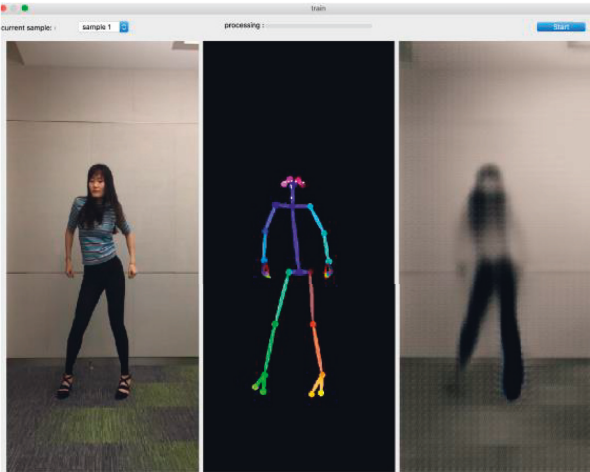


FIGURE 14: The synthetic result of 100 iterations.

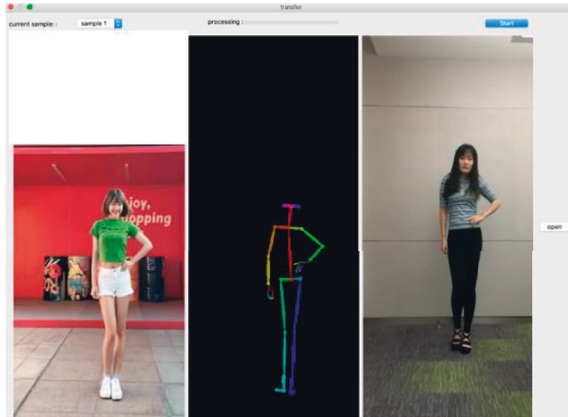


FIGURE 15: Dance generation results.

6. Conclusion

At present, some existing models for generating dance sequences cannot well represent the strong correlation between music and dance, and there is no relatively complete method for evaluating dance synthesis models. This paper proposes a general video generation framework for human dance generation. With well-designed generator and discriminator networks and various loss functions as objective functions, we can synthesize high-resolution, realistic dance videos. Extensive experiments show that the results generated by our application are significantly better than those generated by other methods.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis and System Design of Mechanical Fault Diagnosis Based on Deep Neural Network

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The operating environment of mechanical equipment is complex, and it is in high-intensity working conditions for a long time. The condition monitoring and fault diagnosis of equipment are very important. As a kind of precision part commonly used in mechanical equipment, the healthy operation of the rolling bearing is a necessary condition to ensure the reliable operation of the whole equipment. This research takes rolling bearing as the research object and is devoted to mechanical fault diagnosis analysis and system design. This paper studies the structure and working principle of rolling bearing, analyzes the types and locations of rolling bearing faults, and puts forward the overall framework of the fault diagnosis system and the workflow of the fault diagnosis system. This paper also studies the relevant theory of deep learning, proposes a neural network model framework for rolling bearing fault diagnosis, and preprocesses the rolling bearing vibration data. It uses a dropout algorithm and GRU to reduce the model parameter size and reduce the risk of overfitting.

1. Introduction

With the rapid progress of electronic technology, electromechanical equipment is gradually developing towards integration, large scale, and intelligence. There is close cooperation between different parts and components of electromechanical equipment, forming an organic whole [1–5]. Generally, the operation environment of electromechanical equipment is complex, and it is under high-intensity working conditions for a long time [6–11]. At least, the equipment is prone to failure, and at worst, it will cause casualties and serious social harm. In recent years, there have been many accidents caused by bearing failure all over the world, resulting in significant economic losses.

In this case, the equipment condition monitoring and fault diagnosis technology can be produced and developed [12, 13]. It generally requires the real-time monitoring of the status of the equipment during operation to determine the overall and local operation of the equipment [14–17]. One of the key technologies to ensure the safety and reliability of complex systems is to determine the reasonable maintenance time and formulate the corresponding maintenance

system through real-time condition monitoring and fault diagnosis of electromechanical equipment. As a basic component of rotating mechanical equipment, rolling bearings are widely used in various mechanical equipment. The normal state of rolling bearings directly affects the normal operation of mechanical equipment. Rolling bearings have the advantages of low running friction resistance, high working efficiency, easy assembly, and use, so they are widely used in electromechanical equipment and play a vital role. One of the main reasons for the failure of rotating machinery is the failure of rolling bearings. The working quality of rolling bearings has a great impact on the working state of mechanical equipment.

According to statistics, 70% of mechanical faults are caused by vibration faults, while 30% of vibration faults are caused by rolling bearings [18–20]. The main reason is that the rolling bearings in mechanical equipment often play a key role in bearing and transmitting loads at the same time, and the working conditions of rolling bearings are generally poor, which is more prone to failure. The direct consequence caused by the failure of rolling bearings is to reduce and lose some functions of the electromechanical system or to cause

catastrophic accidents. On the other hand, compared with other mechanical parts, the service life of rolling bearings is very discrete. Even if the production personnel, equipment, materials, and processes are the same, the service life of a batch of bearings processed is very different. Because of this, in the actual use process, some bearings have greatly exceeded the design life but are still in good condition and normal operation, while some bearings are far from reaching the design life but have various faults and can only be replaced in advance.

Therefore, at present, enterprises generally adopt the method of regular maintenance according to the design life of bearings, which often leads to two situations: on the one hand, the rolling bearings that exceed the design life and are intact and in normal operation are removed as scrap parts during maintenance, resulting in material waste. On the other hand, the bearing that fails due to failure before reaching the design life is still working on the mechanical equipment with failure, which reduces the working accuracy of the electromechanical equipment between the bearing failure and the removal and scrapping. If the bearing damage intensifies during this period, it will lead to a serious failure of the whole equipment and threaten the production safety. Therefore, online monitoring of rolling bearings can effectively prevent the decline of equipment working accuracy and reduce accidents, and on the other hand, it can maximize the working capacity of bearings and save material costs. Therefore, the fault diagnosis method of rolling bearings has always been one of the key technologies in mechanical fault diagnosis.

2. Overall Design of Mechanical Fault Diagnosis System

Bearings are easily damaged during use. On the one hand, due to the problems of low machining accuracy and imperfect technology in the production process of the bearing, the bearing will inevitably have many defects when it leaves the factory. On the other hand, the working environment of rolling bearings is usually harsh. When rolling bearings work in exposed situations, dust, small stones, and the impact load and overload of the machine itself will also damage the bearings.

Rolling bearing failures can be divided into the following types:

2.1. Fatigue Spalling. Fatigue spalling is caused by cyclically acting loads between the raceways and rolling elements. Cracks first appeared in the interior, and over time, the cracks slowly extended towards the surface. Finally, it extends to the contact surface to form peeling pits visible to the naked eye. Each spalling hole gradually extended and eventually joined together to form a large spalling. Fatigue spalling further contributes to bearing damage by causing vibration and noise during operation.

2.2. Wear. The entry of foreign objects into the bearing body is the main factor causing bearing wear. Raceways, rolling elements, cages, and journals are all easily accessed by

foreign objects. Wear will increase the rolling bearing clearance and raise the noise and vibration during operation.

2.3. Plastic Deformation. When the rolling bearing is overloaded or invaded by foreign matter with high hardness, the raceway will be plastically deformed to form a pit. Dimples can cause flaking around and cause vibration and noise.

2.4. Corrosion. Corrosion is usually surface rust caused by chemical action such as water, lubricating oil, and air.

2.5. Broken. The excessive load on the bearing often causes breakers during the working process.

2.6. Gluing. Bearing gluing refers to the phenomenon that the surface of one part of the bearing and the surface of another part stick to each other. It is usually caused by poor lubrication conditions of rolling bearings under high-speed and heavy-load conditions.

Rolling bearing faults can be divided into three types: inner and outer ring faults and rolling element faults according to the location of the fault. Due to the need to collect data on various faults when classifying according to the form of faults and conducting experiments, these failures are often accompanied, and it is impossible to extract a single type of data accurately. And these faults often need to work for a long time under certain conditions to form inconvenient experimental acquisition. Therefore, this paper adopts the method of fault location to classify the faults.

According to the acceleration, rotational speed, vibration, and other signals collected during the working process of the rolling bearing, the method of deep learning [21–26] is used for fault diagnosis, and the online fault diagnosis system for the rolling bearing is designed. On this basis, mechanical equipment's health management and failure prediction are realized.

First, the rolling bearing acceleration data collected by the data recorder installed at the work site are transmitted to Ethernet's remote monitoring center. Then, the data on the remote monitoring center server are normalized. Finally, we input the processed data into the trained rolling bearing fault diagnosis system and output the current operating status information of the bearing after identification and display it on the interface. The specific fault diagnosis process is shown in Figure 1.

The data recorder collects the vibration signal of the rolling bearing, and the collected data are transmitted to the remote monitoring center through the Ethernet and pre-processed, such as denoising and normalization. Then, we input it into the trained neural network to obtain the current state information of the rolling bearing to realize the remote monitoring of the running state of the rolling bearing.

As shown in Figure 1, the fault diagnosis model based on GRU belongs to the field of deep learning, and the training process requires many data samples with labels. If the data are only collected through experiments, it requires a lot of

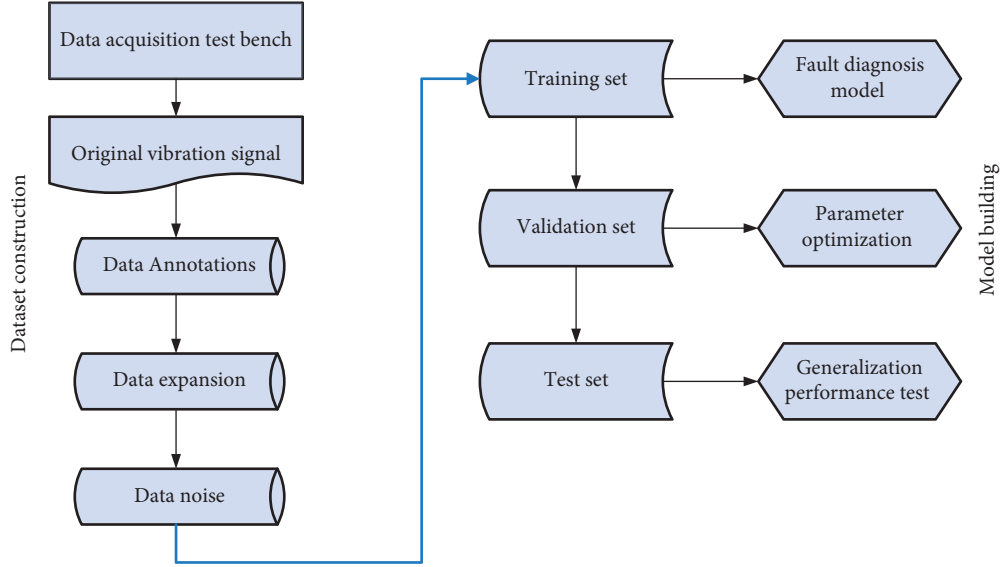


FIGURE 1: Fault diagnosis process.

labor and time costs or cannot collect enough samples. In addition, considering the actual data will inevitably have noise problems due to external interference and the sensor itself. Therefore, the method of adding different forms of noise to the collected raw data is adopted, and artificially adding noise; on the one hand, the number of datasets is expanded, reducing labor and time costs; on the other hand, the model can also obtain an “immune” effect to noise and improve robustness.

The collected data are marked with one-hot encoding, convenient for later training. The evaluation method of the model is analyzed, and the k-fold validation method is selected to divide the dataset into three parts: training, validation, and testing. Given the characteristic that the vibration signal is a time series, the two-way loop GRU stacking, fully connected layer, dropout, recurrent dropout, regularization, and other technologies are used to construct the fault diagnosis model of rolling bearing.

After the model is constructed, to further ameliorate its diagnostic performance, improve the differential evolution algorithm, use the improved differential evolution algorithm to optimize the model hyperparameters on the validation set, train on the training set, and verify the model performance on the test set.

3. Design of Fault Diagnosis Model for Rolling Bearing

3.1. Two-Way Loop GRU. The three types of recurrent neural networks can process time series, but the information flow can only be passed from the front to back in time [27, 28]. Recurrent neural networks are so dependent on the order of data that the features extracted by forwarding processing of data and reverse processing of data by using recurrent neural networks may be completely different. Although using reverse-order features alone for feature execution tasks may not be ideal, it is important that reverse-order features can

compensate for details not captured by positive-order features. Therefore, to further improve fault diagnosis performance, a two-way loop GRU layer is introduced into the model, which contains two gated recurrent units. Each gated recurrent unit processes the input sequence along a time direction. The representations of the two are combined after processing. Two-way loop GRU can often capture patterns that cannot be captured by unidirectional GRUs through forward- and reverse-order feature extraction.

3.2. Dense Connected Layer. The dense connection layer is also called the fully connected layer, and its main function is to realize the mutual mapping between linear spaces. It can map a 1×6 vector to a 1×5 vector. The fully connected layer is the most basic and widely used neural network. The fully connected layer is a network layer in which each node of this layer receives the output of all nodes in the previous layer. Due to this feature, the fully connected layer usually contains the most trainable parameters compared to other structures. According to statistics, the parameters of the fully connected layer account for about 80% of the parameters of the entire model. By inputting all data vectors into the fully connected layer, the fully connected layer can learn the overall distribution characteristics of the vector.

3.3. Final Model Structure. By combining two-way loop GRU and dense connection layer and then processing the input data simultaneously, the model can be made to learn the data characteristics from both the time dimension and the whole, by building a model in keras in TensorFlow using python and visualizing it on tensorboard. The length of the processed vibration signal samples is 300; the corresponding relationship between the labels of the samples after one-hot encoding is shown in Table 1.

The processing process after the vibration data is input into the model is as follows:

TABLE 1: One-hot coded after the label.

State	Class
Normal	0
Outer ring failure	1
Inner ring failure	2
Rolling element failure	3

Step 1: the vibration signal vector with a length of 300 is input into the model and divided into left and right parts for processing, respectively, where the left is the two-way loop GRU part and the right is the dense connection layer part.

Step left 1: after receiving the vector of length 300 from Step 1, deform it to (10, 30) through the reshape layer.

Step left 2: after receiving a vector of shape (10, 30) and inputting it into the two-way loop GRU network stacked in two layers, in order for the second layer to can process the data of the first layer, the output of the first layer GRU is a combination of the output vectors of each time interval.

Step right 1: after receiving the vector, it is processed by two densely connected layers separated by a dropout layer and then output.

Step 2: after the left and right parts are processed separately, the output vectors have the same shape. We use the concatenate layer to combine the processing results of the left and right parts and input them into a 4×1 dense connection layer.

Step 3: the final dense connection layer uses the softmax activation function, the four elements of the output vector represent the probability that the sample belongs to the corresponding type, and the type represented by the element with the most significant value is taken as the predicted label of the sample.

4. Neural Network Model Optimization

With the continuous expansion of the neural network scale [29–32], theoretically, the model's performance is getting better and better. Still, the model also faces unprecedented risks in the training process, and overfitting is one of them. Therefore, the model needs to be optimized for the overfitting problem during the training process.

Overfitting refers to the fact that the model's performance on the training and nontraining sets is too different, and the model that performs well on the training set performs poorly on the test set. This phenomenon is generally because the model learns the individual characteristics of the samples as the common characteristics of the data on the training set. It is hazardous for the model to overfit, which will lead to the loss of the model's basic features, and the generalization performance becomes abysmal.

To improve the generalization ability of the model, this paper will use the following methods to reduce or eliminate the influence of overfitting.

4.1. Regularization. Regularization is the process of introducing additional information to solve a problem or prevent overfitting, which is a common method in machine learning. Occam's razor principle tells us that if an event can be explained in multiple ways, usually the simplest explanation is the most likely to be correct. So, in neural networks, the principle means that simple models have less risk of overfitting than complex models; the simple model is the model with fewer parameters and smaller parameter values. After the model is determined, the number of parameters is fixed. At this time, reducing overfitting can only be achieved by limiting the value of the parameters. This method of making the value of model weights more regular is called weight regularization (referred to as regularization). The main way to achieve regularization is to add a more significant penalty term to encourage the model to tend to smaller weights when the weights are too large. The relationship between punishment and weight is mainly L1 and L2.

The loss function for L1 regularization is defined as

$$J = J_0 + \alpha \sum_w |\omega|, \quad (1)$$

where J is the model's loss function, J_0 is the original loss function, α is the regularization coefficient, and ω is the weight coefficient. A regularizer defined in this way biases the model's weights towards 0, resulting in the sparsity of the weights.

The loss function for L2 regularization is defined as

$$J = J_0 + \alpha \sum_w \omega^2. \quad (2)$$

The meaning of the parameters in the formula is the same as in L1, but unlike L1, this regularization method does not lead to sparsity.

4.2. Dropout. The number of training parameters in a deep learning model is usually huge. If the number of training samples does not meet the standard at this time, it is difficult to avoid overfitting. After the overfitting model, it is almost unusable in practice although it performs well on the training set. At this time, if a combination of multiple different models is used, overfitting can be suppressed to a certain extent. However, the way of combining multiple models will significantly increase the training and testing time of the model.

To solve this problem, the concept of dropout is proposed. The so-called dropout is when the output of neurons in the model has a certain probability of p becoming 0 during the training process. In this way, the neuron is not involved in this process. This enables the model to learn more generalized features rather than relying on the local features of a neuron.

The specific working process of dropout is as follows:

- (1) Set the trigger probability p of dropout, $p \in (0, 1)$. The neuron will be masked out with probability p .
- (2) Make the masked neuron not participate in the training process and keep its input and output fixed.

- (3) For other neurons that are not masked, update their weights and biases in the usual way.
- (4) To restore the masked neurons to normal, repeat steps 2 and 3.

The neurons participating in the dropout will be output to the next layer of neurons through the probability component internally during the training process.

Before adding dropout, the calculation formula of the network is

$$\begin{aligned} z &= \sum_{i=1}^n w_i y_i + \text{bias}, \\ y &= f(z). \end{aligned} \quad (3)$$

After adding dropout, the calculation formula of the network becomes

$$y'_i = y_i r_i, \quad (4)$$

where

$$\begin{aligned} r_i &\sim \text{Bernoulli}(p), \\ z &= \sum_{i=1}^n w_i y'_i + \text{bias}, \\ y &= f(z), \end{aligned} \quad (5)$$

where $\text{Bernoulli}()$ represents a $[0, 1]$ random variable obeying a Bernoulli distribution.

In the testing process, the network with dropout no longer randomly shields neurons as it does during training but multiplies the output value of the neuron by the probability $(1 - p)$ before outputting.

Principle analysis of dropout to reduce overfitting is as follows.

4.2.1. Play the Effect of the Multimodel Ensemble. Model ensemble refers to a means of building multiple models and combining them to work together to achieve better performance than a single model. The model ensemble can convert several low-performance models into a high-performance model through voting output.

For example, in a binary classification scenario, there are three classifier models m_1 , m_2 , and m_3 . Then, the effects of their ensemble may have the following situations (Tables 2–4).

As shown in Table 4, the correct rate of every single model is 1/3, and the correct rate after ensemble not only does not decrease but increases. This is because when the ensemble model uses the “minority-by-majority voting” method to make predictions, the majority model gives the wrong answer, so it does not work. This shows that when performing a model ensemble, the performance of a single model cannot be abysmal. Fortunately, the performance of neural network models generally does not have this problem. In Tables 2 and 3, the single-model accuracy rate is 2/3. Only the accuracy rate of Tables 1–3 is increased to 100% after the ensemble, and the results in Table 2 are the same as before the ensemble, that is, no rise and no fall. The results in

TABLE 2: Multimodel ensemble may have effects 1.

Model	Sample1	Sample2	Sample3
m_1	Correct	Correct	Mistake
m_2	Mistake	Correct	Correct
m_3	Correct	Mistake	Correct
Output after ensemble	Correct	Correct	Correct

TABLE 3: Multimodel ensemble may have effects 2.

Model	Sample1	Sample2	Sample3
m_1	Correct	Correct	Mistake
m_2	Correct	Correct	Mistake
m_3	Correct	Correct	Mistake
Output after ensemble	Correct	Correct	Mistake

TABLE 4: Multimodel ensemble may have effects 3.

Model	Sample1	Sample2	Sample3
m_1	Mistake	Mistake	Correct
m_2	Correct	Mistake	Mistake
m_3	Mistake	Correct	Mistake
Output after ensemble	Mistake	Mistake	Mistake

Table 3 are that the 3 models are all predicting the same results for the same example, and the way to vote in 3 identical models obviously does not make sense. Like the results in Table 1, for the same example, the performance of the ensemble model will be improved only when the majority of the models can give the correct answer, thus correcting the errors of the few models.

Dropout shielding neurons are random, so a neural network with different structures can be formed after each dropout. And the performance of these networks will not be terrible; therefore, in this way, it forms a model ensemble situation similar to Table 1, thereby improving the model's performance.

4.2.2. Improve Model Generalization Performance. Due to randomness, it is difficult for neurons to ensure that they are not masked every time; therefore, if the weight update relies too much on some fixed neurons, the network performance will be significantly degraded when they are masked. This reason drives the network to learn more general features that do not depend on certain neurons and thus make the network more generalizable. This is similar to the effect of regularization, which reduces the weight of neurons, thereby improving the network's performance.

5. Simulation

To verify the fault diagnosis performance of the designed model, the simulation experiments were carried out on the model using the Bearing Dataset of Western Reserve University. The hardware and software environment of the experiment is shown in Table 5.

The simulation experiment is initially selected as the output size of the two-way loop GRU layer is 32. The output

TABLE 5: Simulation experiment hardware and software environment.

Hardware environment	
Hardware	Parameter
Memory	32 g
GPU	NVIDIA Ge force GTX 1060
Hard disk	2T
CPU	Intel core (TM) i5 9400F
Software environment	
Software	Parameter
Python	3.8
Matlab	2018b
Tensorflow	2.3.1
Cuda	10.1

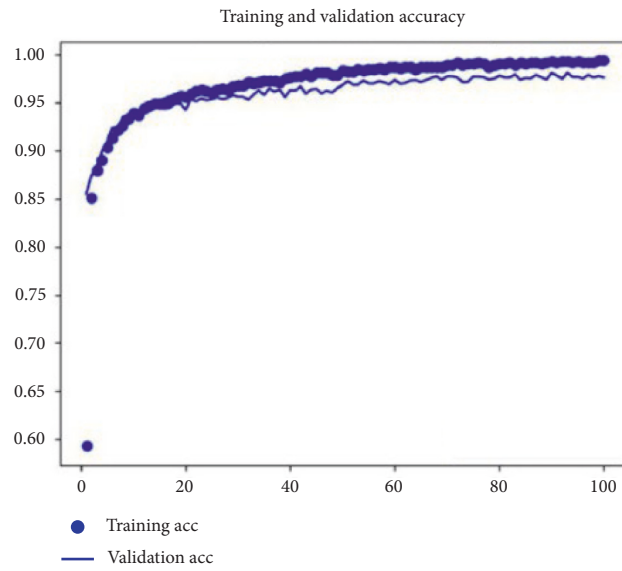


FIGURE 2: Simulation experiment training and verification accuracy.

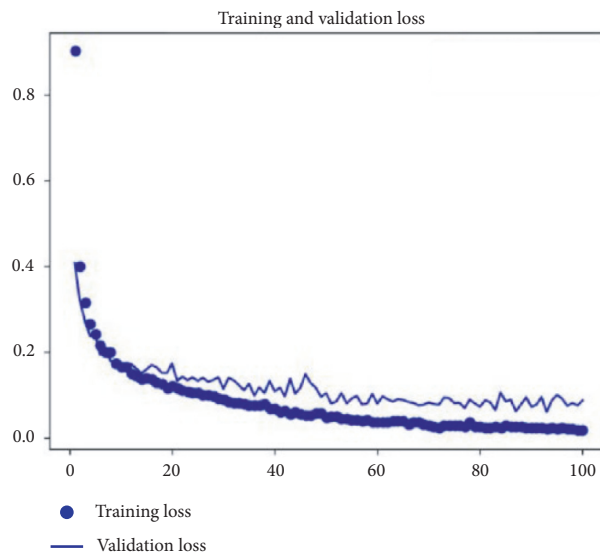


FIGURE 3: Simulation experiments to train and verify losses.

size of the first dense connection layer is 64, and the output size of the first dense connection layer is 32.

The training parameter epoch takes 100, the loss takes categorical_crossentropy, and the optimizer takes Adam.

Simulation experiment training and validation accuracies and training and validation losses are shown in Figures 2 and 3.

The model's accuracy after training is 0.9685499804619234. It can be seen from the above data results that the accuracy of the fault diagnosis model designed in this paper reaches 96.85% on the test set, which is comparable to the performance of the model on the training set and validation set, which indicates that the model does not have overfitting. And as can be seen from the accuracy graph (Figure 2) and loss graph (Figure 3), after 100 iterations, although the curve gradually flattens, it is not horizontal, which shows that by increasing the size of the epoch, the model's performance can continue to improve.

6. Conclusions

As a kind of precision part commonly used in mechanical equipment, the healthy operation of the rolling bearing is a necessary condition to ensure the reliable operation of the whole equipment. According to the practical needs of rolling bearing fault diagnosis, a fault diagnosis model is designed. The model improves the performance of the model by processing and combining the vibration signals in two different ways: bidirectional GRU and dense connection layer. Dropout and regularization techniques are used to solve the overfitting problem. The simulation results show that the accuracy of the test set is as high as 96.85%, which fully meets the practical engineering needs of rolling bearing fault diagnosis.

In this paper, a fault diagnosis system is established only for the single-point fault at different positions of the rolling bearing. As for other faults, due to the difficulty of data acquisition, no further exploration is made. The fault diagnosis system established in this paper can judge the fault position of the rolling bearing, and the function is rough. In the next step of research, quantitative analysis and prediction of the severity of the fault and the remaining life of the bearing in this state can be continued to further enrich the system functions.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Numerical Simulation of Smoke Control in Underground Space

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As the underground space is relatively closed compared to other buildings, the space is hardly connected to the outside world through entrances and exits, which makes it difficult to ventilate and exchange heat with the outside. In this case, it is easy to cause a large number of casualties when a fire breaks out. When the fire happens smoke will be discharged merely by the mechanical exhaust, and air system should work simultaneously to replenish the oxygen inside. By setting four-group models, the paper analyzes the strategies for smoke extraction and air makeup in the underground construction. The paper points out that when the fire happens in a smoke bay, the neighborhood smoke extraction fan should be opened and the air makeup system should not be located at the top to disturb the smoke layer. By comparing and analyzing the performance of the smoke extraction and air conditioning system, the casualties caused by the high temperature toxic smoke from the fire can be reduced as far as possible.

1. Introduction

As the city develops, the land resource is becoming extremely scarce, which has impelled people to exploit the underground space [1–3]. As a result, the underground constructions are emerging constantly in cities, such as the subways, the underground commercial streets, the underground concourses, and the underground parks. The development of underground space started much earlier in European countries and 150 years have passed since the London's first subway constructed in 1845. In China, the exploitation of urban underground space goes back to 1950s. Whereas Chinese underground space shows an enormous development potential, new problems for the fire safety arises as well.

The underground construction has a poor ability of natural ventilation. While the ground building can organize natural ventilation by windows, underground space can only connect the outsides through mechanical devices such as entrances, exits, ventilated shafts and the narrow cross-section. Once the fire happens in the underground space, the

smoke moves following the same direction of personnel evacuation, which will give rise to a more severe damage compared with a fire in the surface of the building. In recent years, domestic and foreign researches have been carried out on smoke control in underground constructions.

Yang [4] carried out a group of full-size experiments in the MRT system and put forward smoke exhaustion strategies corresponding to different fire positions, which serves as a good reference. Huang et al. [5] study analyzed the effect of fire location on carbon monoxide concentration and smoke layer height and the effects of mechanical exhaust on temperature, exhaust system layout, and exhaust rate. Liu et al. [6] studied the spread of smoke under natural ventilation and found that the maximum temperature in the smoke layer decreased with the longitudinal spread of smoke. Hu et al. [7] made a full-size experiment about the performance of mechanical smoke extraction in an underground corridor, studied on how the relative distance between the air makeup vent and the smoke vent affected the efficiency of mechanical smoke extraction. He found that the

smoke would be exhausted more efficiently provided that the position of air makeup has a distance from the smoke vent, therefore the future research should be directed at the quantitative study on finding the best distance between the air makeup vent and the smoke vent. Hu et al. [7] pointed out as well that activating the smoke control system too early would have a malign effect on smoke extraction. In order to ensure the safety and reliability of underground subway ventilation system, Wang et al. [8] simulated and recorded the height of smoke layer, air flux of shaft, and smoke movement route. It was found that smoke diffusion along the ground floor ceiling could be suppressed by outdoor air flowing into the exhaust fan and smoke did not accumulate in the mezzanine. Long et al. [9] conducted a full-scale fire experimental study on smoke movement and control in subway stations. It is found that the influence of exhaust system on smoke propagation time is related to the location of fire source. Shi et al. [10], through theory analysis, built up a calculation model of mechanical ventilation rate for the large space in a warehouse. His team carried out a whole size of hot smoke test to study the course of fire spreading according to the air change per hour in the warehouse, and put forward the method of assisting the mechanical smoke extraction in the dangerous warehouse. Liu et al. [11] studied the ceiling temperature, smoke layer thickness, and temperature distribution in the station through full-scale experiments. Experiments have proved that the spread of smoke can be effectively controlled when the mechanical smoke exhaust system is turned on. Zhou et al. [12] carried out numerical simulation on the effect of positive pressure ventilation in superlarge underground space. The smoke control effect under this condition was analyzed. The study found that the mechanical exhaust volume has a greater impact on the flue gas control effect than the air supply volume. Through a small size experiment, Ji et al. [13] from USTC draw a conclusion that the smoke vent should not be set at the position where the smoke took one-dimensional horizontal motion in a long aisle, and the distance between the smoke vent and the fire source should not exceed 1.33 times in width than that of the aisle so as to decrease the air turbulence in the low-layer caused by the exhaust. When the mechanical smoke extraction was operated in an aisle with one opening, it would be better to start solely the smoke vent opposite the makeup air vent or to unlock the smoke vents on each side of the fire source. However, in an aisle with openings at both ends, the smoke vents on each side of the fire source should be activated [13]. In model experiments conducted by Luo et al. [14], while fire occurred in large space metro station hall, the ceiling exhaust nearly caused no reduction effect on smoke temperature, because the ceiling vents were too small compared with the space. Wang et al. [15] analyzed the characteristics of a subway fire site, ventilation and smoke exhaust device, put forward the idea of active disaster relief, put forward the expert system-decision support system for disaster rescue autonomous dynamic decision method, and determined the best air control and smoke exhaust scheme. It has high reference value. Tie [16] studied the smoke propagation process during fire in a

1/12th large space building apparatus, found that the smoke descent faster with fire occurred in the middle than in one end.

In this study to an underground bus station as the prototype, the chosen building smoke bay geometric model is established and FDS is suitable for solving the N-S equation of low-speed heat-driven flow. When a fire occurs in the underground Space, the software can well simulate the smoke flow and temperature changes during the fire. Through the comparative analysis of the relevant parameters of the exhaust air supply system performance, to provide theoretical support for the study of such problems.

2. Geometric Model

The details of an underground bus station are listed as follows: fire resistance rating: I, construction category: I, overall building area: about 38000 m², and three parts of the layout: the municipal traffic road, the bus area, and the waiting area. Automatic fire alarm system, sprinkler system, and mechanical smoke extraction system are installed in the building. There are five smoke screens (each 2 m high) in the bus area and six light courts (each 300 m²) in the waiting area. A firewall is installed along the centerline of the municipal traffic road to separate the station into two longitudinal symmetry fire compartments, as shown in Figure 1.

The paper selects the smoke bay in the middle of the building to make a numerical simulation analysis of the smoke control. The CFD model used in this study is FDS developed by NIST. FDS [17–19] is suitable for solving the N-S equation of low-speed heat-driven flow, and it can simulate the smoke flow and the heat transfer commendably. To highlight the movement of smoke, this simulation adopts the combustion parameters of polyurethane with the smoke generation fraction of 0.05.

The model size is 50m × 60 m × 7 m, and the area of the smoke bay is 2200 m². Under the premise of economy and engineering calculation accuracy, the mesh size is set as 0.5 m × 0.5 m × 0.5 m. The fire source is located in the middle of the bay, as shown in Figure 2. The white on the left is the firewall, the right side is the exterior wall with a stairwell close to it, and the anteroposterior yellow baffles are smoke screens.

3. Model Analysis and Numerical Simulation

3.1. Fire Source. As the underground bus station is equipped with automatic alarm system and automatic sprinkler system, and the chief fire source might be the luggage carried by passengers. According to the building specification and the parameters of the sprinkler head, the safety factor is set as 1.5-fold. It could be confirmed that the maximum heat release rate in the fire is 6.0 MW under the control of automatic fire extinguishing system, as shown in Figure 3. In the simulation test, the fire source is *T* square fire and the growth factor is 0.0765 kW/s², which belongs to the rapid fire [20], as shown in Table 1. Assuming that the smoke

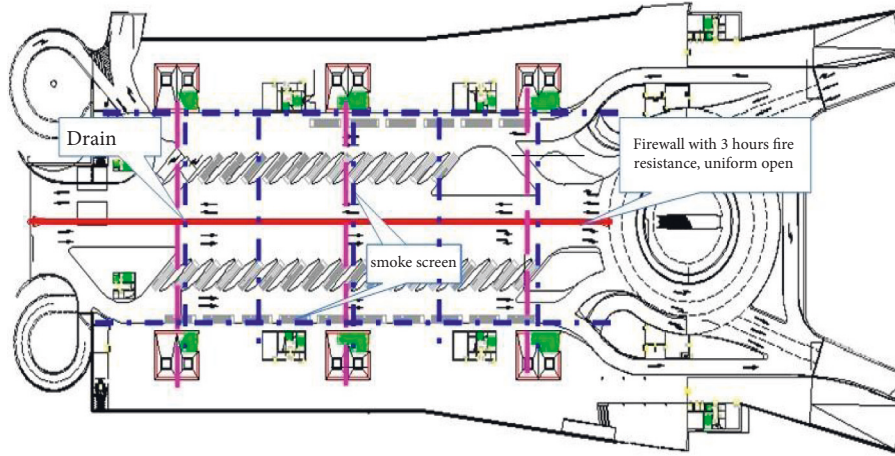


FIGURE 1: A plane graph of the underground bus station.



FIGURE 2: The FDS model of the smoke bay.

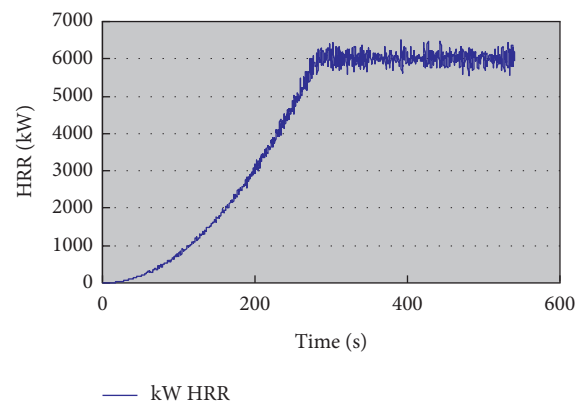


FIGURE 3: Heat release rate changes with the time.

TABLE 1: *T* square fire type.

Growth rate type	α (kW/s ²)	Characteristics of the time (t_g /s)
Slow fire	0.0029	600
Medium fire	0.0117	300
Rapid fire	0.0469	150
Superquick fire	0.1876	75

extraction and the air makeup system open in 30 seconds after the fire occurs.

3.2. Smoke Extraction and Air Makeup System. In this paper, a smoke bay is selected in the underground transit station, and four different smoke control programs are set (Table 2)

to provide a quantitative reference for the smoke exhaust design, compared to the simulation results.

4. Results and Analysis

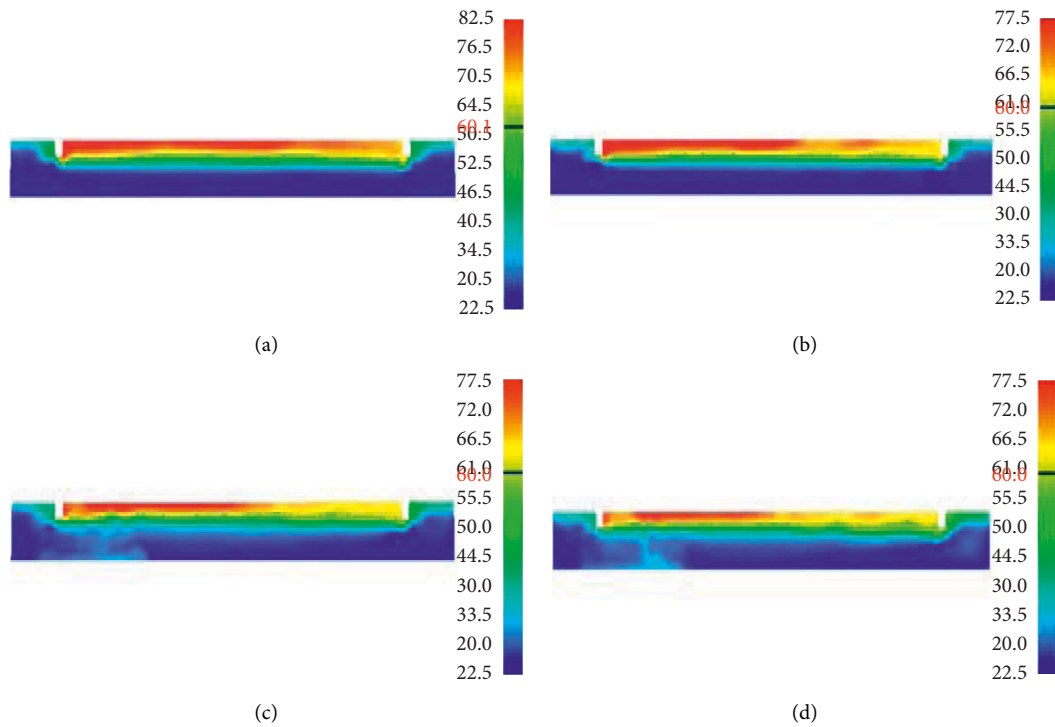
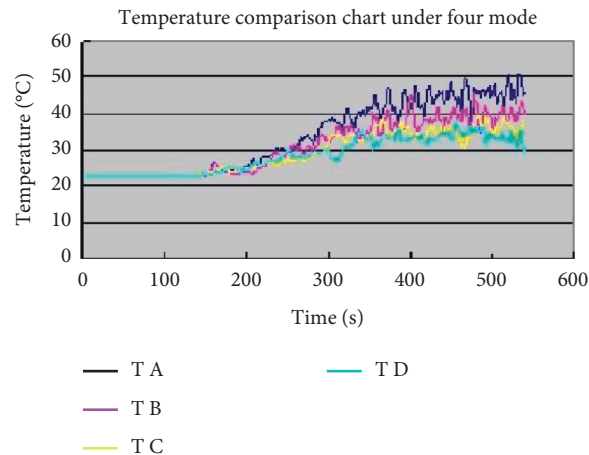
Temperature and visibility slices are generated within FDS in a Y-Z plane, and monitoring point is set to get the

TABLE 2: Four different smoke control modes (“—” means closed).

No.	Exhaust of the smoke bay	Air supply	Exhaust of adjacent smoke bay
A	—	—	—
B	Open	—	—
C	Open	Open	—
D	Open	Open	Open

TABLE 3: Criteria of human safety.

Parameter	Limits	Limits consider the safety factor
Temperature 2 m height from the floor (°C)	<100	≤60
Visibility 2 m height from the floor (m)	>5	≥10

FIGURE 4: Four modes of temperature distribution plane graphs ($X=40$ m). (a) Temperature distribution mode A ($t=480$ s). (b) Temperature distribution mode B ($t=480$ s). (c) Temperature distribution mode C ($t=480$ s). (d) Temperature distribution mode D ($t=480$ s).FIGURE 5: Temperature comparison under 4 modes at the plane graph ($Z=4$ m).

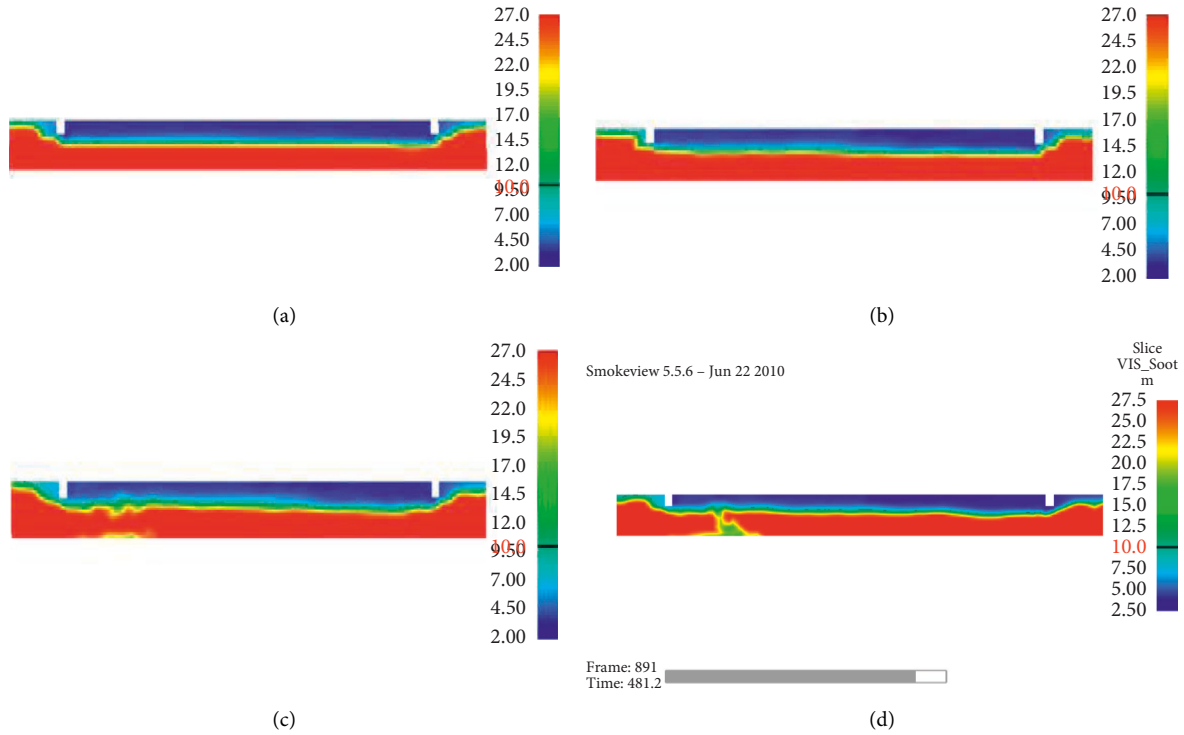


FIGURE 6: Four modes of visibility distribution plane graphs ($X=40$ m). (a) Visibility distribution mode A ($t=480$ s). (b) Visibility distribution mode B ($t=480$ s). (c) Visibility distribution mode C ($t=480$ s). (d) Visibility distribution mode D ($t=480$ s).

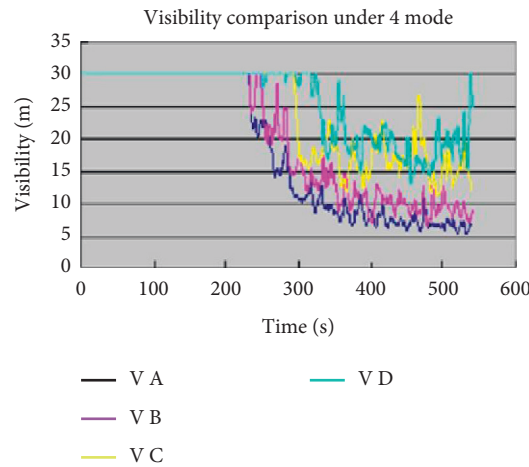


FIGURE 7: Visibility comparison under 4 modes at the plane graph ($Z=4$ m).

temperature and visibility changes. Temperature and visibility requirement of human safety is shown in Table 3.

4.1. Temperature Distribution. It can be seen from Figure 4 that the high temperature areas in the four modes are located in the upper part of the smoke exhaust area. High temperature smoke accumulates in the upper layer and the smoke screens effectively prevent the smoke from spreading to the neighboring partition. In contrast, mode A has a higher temperature (the top layer temperature up to 82°C) and more high temperature regions. Figure 5 reflects that the sequence of the average temperatures at the plane $Z=4$ m from high to low is $A > B > C > D$.

While starting the smoke extraction system, opening the air makeup system will ensure a more efficient smoke exhaust. But it should be noted that the velocity of air makeup should not be too large to disturb the smoke stratification. The makeup volume here is less than half of the exhaust.

4.2. Visibility. Figure 6 conveys that the upper zone visibility is worse and the lower zone is better. There is a clear distinction between the upper and the lower form which we can infer that the smoke layer is stratified well. Because the smoke extraction systems have been activated both in the smoke bay and in the adjacent area, the smoke has been

discharged faster and relatively less smoke occupies the upper area of mode *D*. Meanwhile, Figure 7 shows that at the height of $Z=4$ m, the visibility in the model *A* and *B* is reduced below 10 m, whereas the visibility is no less than 10 m in mode *C* and *D*.

5. Conclusions

As far as this study is concerned, for underground bus stations, the source of fire may mainly come from the luggage carried by passengers. Assuming that the smoke exhaust and air supply system is opened within 30 s after the fire, three devices are set up: exhaust outlet, air supply, and exhaust of adjacent smoke bin. Through temperature comparison, it can be found that the high temperature areas in the four modes are all located in the upper part, and the open-air supplement system can exhaust smoke more effectively. Through the visibility comparison, it can be inferred that the smoke layer is well stratified, and the smoke in the upper area is reduced when the smoke exhaust system is turned on.

Therefore, in case of fire in the local building, the smoke curtain should be activated in time and the smoke exhaust system in the relevant area should be activated. Opening the smoke prevention system in the surrounding area will not only accelerate the diffusion of the smoke to the area, but also accelerate the failure of the smoke to prevent the smoke from sinking. It should be pointed out that once the upper air filling system is opened, the smoke stratification will be disturbed, so it is necessary to consider to fill the air from the lower part. Therefore, in case of fire in the local lower space, the smoke exhaust device should be opened in a timely and effective manner to ensure the smooth air in the underground space and reduce the casualties caused by the high temperature toxic smoke produced by the fire.

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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Research Article

Analysis of Public Big Data Management under Text Analysis

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Based on text analysis, public big data management is studied. The public data management of Mount Wutai tourism network travel notes is discussed. The positive, neutral, and negative effects of the naive Bayesian classification model and decision tree classification model on the tourism sentiment attitude of Mount Wutai are compared. The relationship between tourism resources, tourism facilities, tourism services, tourism environment, and tourism sentiment and attitude of Wutai Mountain is analyzed. The results show that the true positive rate, true negative rate, and F-measure of the Bayesian decision tree classifier to classify positive text are 86.64%, 81.27%, and 84.62%, respectively. The true positive rate for neutral text is 82.05%, the true negative rate is 78.89%, and the F-measure is 77.11%. The true positive rate for negative text is 83.67%, the true negative rate is 98.29%, and the F-measure is 82.83%. The Bayesian decision tree classifier can evaluate positive and negative texts better than neutral texts. The true positive rate of the C4.5 decision tree classifier for positive text is 91.44%, the true negative rate is 86.57%, and the F-measure is 89.45%. The true positive rate for neutral text is 90.17%, the true negative rate is 83.28%, and the F-measure is 84.06%. The true positive rate for negative text is 91.84%, the true negative rate is 99.05%, and the F-measure is 90.91%. The decision tree classifier has a better evaluation effect on positive and negative texts than on neutral texts. The ROC curve of the evaluation effect of the two classifiers shows that the evaluation effect of the two classifiers has a better evaluation effect on positive text than that of the neutral and negative texts, and the evaluation effect of the C4.5 decision tree classifier is better than that of the Bayesian classifier. The promotion degree of tourism resources and facilities in forwarding online travel notes is obviously higher, and there is a high correlation between tourism resources and facilities and forward online travel notes. In negative online travel notes, the promotion degree of tourism service and tourism environment is high, and the correlation between tourism service and tourism environment and negative online travel notes is high. In summary, improving the quality of tourism services and the tourism environment of Mount Wutai scenic spots can better enhance the recognition and satisfaction of tourists with Mount Wutai tourism.

1. Introduction

With the development of Internet technology, network public text data play an important role in people's search for and mastery of information. The management and classification integration of public text data can effectively improve data utilization [1, 2]. Tourism plays an important role in the development of a city. Understanding the status quo and problems of regional tourism is of positive value to guiding the development of the local economy [3, 4]. Tourists' emotional attitudes and recommendation indexes have an important influence on the development of tourist

attractions [5, 6]. Exploring and analyzing tourists' recognition of scenic spots, which is of reference value to guide the improvement and perfection of tourist attractions, is a research hotspot [7, 8].

Tourists' evaluations and emotional attitudes toward scenic spots are expressed mainly online and offline, and online searches have shortcut lines and universality [9]. The online travel notes of travel apps are an important tool to understand tourists' emotional attitudes toward scenic spots. Currently, widely used travel apps mainly include Ctrip, Qunar, Hornet's Nest, Tuniu, and Tongcheng [10]. Mount Wutai, located in Xinzhou City, is a national 5A-level scenic

spot with beautiful scenery and numerous temples. It is a Buddhist holy land with a beautiful natural landscape and profound cultural landscape. It is cool and comfortable in summer and a good place for summer vacation [11]. Mount Wutai scenic spot has many tourists every year, which greatly promotes local economic development and has great development potential. Understanding Mount Wutai's tourism recognition and tourist reputation is of great value to the economic development of Mount Wutai. The emotional attitude assessment of scenic spots based on online travel notes requires text processing, classification, data organization, and management and correlation analysis. Currently, the commonly used machine learning classification methods mainly include naive Bayesian classification models, decision tree classification models, and support vector machine classification models [12–14]. Naive Bayesian classifiers have high classification accuracy and fast running speed [15, 16]. C4.5 decision tree classification can effectively process data with missing values [17, 18].

In this study, 575 online travel journal texts from the Ctrip, Qunar, Mafengwo, Tuniu, and Tongcheng websites are selected to compare the classification and evaluation effects of the naive Bayesian classification model and decision tree classification model on Mount Wutai tourism sentiment and attitude. The relationship between tourism resources, tourism facilities, tourism services, the tourism environment, and Mount Wutai's tourism sentiment and attitude is also analyzed to provide guidance for tourists and a reference for the development and improvement of Mount Wutai scenic spots.

2. Methods

2.1. Data Acquisition. The public data selected in this study are mainly from online travel notes published on various travel websites. The online travel notes published on the Ctrip, Qunar, Horner's Nest, Tuniu, and Tongcheng websites are screened. After the above websites are selected, the keyword "Mount Wutai" in the travel notes of each website is searched. Octopus acquisition software is used to climb Mount Wutai network text data of the above tourism websites one by one. After screening, a total of 575 Mount Wutai travel notes from January 2016 to December 2018 are selected, with a total of 412,528 words. The number of texts on each website is shown in Table 1.

2.2. Data Feature Extraction and Typing. By comparing other similar literature and consulting relevant analysts, the public data of Mount Wutai tourism network text are divided into three types, namely, positive text data, neutral text data, and negative text data. Based on the content description of online travel notes, the description information of travel notes will contain specific descriptive words and short sentences of the Mount Wutai tourism event. For example, the event description in positive text includes keywords expressing positive evaluation such as "satisfactory," "beautiful scenery," and "high-cost performance." Negative text event description includes words expressing

TABLE 1: Mount Wutai tourism network text public data collection.

Website	Number of articles
Ctrip	328
Qunar	72
Hornet's nest	27
Tuniu	45
Tongcheng tourist	103

negative evaluation such as "inconvenient transportation," "expensive tickets," and "poor accommodation." Neutral event descriptions mainly include "check in" and "handle." These specific words are set as keywords and extracted from the input data set for text data classification (Table 2).

2.3. Data Classification

2.3.1. Naive Bayesian Classification Algorithm. The Bayesian classifier supports incremental learning and has high classification accuracy. The classifier assumes that terms are independent of each other and that each sample X in the text set consists of a set of attribute values $(a_1, a_2, a_3, \dots, a_n)$, where a_k is the value of term A_k . W is the classification variable, and w is the value of W . It is supposed that there are two classes, namely, + (positive class) and - (negative class). According to the Bayesian rule, sample X is the probability p of class w , as shown in (1), where X is classified as $W = +$ if and only if and represented by the Bayesian classifier as $f_b(X)$, as shown in (2).

$$p(w|X) = \frac{p(X|w)p(w)}{p(X)}, \quad (1)$$

$$f_b(X) = \frac{p(W = +X)}{p(W = -X)} \geq 1. \quad (2)$$

If the given values of class variables and the terms are independent of each other, the probability p can be expressed as $p(X|w)$, as shown in (3). The naive Bayesian classifier, $f_{nb}(X)$, is obtained, as shown in (4).

$$p(X|w) = p(a_1, a_2, \dots, a_n|w) = \prod_{i=1}^n p(a_i|w), \quad (3)$$

$$f_{nb}(X) = \frac{p(W = +)}{p(W = -)} \prod_{i=1}^n \frac{p(a_i|W = +)}{p(a_i|W = -)}. \quad (4)$$

$P(a_1|w)$, $p(a_2|w)$, $p(a_3|w)$, \dots , and $p(a_n|w)$ can be estimated by the training sample. The posterior probability of each class can be calculated separately, and the class with the highest posterior probability is the prediction class.

2.3.2. Decision Tree Classification Algorithm. C4.5 decision tree classification is a common method in inductive reasoning, which has great advantages in dealing with continuous attributes and discrete attributes. The measure of the uncertainty of feature vector A is the entropy of feature vector A , expressed as $H(A)$, as shown in (5). The conditional entropy of class B of feature vector A under given conditions

TABLE 2: Results of feature extraction in the training set.

Describe	Feature extraction
Wutai Mountain has beautiful scenery and is very comfortable in summer	Beautiful scenery, comfortable
Tickets are expensive and accommodation consumption is high	Tickets are expensive, consumption is high
There are many volunteers in the scenic spot with comprehensive service	Comprehensive service
A good place for self-cultivation and picturesque scenery	Good place, picturesque scenery

is expressed as $H(A/B)$, as shown in (6), which represents the uncertainty of classification of feature vector A under given conditions of class B , where p_k is the probability that A is a_k , $P(A = a_k) = p(a_k)$ and $k = 1, 2, \dots, n$. $P(A_i|B_j)$ is the joint probability distribution. The difference between $H(A)$ and $H(A/B)$ is information gain, and the larger the information gain is, the stronger the classification ability is

$$H(A) = - \sum_{a_i} p(a_i) \log_2 p(a_i), \quad (5)$$

$$H(A|B) = - \sum_j p(b_j) \sum_i p(a_i|b_j) \log_2 p(a_i|b_j). \quad (6)$$

In C4.5, the information gain rate is used to determine the selection of feature test points by measuring the correlation between feature A and class B and the entropy value of feature A and class B , as shown in the following equation:

$$\text{Gain Ratio}(A|B) = \frac{H(A) - H(A|B)}{H(A)}. \quad (7)$$

The C4.5 decision tree algorithm adopts the information gain rate as the feature selection method sets a threshold α and takes it as the stop condition. The feature with the maximum information gain rate is placed on the root node. If the information gain rate of the feature is less than the threshold value, the node constitutes a single-node tree. The class is marked as the class with the most samples in the dataset that satisfies the path condition from the root node to the local node. If the information gain rate of the feature is greater than the threshold, a branch is generated for each feature value of the node, and the training sample is assigned to the corresponding branch. If there are no samples in a branch or all samples belong to the same category, the branch ends; otherwise, the branch node is repeated until all features have been traversed.

2.4. Data Organization and Management. Data organization and management are conducive to better use of data and to improving the efficiency of data search. The obtained network travel notes text data are organized and managed, including time information, emotion and attitude information, and programmatic information. Time information includes year, month, and day, and sentiment and attitude classification includes positive text, neutral text, and negative text. According to the factors affecting tourism evaluation, the compendium of tourism resources, tourism facilities, tourism services, and the tourism environment is divided into three categories. The data organization management framework is shown in Figure 1.

2.5. Data Correlation Analysis. Data correlation analysis is conducted on the factors that affect the text category of online travel notes, and correlation analysis is conducted by using the Apriori algorithm to calculate the support degree, confidence degree, promotion degree, and confidence degree of each factor with positive and negative online travel notes.

2.6. Observation Indexes. The included online travel notes are statistically classified. The number of Mount Wutai online travel notes on different websites in different years is counted, the number of Mount Wutai online travel notes with different emotional attitudes is counted, and the number of online travel notes with revisit intentions and recommendation intentions is counted.

The evaluation results of the Bayesian decision tree classifier and C4.5 decision tree classifier on the emotional attitude of online travel journal texts are calculated, including positive text, neutral text, and negative text. The evaluation indexes mainly include the true positive rate (TPR), true negative rate (TNR), false positive rate (FPR), false negative rate (FNR), precision, recall, and comprehensive evaluation index (F-measure). The calculation method is shown in equations (8)–(14), where TP is true positive, FN is false negative, TN is true negative, and FP is false positive.

$$TPR = \frac{TP}{TP + FN}, \quad (8)$$

$$TNR = \frac{TN}{TN + FP}, \quad (9)$$

$$FPR = \frac{FP}{TN + FP}, \quad (10)$$

$$FNR = \frac{FN}{TP + FN}, \quad (11)$$

$$\text{Precision} = \frac{TP}{TP + FP} \times 100\%, \quad (12)$$

$$\text{Recall} = \frac{TP}{TP + FN} \times 100\%, \quad (13)$$

$$F - \text{measure} = \frac{2 \times TP}{2 \times TP + FP + FN}. \quad (14)$$

The C4.5 decision tree and Bayesian classifier are drawn to evaluate the receiver operating characteristic curve (ROC) of web travel notes with different emotional attitudes.

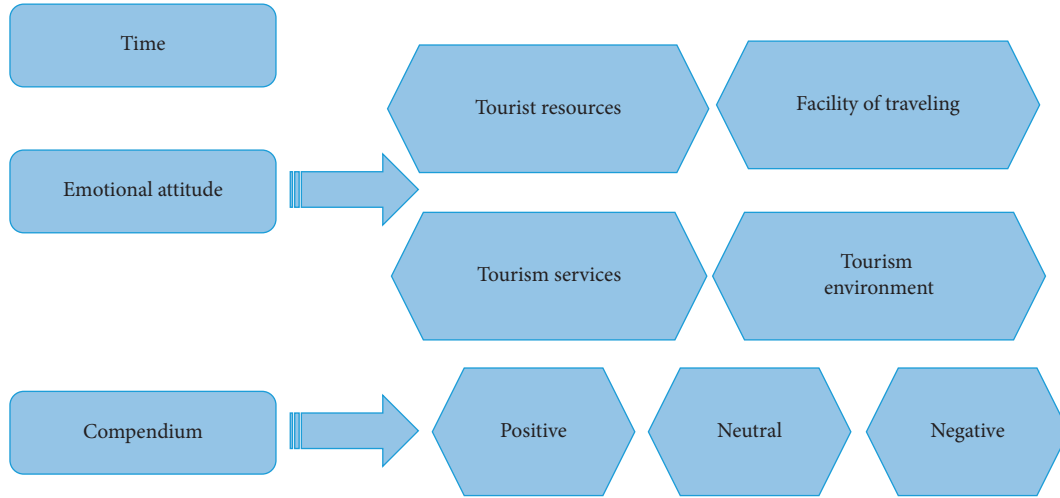


FIGURE 1: Text data organization framework of Mount Wutai tourism network travel notes.

The organization and management results of public data of travel notes on the Mount Wutai tourism network are collected, mainly including the number of tourism resources, tourism facilities, tourism services, and the tourism environment.

The support degree, confidence degree, promotion degree, and confidence degree of each factor and positive and negative online travel notes text are calculated. Support represents the proportion of events containing both X and Y to all events, as shown in (15). Confidence represents the proportion of events containing X that also contain Y events, as shown in (16). The promotion degree represents the proportion of events containing X that also contain Y events, as shown in (17). The calculation of confidence is shown in (18).

$$\text{Support} = P(X \& Y), \quad (15)$$

$$\text{Confidence} = \frac{P(X \& Y)}{P(X)}, \quad (16)$$

$$\begin{aligned} \text{Lift} &= (P(X \& Y) / P(X)) / P(Y) \\ &= P(X \& Y) / P(X) P(Y), \end{aligned} \quad (17)$$

$$\text{Conviction} = \frac{1 - \text{Support}}{1 - \text{Confidence}}. \quad (18)$$

2.7. Statistical Methods. SPSS 20.0 is used for statistical analysis of the data, and a T test is used. Rate (%) represents counting data. ROC curves of the C4.5 decision tree and Bayesian classifier are plotted to evaluate online travel notes with different emotional attitudes. $P < 0.05$ is considered statistically significant.

3. Results

3.1. Public Data Result Statistics Based on Text Analysis. Figure 2 shows the statistics of Mount Wutai tourism articles of different categories. In Ctrip, there are 169 positive travel

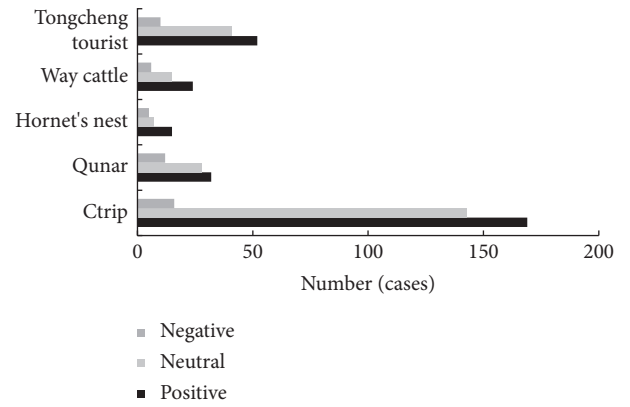


FIGURE 2: Statistics of Mount Wutai tourism articles of different categories.

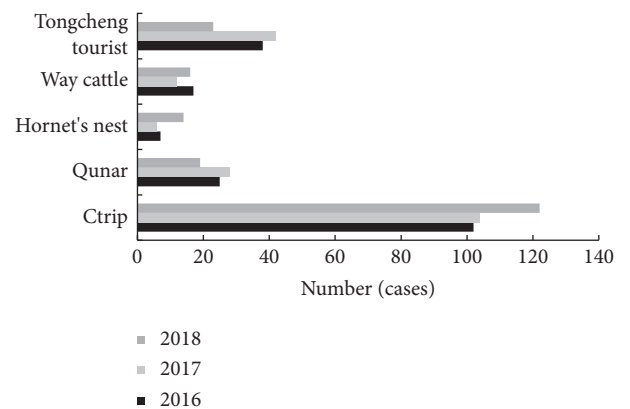


FIGURE 3: Statistics of Mount Wutai tourism articles at different times.

TABLE 3: Statistical table of emotional attitude of online travel notes text.

	Yes	No	Neutral
Revisit	59	22	494
Recommendation	158	65	352

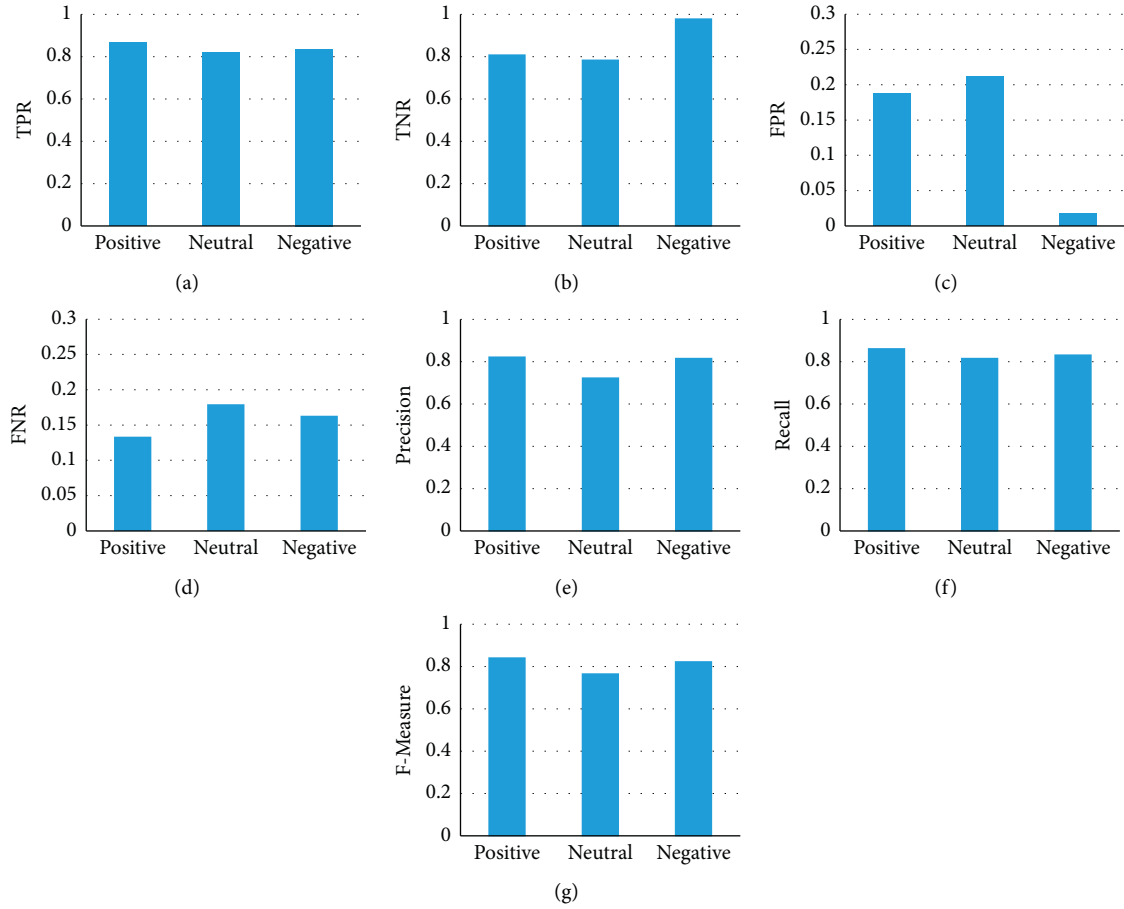


FIGURE 4: Text analysis-based Bayesian decision tree classification evaluation results of public data: (a) TPR, (b) TNR, (c) FPR, (d) FNR, (e) precision, (f) recall, and (g) F-measure.

notes, 143 neutral travel notes, and 16 negative travel notes. In Qunar, there are 32 positive travel notes, 28 neutral travel notes, and 12 negative travel notes. There are 15 positive travel notes, 7 neutral travel notes, and 5 negative travel notes in Horner's nest. In Tuniu, there are 24 positive travel notes, 15 neutral travel notes, and 6 negative travel notes. There are 52 positive travel notes, 41 neutral travel notes, and 10 negative travel notes on the Tongcheng website. Notably, all websites have the most positive online travel notes on Mount Wutai tourism, followed by neutral and negative ones. Figure 3 shows the statistics of Mount Wutai tourism articles at different times. Ctrip had 102 travel notes in 2016, 104 in 2017, and 122 in 2018. In Qunar, there were 25 travel notes in 2016, 28 in 2017, and 19 in 2018. There were 7 travel notes in 2016, 6 in 2017, and 14 in 2018 on Horner's nest. There are 17 travel notes on Tuniu in 2016, 12 in 2017, and 16 in 2018. There were 38 travel notes on Tongcheng in 2016, 42 in 2017, and 23 in 2018. Table 3 is the statistical table of the emotional attitude of online travel notes. The number of tourists who have the intention to revisit and recommend is significantly higher than that of those who do not.

3.2. Public Data Bayesian Decision Tree Classification and Evaluation Based on Text Analysis. Figure 4 shows the classification and evaluation results of the public data

Bayesian decision tree based on text analysis. The true positive rate and true negative rate of the Bayesian decision tree classifier for positive text are 86.64% and 81.27%, respectively. The false positive rate was 18.73%, and the false negative rate was 13.36%. The precision is 82.68%, recall is 86.64%, and F-measure is 84.62%. The true positive rate of the Bayesian decision tree classifier for neutral text is 82.05%, and the true negative rate is 78.89%. The false positive rate, false negative rate, precision, recall, and F-measure are 21.11%, 17.95%, 72.73%, 82.05%, and 77.11%, respectively. The true positive rate of the Bayesian decision tree classifier for negative text is 83.67%, the true negative rate is 98.29%, the false positive rate is 1.71%, and the false negative rate is 16.33%. The precision is 82.00%, recall is 83.67%, and F-measure is 82.83%. The F-measure of the Bayesian decision tree classifier for positive and negative texts is higher than that for neutral texts. Hence, the Bayesian decision tree classifier is better than neutral text in evaluating positive and negative texts.

3.3. Public Data C4.5 Decision Tree Classification and Evaluation Results Based on Text Analysis. Figure 5 shows the C4.5 decision tree classification evaluation results of public data based on text analysis. The true positive rate of the C4.5 decision tree classifier for positive text is 91.44%, the true negative rate is 86.57%, the false positive rate is 13.43%, and

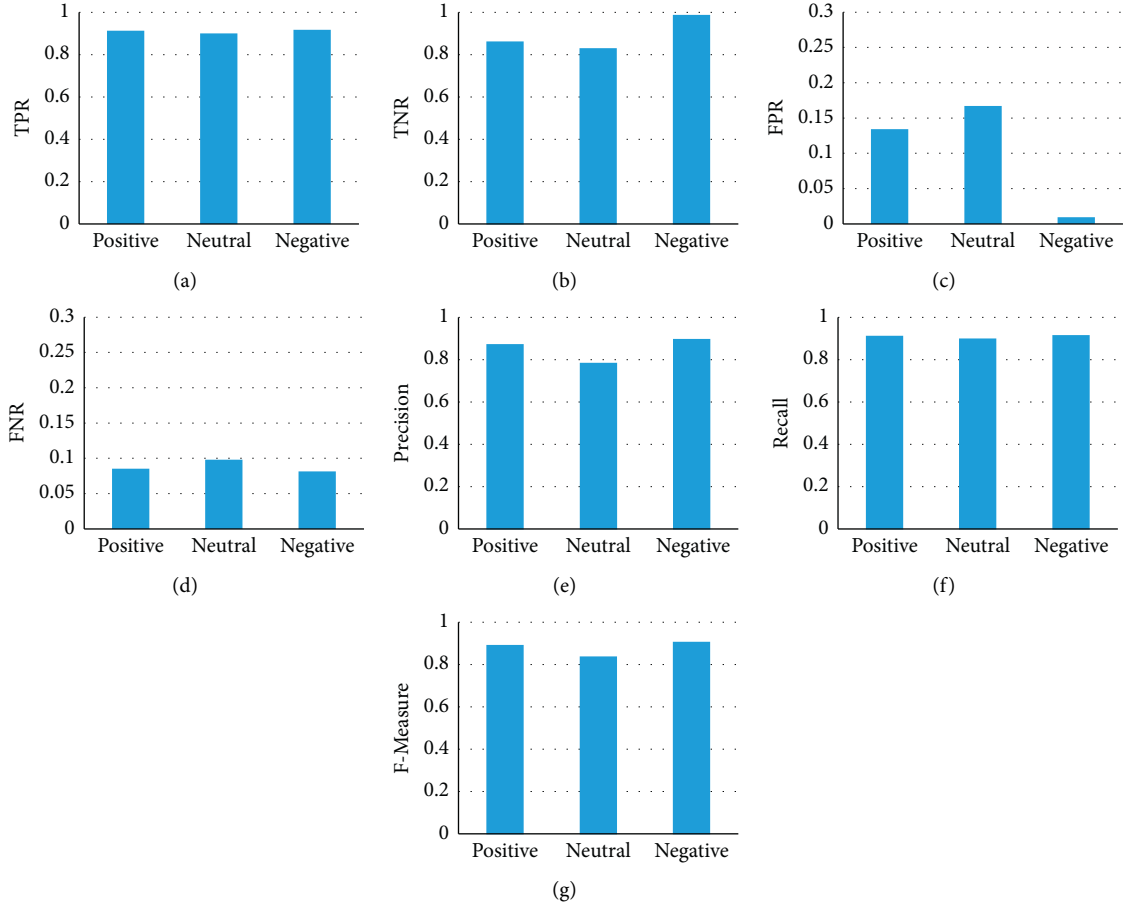


FIGURE 5: Public data C4.5 decision tree classification and evaluation results based on text analysis: (a) TPR, (b) TNR, (c) FPR, (d) FNR, (e) precision, (f) recall, and (g) F-measure.

the false negative rate is 8.56%. The precision, recall, and F-measure are 87.54%, 91.44%, and 89.45%, respectively. The true positive rate of the C4.5 decision tree classifier for neutral text is 90.17%, the true negative rate is 83.28%, the false positive rate is 16.72%, and the false negative rate is 9.83%. The precision, recall, and F-measure are 78.73%, 90.17%, and 84.06%, respectively. The true positive rate of the C4.5 decision tree classifier for negative text is 91.84%, the true negative rate is 99.05%, the false positive rate is 0.95%, and the false negative rate is 8.16%. The precision is 90.00%, recall is 91.84%, and F-measure is 90.91%. The F-measure of the C4.5 decision tree classifier for positive and negative texts is higher than that for neutral texts. Hence, the evaluation effect of the C4.5 decision tree classifier for positive and negative texts is better than that for neutral texts.

3.4. Evaluation Comparison between the C4.5 Decision Tree and Bayesian Classifier. Figure 6 shows the comparison of evaluation between the C4.5 decision tree and Bayesian classifier, where A is the positive text, B is the neutral text, and C is the negative text. The evaluation effect of the two classifiers on the positive text is significantly better than that of the neutral and negative text, and the evaluation effect of the C4.5 decision tree classifier is better than that of the Bayesian classifier.

3.5. Public Data Organization Manages Results. Figure 7 shows the organization and management results of public data of online travel notes of Mount Wutai tourism. There are 513 online travel notes related to tourism resources, 279 online travel notes related to tourism facilities, and 193 online travel notes related to tourism services. There are a total of 163 online travel notes related to the tourism environment, and a large number of them are related to tourism resources and tourism facilities.

3.6. Forward Common Data Association Analysis. Figure 8 shows the association analysis of forward public data, where A is the support degree, B is the confidence degree, C is the promotion degree, and D is the conviction degree. The promotion degree of tourism resources and facilities in forward online travel notes is significantly higher, indicating that tourism resources and facilities are highly correlated with forward online travel notes.

3.7. Negative Public Data Association Analysis. Figure 9 shows the association analysis of negative public data, where A is the support degree, B is the confidence degree, C is the improvement degree, and D is the confidence degree. The promotion degree of tourism service and the tourism

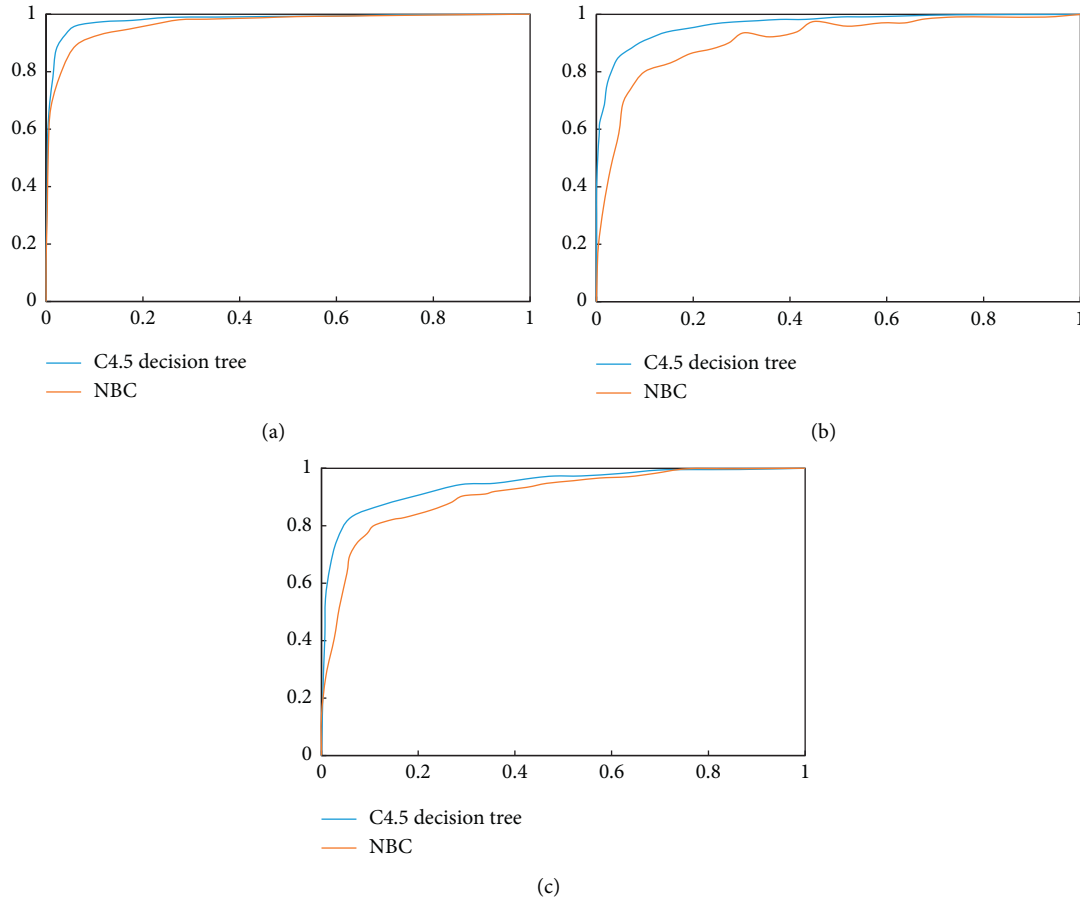


FIGURE 6: Evaluation comparison between the C4.5 decision tree and Bayesian classifier: (a) positive text, (b) neutral text, and (c) negative text.

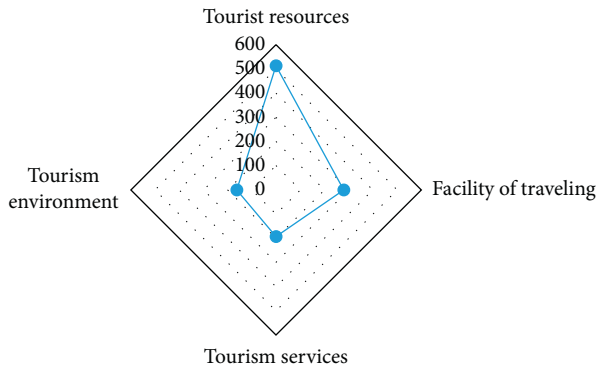


FIGURE 7: Mount Wutai travel notes text public data organization and management results.

environment in negative online travel notes is higher, indicating that tourism service and the tourism environment are highly correlated with negative online travel notes.

4. Discussion

The development of big data provides convenient conditions for people to collect and use information. With the development of informatization, the Internet has become the

main way for people to release and search for information [19, 20]. The new media form of tourism has been widely recognized. An increasing number of tourists express their feelings and attitudes during travel through the Internet, showing their travel process and expressing their travel feelings in the form of online travel notes and comments [21, 22]. These network texts are authentic and extensive and play an important role in shaping the image of tourist destinations and providing a reference for tourists [23]. Based on the online travel notes of tourism websites, the evaluation and correlation factors of tourists' emotional attitudes on Mount Wutai are analyzed. Text classification plays an important role in text analysis and management. McCallum and Nigam [24] compared the naive Bayesian text classification model with the unigram language model with integer words and found that the naive Bayesian text classification model performed well and had certain advantages. Tong and Koller [25] applied text classification with support vector machine active learning and achieved good results. Fesseha et al. [26] carried out text classification of Tigrinian based on a convolutional neural network and found that a convolutional neural network has higher accuracy in classification compared with other traditional machine learning models. Hutama et al. [27] used naive Bayesian and decision tree to create a classification model and classified the text

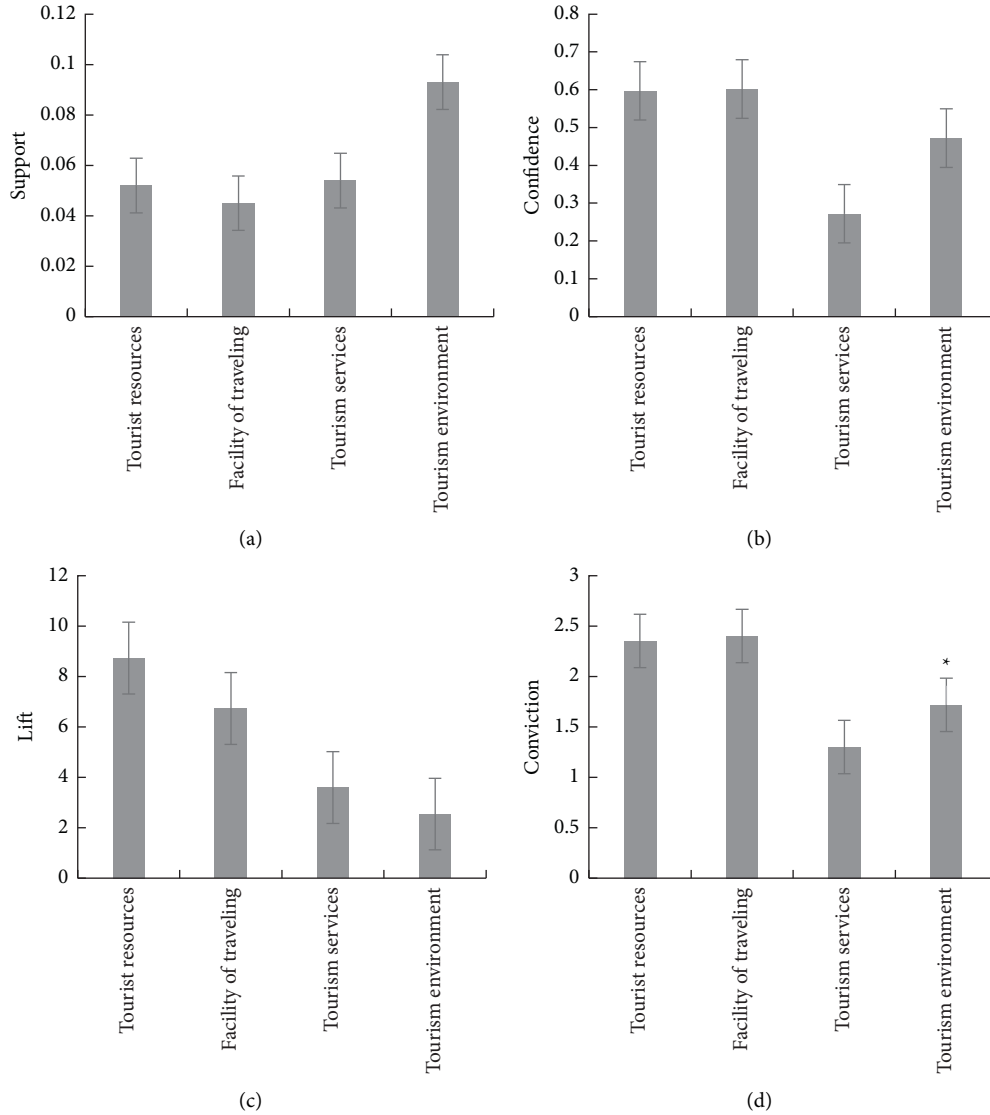


FIGURE 8: Positive association analysis of common data: (a) support, (b) confidence, (c) improvement, and (d) confidence.

data of work culture. They found that the accuracy of the three constructed work cultures was 33%, 66%, and 80%, respectively, and the accuracy of Bayesian was 83%, 50%, and 60%, respectively. Both methods had good performance.

The text classification method in this study adopts a naive Bayesian classification model and decision tree classification model [28–37]. The results show that the true positive rate of the Bayesian decision tree classifier for positive text is 86.64%, the true negative rate is 81.27%, and the F-measure is 84.62%. The true positive rate for neutral text is 82.05%, the true negative rate is 78.89%, and the F-measure is 77.11%. The true positive rate for negative text is 83.67%, the true negative rate is 98.29%, and the F-measure is 82.83%. Notably, the evaluation effect of the Bayesian decision tree classifier on positive and negative text is better than that of neutral text. The true positive rate of the C4.5 decision tree classifier for positive text is 91.44%, the true negative rate is 86.57%, and the F-measure is 89.45%. The true positive rate for neutral text is 90.17%, the true

negative rate is 83.28%, and the F-measure is 84.06%. The true positive rate for negative text is 91.84%, the true negative rate is 99.05%, and the F-measure is 90.91%. The C4.5 decision tree classifier has a better evaluation effect on positive and negative texts than on neutral texts. The ROC curve of the C4.5 decision tree and Bayesian classifier shows that the evaluation effect of the two classifiers on positive text is significantly better than that of neutral and negative text, and the evaluation effect of the C4.5 decision tree classifier is better than that of the Bayesian classifier.

This study also analyzes the correlation between the factors affecting the categories of online travel notes and the emotional attitudes of online travel notes. Using the Apriori algorithm for correlation analysis, the support degree, confidence degree, promotion degree, and confidence degree between tourism resources, tourism facilities, tourism services, and the tourism environment and online travel notes with different emotional attitudes are calculated. The results show that the promotion degree of tourism resources and

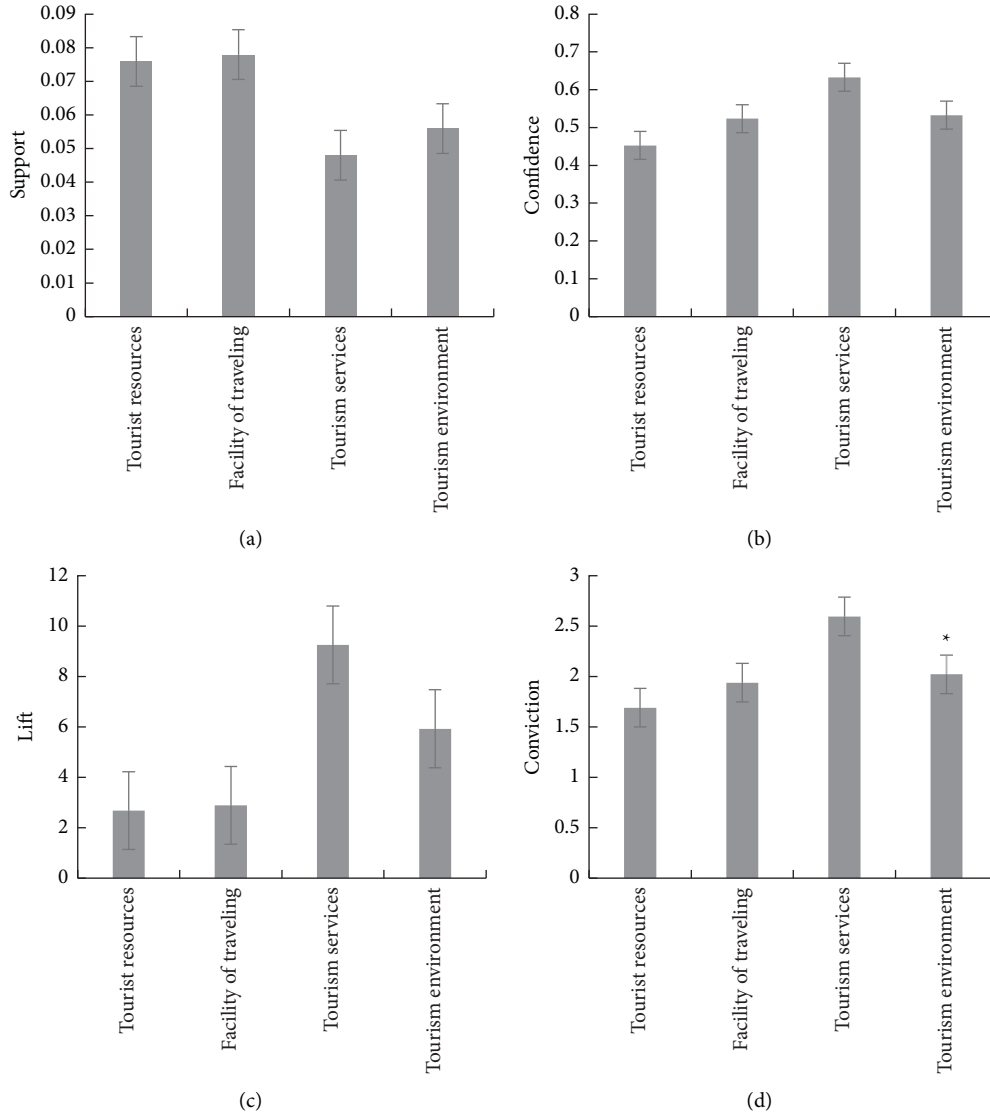


FIGURE 9: Negative association analysis of common data: (a) support, (b) confidence, (c) improvement, and (d) confidence.

facilities in the forward online travel notes is significantly higher, indicating that tourism resources and facilities are highly correlated with the forward online travel notes. The promotion degree of tourism service and the tourism environment in negative online travel notes is higher, indicating that tourism service and the tourism environment are highly correlated with negative online travel notes. The tourism service quality and environment of Mount Wutai scenic area should be greatly improved to make up the shortcomings and promote the development of Mount Wutai tourism.

5. Conclusion

In this study, a naive Bayesian classification model and decision tree classification model are used to classify the emotional attitude of Mount Wutai travel notes online, and it is found that the decision tree classification model has a better classification effect. The relationship between tourism resources, tourism facilities, tourism services, the tourism

environment, and the emotional attitude of online travel notes is discussed, and it is revealed that tourism resources and tourism facilities are strongly correlated with the positive text, while tourism services and the tourism environment are strongly correlated with the negative text.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis of Human Capital Social Network Model Based on Industry Distribution

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As the most critical resource to promote the continuous growth of economic volume, human resources are indispensable to the development of the industry. With the development of market economy and the improvement of people's pursuit of quality of life, the time of talent flow is increasing, which forms the social network of human capital. As a new stock, human capital social network can have an impact on individual thoughts or behaviors. This paper with a recruitment website workers repeatedly changes employment resume as the research object and uses literature research and empirical analysis based on human capital social network model analysis for the industry distribution of employment analysis and discussion. The results show that the IT internet industry in labor cross-industry network has high resource control and information advantage and has large correlation with other industries; traditional industry is limited; construction, leasing, and business services, electricity, heat, coal, and water flow frequency are the lowest; and the network structure is more stable.

1. Introduction

With the continuous development of modern information technology, the work of various industries and people's daily lives are interrelated with big data, which not only brings simplicity and quickness to everyone but also gradually changes the world form into a huge social network. Different social networks are different under different problems and schemes and are not generalized. Through the construction of human capital social network to study the relationship of network location and enterprise innovation [1], relevant research in the field of social networks and enterprise risk has been enriched [2]. A large number of studies have proved that social networks will affect various forms of regional economy in different ways. In recent years, the world economy has slowed down, the international economic situation is unstable, and market demand has weakened. In the state of economic downturn, the pressure of international competition for traditional products has further increased, which has led to a sharp increase in the pressure on workers. The Ministry of Education announced that the national college

entrance examination will recruit 10.71 million students and 8.74 million college graduates in 2020, an increase of 400,000 over the previous year. In the previous research on social network, the direction was mostly focused on the economic perspective, and the research objects mostly listed companies or special groups. Few people study the human capital social network from the open employee resume system. In order to study the social network and enrich human resources from a more comprehensive perspective, the human capital social network formed by a large number of workers due to job changes and employment has become the focus of this paper. Based on the analysis of industry distribution, this paper provides a new perspective and direction for the follow-up social network research.

2. Related Definitions

2.1. Definitions

2.1.1. Talent Flow. As the objective requirement and necessary premise of the development of market economy,

talent flow is an important mechanism to adjust the relationship between supply and demand of talent market and give full play to the benefits of talents [3]. The flow of talent occurs across industries, between professions, between industries, and between regions. Talent flow refers to the realization of talents by changing their working state [4]. Everyone's job, workplace, occupational nature, service object, and nature are different, so the form of talent flow will be determined according to each person's different factors.

2.1.2. Social Network. The concept of "network" was first proposed by G. Simmel. The term "social network" was first proposed by British anthropologist Brown. For social network, Brown was more concerned about the interdependence of structural elements, emphasizing the importance of informal connections in complex interpersonal networks. Granovetter believes that network relations are a close connection between different individuals and organizations due to various communication activities, which is different from emotion, class, or other abstract attributes in traditional sociology [5]. Network relations actually exist, rather than abstract concepts. Mitchell defined it as a group of people with attribute relationships, including direct social relationships, such as relatives, friends, teachers, and students, or certain social relations, such as indirect social relations formed through environmental or cultural connections.

2.2. Theoretics

2.2.1. Social Capital Theory. In 1916, Hanifan first proposed what social capital was. In 1988, James Coleman first explained what is social capital and its related concepts and social significance. Coleman proposes from the perspective of structure and functionalism that social capital can be divided into three aspects: social network, social groups, and network acquisition. In 1961, Jacobs argued that social networks were an intrinsic property of social capital. In 1986, Bourdieu, from the perspective of social capital resources, proposed the common familiar or recognized social network to form social capital.

2.2.2. Weak Connection Advantage Theory. The birth of Granovetter is a sign of the deep development of social networks. He believed that, in the social network, the actors maintaining weak contact is the most advantage and pointed out that only the weak contact network will appear information bridge because the weak contact distribution is more widely, and the cost of information transmission between weak contact is lower than the strong connection, so the information and resources are more valuable.

2.2.3. Structure Hole Theory. If a particular node in the network maintains a relationship with many individuals that has no relationship to each other, that is, if the node has many structural holes, then the node will benefit from this special

structure, that is, the third party. If the structure of the node hole is enlarged, such as the node is the key connection between multiple unrelated groups, the node will get more benefits. As long as there is no contact of two individuals, structure hole will be produced, so in the social network structure hole is common, it is more emphasis on the quality of network relationship rather than quantity. Burt believes that enterprises occupying structural hole positions have a natural intermediate advantage. When enterprises are in the middle of all resources, they can approach many different information streams, obtain more updated first-hand non-redundant resources and information, and have the advantage of maintaining and controlling information.

2.2.4. Embedded Theory. Granovetter first proposed the concept of the embeddedness of the network relations, and he believed that all the economic activities in the society are embedded in the human social networks. The foundation of embedding comes from the trust, which is the concrete manifestation of the social network relationship, so the trust requires a long period of contact and maintenance to strengthen the social network relationship. Uzzi further divided the embeddedness and proposed three dimensions: trust, quality information sharing, and joint problem solving.

2.2.5. Strong Connection Advantage Theory. Krackhardt believes that only when two actors in social networks establish strong connections can mutual trust be supported and consolidated and their cooperation can be tacit. In the complex and changeable market environment and various uncertainties, the strong connection will make its network relationship stronger. He also believes that strong connection pays more attention to the depth of the relationship content between enterprises and can promote the division of labor and resource allocation of various actors in the network, so as to achieve the purpose, so strong connection is very meaningful in the social network.

3. Literature Research

3.1. Defining Research. The growth of talent flow scale has attracted the attention of countries all over the world. Scholars have studied talent flow from different research perspectives and achieved a series of research results. The rationality and necessity of talent flow have become the primary problem of many scholars. In the objective economic law and the so-called sense of competition, talents include individuals or organizations who make reasonable decisions on talent flow through the joint action of talent market supply, demand, and price.

According to the theory, career usually has four stages: exploration, career, (career) maintenance, and resignation. In the course of each life, there are different tasks, activities, relationships, and so on in everyone's career. At present, the research method of talent flow is relatively mature, and the diversified research perspectives and rich research content make the theoretical system of talent flow increasingly perfect. Theodore proposed that the realization and

appreciation of the value of human capital mostly realize its own value by the flow of labor force [6]. Owen studied that people's needs can be divided into survival needs, relationship needs, and growth needs, and they flow according to human needs [7]. Choi and Thompson proposed that the team members did the comparison experiment and compared the two groups with any internal mobility and found that the groups with personnel mobility had a higher level of creativity and better performance. Therefore, they believed that personnel flow and subject change should occur in time [8]. Lewin and McCarthy proposed that a person's personal ability does not fully represent a person's work performance, and the external environment has a greater impact. Therefore, when the individual cannot adapt to the working environment, he will choose to leave the environment and turn to a more suitable environment [9]. Wallace et al. proposed that the moderate talent flow is conducive to the information communication within the organization and is beneficial to the organization. Their organizational life theory also proved the feasibility and necessity of human mobility, while they also pointed out that the flow of people should be moderate, the frequency of flow should not be too fast, and too many flows will cause reflux but will reduce the benefit [10]. Petersen and Sugimoto proposed that, from the perspective of the whole society, the flow of talents is an inevitable requirement to optimize resource allocation and develop human resources. He proposed that whether the flow of talents can depend on the combination of individual talent decisions and organizational decision results [11, 12]. Karahasan and Bilgel presented that, in essence, talent flow refers to the optimal allocation to maximize the expected return. Through the market intermediary, human capital changes the intermediate state and transfers the space and finally realizes the result of talent flow [13]. Zhang et al. presented that, for an organization, when talents flow from one organization to another, because the organizational environment and its own management status are often changing, talents always flow toward the talent saturation of the same organizational system and always tend to quasi-saturation [14].

3.2. Theory Research. Domestic and foreign for the definition of talent flow has broad and narrow [15–17]. Narrow sense of talent flow for the flow between different organizations, namely talent from one organization to another organization status change. In this paper, it is the narrow sense of talent flow, mainly including talent departure and talent career two stages. In a broad sense, talent flow includes changes within the organization, namely, the talent flow within organization. Therefore, according to the certain factors of working status, the talent flow between industries, and the talent flow involved in the research institute is understood in a narrow sense; for the accounting method of talent flow, the academic community has not yet formed a unified standard. Scholars' research on social network is aimed at economics and sociology. Starting with the definition of social network, after a long-term evolutionary interpretation, they have not yet reached a unified

conclusion. The social network of human capital is formed through the flow of talents under the distribution of social network [18–21]. Its innovation point also puts forward a new perspective on Liu's research direction and conducts human capital social network analysis based on the industry distribution. The social network analysis method is a quantitative analysis method combining comprehensive map and mathematical model to obtain each index and explain the structural characteristics and function of the social network to reveal the meaning of the research object in the real world [16].

This paper takes the network center degree (DCit) and structure hole (SHDit) index as the explanatory variables of the human capital social network to represent the position of the industry in the human capital social network and analyzes the industry characteristics through the social network analysis method of this paper.

4. Research Hypothesis

4.1. Selected Object. This paper takes 73659 resume data in a recruitment website as the research object and selects the workers through the way of employment to choose 1–7 new jobs or new company resume information through a large amount of data in the occupation flow between the industry constituting a social network based on the social network analysis of the industry. This study uses the social network analysis method with centrality and structural hole as variables to measure the location of human capital social network and uses COOC and UCINET software to map and calculate the social network diagram. The industry-based human capital social network analysis is calculated based on the same data.

4.2. Research Hypothesis.

- (i) The IT Internet industry flows the most frequently in all industries
- (ii) The flow of service-related industries tends to be stable level
- (iii) Traditional industries have the lowest flow frequency

5. Empirical Process

5.1. Source of Data. Based on the existing employment resume data and the analysis and discussion of the social network of human capital in the industry, this paper selects the data of a recruitment website (1970–2019). By screening 73659 resumes on the recruitment website and deleting invalid data, 6604 valid data involving 13 industries were obtained for employee industry analysis.

5.2. Analysis

5.2.1. Part I: Centrality. Centrality is often used to characterize network centrality, the association of points in the network with other loci. The degree centrality of the point

calculates the number of other points directly connected. If a node of the network has a high degree of center, it is called at the core of the network, has a high correlation with other nodes, and is closely related. In terms of the labor mobility network in this paper, this network is a directed network, so the degree centrality can be divided into outlet center degree and entry center degree. Outlet center degree refers to the number of network nodes sent to other nodes, and entry center degree refers to the number of nodes receiving other nodes in the network. Specifically, referring to the labor industry flow network we investigated, the outlet center degree and the entry center degree reflect the labor outflow scale and inflow scale of a certain industry in the network, respectively. The calculation formula of the degree center degree is as follows:

$$\begin{aligned} Out_i &= \sum_j X_{ij}, \\ In_i &= \sum_j X_{ji}. \end{aligned} \quad (1)$$

The above two formulas are absolute indicators of the centrality and the degree centrality.

$$\begin{aligned} NromOut_i &= \frac{\sum_j X_{ij}}{n-1}, \\ NormIn_i &= \frac{\sum_j X_{ji}}{n-1}. \end{aligned} \quad (2)$$

The above two formulas give the relative index of the center degree and the center degree, excluding the influence of the industry network size. In the above formula, " X_{ij} " means the number of labor flows from " i " to " j ," and " n " is the total number of the industry.

5.2.2. Part II: Structure Hole. The existence of structural holes makes the industries in the middle of the network have important relevance and can control the flow of resources to a large extent. The calculation of structural hole involves four indicators: effective scale, efficiency, limit system, and hierarchy. The calculation formula is as follows:

$$\begin{aligned} Shd_i &= 1 - C_i, \\ C_i &= \sum_j C_{ij}, \\ C_{ij} &= \left(p_{ij} + \sum_q p_{iq} p_{qj} \right)^2, q \neq i, j. \end{aligned} \quad (3)$$

In the above formula, Shd_i represents the structural hole index; larger Shd_i means more structural holes " i " occupies in the industry; the industry is relatively free in the labor flow network; C_i represents the total constraint of industry " i " in the network; the greater the total constraint, the fewer the structural holes. Since " C_i " is 1, scholars generally use $1 - C_i$ to represent the structural hole; C_{ij} represents the constraint degree between industry " i " and industry " j ." Among them, " p_{ij} " represents the direct association between industry " i "

and industry " j ," while " p_{iq}, p_{qj} " represents the indirect association between industry " i " and industry " j ."

There are 13 items of data involved in this paper: IT Internet; manufacturing industry; scientific research and technical services; health and society; construction; real estate; wholesale and retail; accommodation and catering; education and training; culture and sports and entertainment; leasing and business-services; finance; electricity, heat, coal, and water. In this paper, we use Ucinet software. Thicker lines indicate more flows, while thinner lines indicate less flows; arrows indicate the flow direction of the worker.

The most frequent employment flows occur between manufacturing and scientific research and technology services, as well as between Internet and scientific research and technology services (Figure 1). Secondly, the labor flow between internet and wholesale and retail, education and training, culture, sports, entertainment, and finance is also more frequent. In addition to the deep integration into the secondary industry, information and intelligence also have the general trend of integration into the tertiary industry.

With the continuous development of the Internet and the support of information technology, traditional service industries have gradually opened up the "online" service mode. The consumption of online shopping platforms such as Taobao, Tmall, and jd.com has become the norm. At the end of 2019, the monthly active users of Taobao mobile exceeded 800 million for the first time. In 2019, the transaction volume of Tmall's double 11 reached 268.4 billion, an increase of 26% over 2018, and the total orders exceeded 1.292 billion. Online education platforms such as ape counseling have also been used by a large number of families. As of January 15, 2020, the cumulative number of ape counseling has exceeded 400 million. At the beginning of 2020, TikTok released the 2019 data report, and by 2019, the number of daily active users will reach 400 million. As of the third quarter of 2019, Alipay had more than 1 billion and 200 million users. Online errands, like Meituan and Eleme, are very popular. Meituan APP monthly number reached 44.1857 million, while Eleme APP monthly number reached 6268.93 million by the end of 2018.

Based on the network collinear matrix, Ucinet software [22–25], the results obtained are shown in Table 1.

6. Results and Discussion

Through the research on the social network of talent capital, the following conclusions are drawn:

- (1) The IT internet flows most frequently in all industries. The proposal of "Made in China 2025" accelerates the pace of transformation and upgrading of the manufacturing industry, and intelligence, information, and service-oriented are gradually integrated into the development path of the manufacturing industry. Therefore, the traditional manufacturing industry has attracted a large number of scientific research and technical talents into the manufacturing industry to promote the

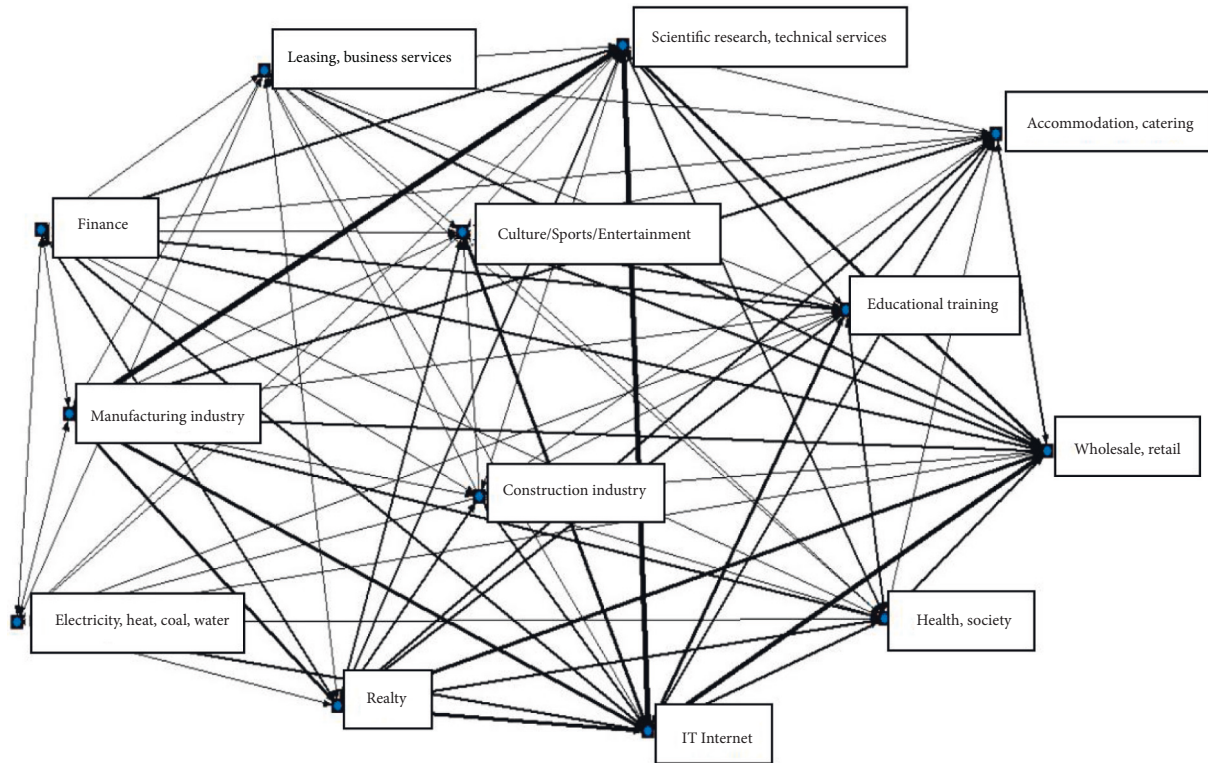


FIGURE 1: Labor force industry mobility network map.

TABLE 1: Labor force industry flow network center and structure hole.

Profession	Industry code	Out of the center degree	Enter the center degree	Relative outflow centrality degree	Relative degree centrality	Structural hole index
IT Internet	1	352	273	29.333	22.750	0.657
Scientific research and technical services	2	250	216	20.833	18.000	0.574
Realty	3	209	173	17.417	14.417	0.610
Wholesale and retail	4	193	224	16.083	18.667	0.601
Manufacturing industry	5	145	219	12.083	18.250	0.561
Educational training	6	127	131	10.583	10.917	0.575
Health and society	7	122	107	10.167	8.917	0.550
Finance	8	85	74	7.083	6.167	0.580
Culture, sports, and entertainment	9	74	106	6.167	8.833	0.507
Accommodation and catering	10	64	110	5.333	9.167	0.582
Construction industry	11	60	53	5.000	4.417	0.567
Rental and business services	12	50	46	4.167	3.833	0.597
Electricity, heat, coal, and water	13	37	36	3.083	3.000	0.535

transformation and upgrading of the manufacturing industry. "Internet +," 5G industry, AI, VR, and IT internet industry, such emerging industry development relying on network technology needs basic research support. The traditional service industry data reflects the status quo: internet industry is already closely related to human production and life, and it is natural for IT technical talents to flow more to such service industries; therefore, IT internet industry and scientific research and technical service

industry also have a lot of labor flow, communication, and mutual progress, jointly promoting the development of emerging industries.

- (2) The flow of service-related industries tends to be stable level. At present, all industries are seeking breakthroughs in the emerging innovative industries, and the service industry has seized this opportunity like a tiger with wings and made full use of modern information technology to achieve a qualitative leap, which not only realizes safer and more

convenient producers but also saves worry, trouble, and time for consumers.

- (3) Traditional industries have the lowest flow frequency. Compared with the frequent flow of talent in the IT industry, employers in traditional industries, such as electricity, heat, coal, water, and construction are relatively immobile. It is also fundamentally because the transformation of traditional industries is difficult to integrate with other industries. Figure 1 shows a correlation between the electricity, heat, coal, and water industry and the construction industry and other industries, but in traditional industries, compared to other industries, improvements or changes in people's living standards are not enough to support or attract the flow of talent to their industries. On the other hand, traditional industries are different from other industries, and it is more difficult to integrate with other majors in terms of professionalism. Therefore, the frequency of talent flow in the process of traditional industries with other industries is lower.

The research results show that the popularity of the IT Internet industry is still high, and it is also the most connected industry to other industries; so, whether it flows in or out, the IT Internet industry is still the first choice for many people. In short, the IT Internet industry has long been the biggest winner in the entire market. The Internet has long been closely related to our lives, and it also means that the Internet will not disappear in our lives. Not only that, as we will find out, the IT Internet industry occupies the entire market. Traditional industries suffer more than just stormy blows, even after a hurricane, and the whole industry will disappear. Industries that are unlikely to stagnate in social networks are scientific research and technical services, real estate, wholesale and retail, manufacturing, education and training, and health and social work. These industries are the source of people's lives. No matter how the society changes and how the times progress, these industries will not disappear with the changes of the times, which means that they are the most basic and solid industries. Employees should pay more attention to the needs and self matching degree of the IT Internet industry. Secondly, the reason for the frequent network relationships in the IT Internet industry is that people frequently enter and leave the IT Internet industry. Therefore, employees should pay more attention to whether they can adapt to the rules of the IT Internet industry. These should be the concerns of workers, and then workers should choose the industry that is most suitable for them.

This study takes the systematic data of a public resume on the basis of sorting out relevant literature, summarizes the research status of talent flow and social network, demonstrates the model and hypothesis through large samples, and obtains some research results and discussion, which is an expansion of the research of human capital social network. However, due to the complexity of social network analysis methods and the limited ability of authors, it is hoped that, in future research, the nonspecial groups of

human capital social network can be systematically analyzed and the practical value and significance of human capital social network for workers themselves can be discussed.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Internet of Vehicles Resource Scheduling Based on Blockchain and Game Theory

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With the popularity of on-board intelligent devices, the number of vehicle computing intensive applications is also increasing rapidly. Due to the high mobility and limited computing power of the vehicle, and the extensive and changing demand for computing resources of the vehicle terminal, the vehicle often has insufficient computing power. In order to meet the needs of intensive computing applications of vehicle terminals, the computing tasks of vehicles can be unloaded to edge cloud servers (ECSs) with rich resources and high performance to enhance the computing power of vehicle terminals. However, the resource charge of ECS is high, and the scheme needs to consider such issues as ECS signal coverage, long task transmission delay caused by network congestion, and insufficient computing capacity of ECS. Therefore, this study considers unloading the computing tasks of vehicles with insufficient computing resources to nearby vehicles with redundant computing capacity and proposes a resource scheduling method for the Internet of vehicles based on blockchain and game theory. The scheduling of computing resources can reduce the computing workload of buyers' vehicles and improve the operation efficiency of the whole vehicle network.

1. Introduction

In recent years, the Internet of things (IoT) [1–4] has attracted great attention from academia and the industry. Its applications in life can be seen everywhere, such as smart phones, tablet computers, smart TVs, and smart vehicles. As a key branch of the Internet of things, the Internet of vehicles (IOV) [5–7] has also become a key research field and development direction concerned by all walks of life. The vigorous development of the Internet of vehicles has a strong foundation. It is safer, more environmentally friendly, and more convenient to drive. Functionally speaking, it can communicate and add more on-board entertainment, self-diagnosis, and repair, which are the necessary conditions for the realization of unmanned driving. On a deeper level, if the Internet of vehicles is used to realize driverless, the car is not only a vehicle, but also a mobile space. In addition, the Internet of vehicles can also realize vehicle to everything (V2X), where x can be an entity or nonentity [8, 9].

However, with the rapid development of the Internet of vehicles, the data of the Internet of vehicles has also experienced a blowout growth in recent years [10–14]. Intel's Research Report on the amount of data used by Internet of vehicles users a few years ago pointed out that, in 2020, the amount of data used by a car that realizes automatic driving will be 4000 GB [15]. At the same time, in the face of the huge and complicated number of vehicles and roads, plus the huge number of sensors, the Internet of vehicles puts forward high requirements for the processing delay of data tasks and network bandwidth resources.

Although the resource scheduling of mobile vehicles in IOV has many advantages, the current resource scheduling scheme still has many problems [16]. Resource scheduling in IOV is mainly conducted through vehicle to vehicle (V2V) and vehicle to RSU (V2R). However, since V2V communication and V2R communication do not encrypt data, malicious nodes can intercept or even tamper with communication data in the process of data transmission [17]. On

the other hand, the information between entities participating in resource scheduling is opaque, RSUs located on the roadside are vulnerable to external attacks, and there is a lack of an effective trust mechanism between entities participating in resource scheduling. For the sake of privacy and data security, vehicles may not be willing to participate in the resource scheduling of IOV [18, 19]. Most importantly, there is a lack of an efficient resource scheduling mechanism in IOV, which can not meet the needs of the rapidly changing IOV resource scheduling market. To sum up, the current IOV resource scheduling including data sharing and computing task unloading mainly faces the following three challenges.

1.1. Unsafe Data Transmission. During the process of data sharing and computing task unloading, the communication node does not encrypt the data, so the data is easy to be intercepted or even tampered by malicious nodes during transmission, which poses a serious threat to the data security of IOV.

1.2. Low Efficiency of the Centralized Dispatching System. In the traditional IOV, the resource scheduling between vehicles is centrally controlled by the authority. Today, with the increasing scale of IOV, the centralized scheduling time and energy consumption are relatively large. On the other hand, if the dispatching organization is attacked, large-scale data leakage may occur, resulting in a series of uncontrollable events.

1.3. Lack of Efficient Resource Scheduling Mechanism. The resource scheduling in IOV involves multiple entities involved in scheduling, which makes the process of resource scheduling very complex. This requires us to design an efficient resource scheduling strategy for the two resource scheduling scenarios of data sharing and computing task unloading to meet the needs of the IOV resource scheduling market.

In recent years, blockchain technology [20–23] has developed rapidly. Due to its characteristics of decentralization, anonymity, and trust, a large number of researchers have done more and more research work on the combination of blockchain and Internet of vehicles from different angles.

Blockchain is a chained data structure. Consensus nodes package transaction records into blocks and link blocks to the blockchain according to the time sequence of block generation. In fact, blockchain can be regarded as a distributed database, which uses encryption technology to ensure that data cannot be tampered with and forged. When the distributed nodes share data, each node can verify the validity of the transaction signature based on the public key in the distributed network to ensure the authenticity of the shared data. In addition, smart contract is also an important technology in blockchain. It is a commitment in digital form, including the specific algorithm to be executed and the algorithm execution conditions. After the smart contract is

deployed, it will be automatically executed by computer programs. Through the smart contract blockchain, various distributed applications can be supported to achieve more complex functions. In addition, the blockchain will distribute digital currency rewards to the consensus nodes that have obtained the bookkeeping right, which can motivate the nodes to provide computing power and resources.

Blockchain can promote the establishment of a secure, mutual trust, and decentralized intelligent transportation network to solve the resource scheduling problem in IOV and help make better use of transportation infrastructure and resources.

2. System Model

We mainly study the mobile vehicle computing task unloading problem in the resource scheduling of the Internet of vehicles. At present, there are many researches on mobile vehicle computing task unloading, but there are still many problems in the existing schemes, such as vehicle privacy and data leakage, low system operation efficiency, inability to provide an effective incentive mechanism, and so on. Therefore, we propose a scheme for mobile vehicle computing task unloading and build a system framework based on the alliance blockchain.

2.1. System Entities. Figure 1 is the model diagram of the mobile vehicle computing task offloading system based on the alliance blockchain [20–23] designed in this paper. The model mainly includes three classes of entities: trusted Authority (TA), roadside unit (RSU), and mobile vehicles.

The details of the functions of each entity in the system are as follows.

2.1.1. Trusted Authority (TA). The function of the TA is the same as that of the TA introduced in Section 3.1, both of which deal with the registration and authentication of entities in the system and send a digital certificate, public key, and private key to the entity to ensure the security of entity data transmission.

2.1.2. Roadside Unit (RSU). In the system model, the RSU acts as a vehicle computing task offloading agent responsible for hosting and directing the auction process to handle calculating resource scheduling problems. At the same time, RSU is also the consensus node of the alliance blockchain. A smart contract (Computation Offloading Smart Contract, COSC) that controls the offloading of vehicle computing tasks is deployed on the RSU. A copy of the alliance blockchain is saved on each RSU. There are multiple RSUs beside the road, and the coverage radius is defined as RSUR. Similarly, all RSUs are carried out through communication cables, and mobile vehicles can communicate with RSUs through V2R wireless communication.

2.1.3. Mobile Vehicles. Mobile vehicles with compute-intensive applications waiting to be offloaded act as buyers of

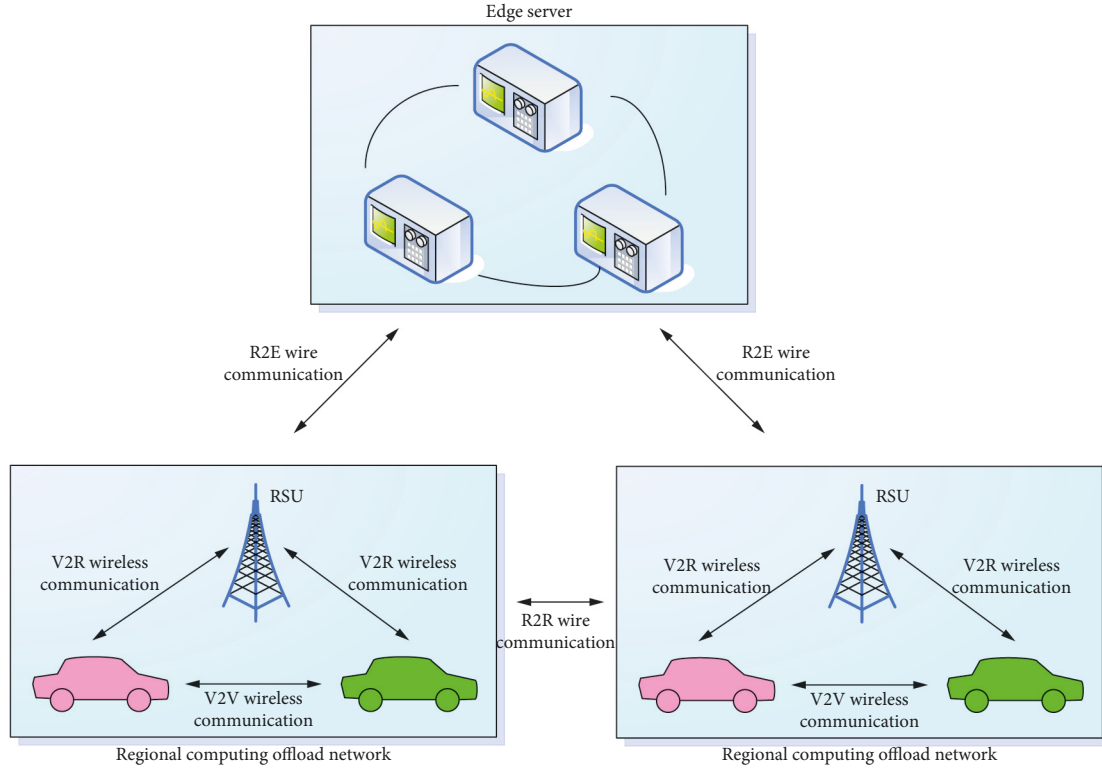


FIGURE 1: System model.

computing resources. Vehicle users with idle computing resources can be rented to buyers to act as computing resource suppliers, i.e., sellers. Vehicles can communicate with the RSU through V2R, and the vehicles communicate through V2V. The vehicle also has a wallet for storing resource coins and a virtual identity for privacy protection.

As shown in the system model diagram in Figure 1, the smart contract COSC divides each RSU and the mobile vehicles within its communication range into a network area according to the communication range R^{RSU} of each RSU, and the network area is named regional computation offloading network (RCON). As the regional manager of an RCON, each RSU manages the offloading of vehicle computing tasks in the RCON and acts as a consensus node of the alliance blockchain on the other hand. RSU will package the transaction records into blocks and pass the corresponding consensus mechanism to link the block to the consortium blockchain. In addition, RCONs are connected by cable, and the same is true between RCONs and the edge server cloud, and they can all communicate with each other. Vehicles can offload computing tasks to other vehicles with spare computing resources in the same RCON through RSU scheduling or offload computing tasks to edge cloud servers through RSU. We focus on the case where a vehicle offloads computational tasks to a nearby moving vehicle.

2.2. Basic Assumptions of the Computing Task Offloading Model. The research on computing task offloading [24–26] of mobile vehicles will be based on the following assumptions:

- (1) First, consider the communication between model entities. Figure 1 shows that wired communication between RCONs and between RCONs and edge cloud servers will be carried out through cables. The communication between them does not need to consider the effect of communication range.

The V2R communication between the RSU and the vehicle is affected by the communication range R^{RSU} of the RSU. In contrast, the communication between them does not need to consider the effect of communication range. V2R communication between RSU and vehicle is affected by RSU's communication range R^{RSU} . At the same time, only when the reliability of data transmission can be guaranteed by one-hop V2V connection the calculation offload can be performed between the two vehicles; otherwise, there may be data loss during the transmission process.

- (2) We also assume that time is time-slotted and studies the computing task offloading strategy of moving vehicles in a specific period.
- (3) Assuming there is a lack of information in the computing task offloading market, the RSU and buyer cannot know the seller's bid, and the seller cannot know the bids of other sellers. RSU manages the computing task offloading market through the smart contract COSC of the alliance blockchain. RSU will not favor any buyer or seller, nor can it refuse to help any vehicle that wants to participate in computing task offloading. In addition, due to the

characteristics of the consortium blockchain system, various entities cannot collude with each other.

- (4) In the process of computing task offloading, one buyer can only uninstall its application to one seller, but one seller can provide services for multiple buyers. At the same time, since the computing task offloading scheme proposed applies to all RCONs, to simplify the discussion, in the follow-up work, we will take an RCON as an example to study computing task offloading.
- (5) It is assumed that a computing task can be divided into a computing program with fixed data size. This computing program is the smallest unit of computing task division.

3. The Specific Process of Computing Task Offloading

The particular process of vehicle computing task offloading is shown as follows.

3.1. System Initialization. All entities must be registered with TA and submit a certain amount of resource coins as a deposit to the account under the supervision of TA. Then download the latest data information from the nearby alliance blockchain nodes' storage pool to synchronize the entity system's state, which will not be repeated here.

3.2. Both Buyers and Sellers Submit Relevant Information to RSU. In RCON, buyers and sellers of vehicles who intend to participate in the offloading of computing tasks will submit relevant information to RSU. The information submitted by the buyer's vehicle b_i can be described by vector $I_{b_i} = \{\text{sign}_i^B, d_i, v_i^B, l_i^B\}$, where sign_i^B marks the vehicle b_i as the buyer. That is, it needs external computing resources to unload its intensive computing tasks, d_i is the data amount of computing tasks that need to be unloaded by vehicle b_i , and v_i^B and l_i^B are the current speed and position of vehicle b_i ; on the other hand, the information vector submitted by the seller's vehicle s_j can be expressed as $I_{s_j} = \{\text{sign}_j^S, c_j, v_j^S, l_j^S, p_j, r_j\}$, where sign_j^S represents that the vehicle s_j is the seller. That is, the vehicle s_j has redundant computing resources and is willing to provide computing task offloading services for other vehicles, c_j is the computing power of the vehicle s_j , described by the number of CPU cycles per second of the vehicle, v_j^S and l_j^S are the current speed and position of the vehicle s_j , and p_j is the bid of the vehicle s_j to process the application data of one computing task. r_j represents the idle computing resources of vehicle s_j virtualized as resource blocks (CPU cycles).

In addition, it should be noted that all buyers and sellers participating in the offloading of computing tasks are within the communication range R^{RSU} of RSU. Therefore, their information can be sent to RSU through V2R. At the same time, it is assumed that the RCON contains n buyers $B = \{b_1, b_2, \dots, b_n\}$ and m sellers $S = \{s_1, s_2, \dots, s_m\}$; these vehicles have the same communication range R^V .

3.3. RSU Calculates the Scheduling Results and Publishes the Results to Both Buyers and Sellers. After receiving the relevant information about the buyer's vehicle and the seller's vehicle, the RSU will extract and integrate the information, and then according to the reverse auction mechanism proposed in this chapter, the RSU will match buyers and sellers and send the best match results back to buyers and sellers.

3.4. Unloading and Payment of Computing Tasks. After receiving the scheduling result of RSU, the buyer's vehicle will directly unload the computing task to the seller's vehicle through one-hop V2V. After the seller's vehicle completes the calculation, it will return the calculation result to the buyer. Since the data size of the application result is much smaller than the input data, the result feedback delay can be further ignored.

After the buyer confirms the receipt of the calculation result, the buyer will forward a resource currency to the corresponding seller's vehicle through its wallet as the cost of unloading the calculation task. At the same time, the buyer sends a transaction completion message to the RSU. When the seller receives the fee, a transaction completion message will also be sent to RSU, which represents that the transaction has been completed. The transaction record will be placed in the RSU memory pool and broadcast to the entire network, waiting to be added to the block.

If there is any objection between the buyer and the seller during the transaction, for example, the buyer has not received the calculation result, the seller has not received the corresponding fee, etc., the objecting party can file a complaint with RSU, and RSU initiates verification of data transmission and wallet payment in the inspection network. For vehicles with cheating, RSU will deduct a part of the security deposit for the vehicle. This mechanism can restrain some vehicles from doing damage to the interests of other vehicles for their own interests during the unloading process of computing tasks and ensure the stability of the system operation.

3.5. Blocks Are Generated and Linked to the Blockchain. When generating the blockchain, this chapter proposes a new consensus mechanism based on the total amount of buyer computing task data received by all sellers in the RCON managed by each RSU node to elect the accounting node (Proof of Computation Resource, POCR). The RSU with the most significant amount of buyer computing tasks received by all sellers in the RCON area is elected as the accounting node within a block generation interval.

It should be noted that when an RSU successfully obtains the accounting right and generates a block link to the blockchain, the system will also distribute a certain amount of resource coins to it as a reward. RSU will distribute resource coins proportionally to the seller as a reward according to the contribution of the seller's vehicle's computing resources in the process of computing task offloading to encourage them to continue to participate in computing tasks offloading. That is, the POCR consensus mechanism uses the total amount of buyer computing task data received by the seller to measure the seller's computing resource contribution.

4. Modeling and Solution

4.1. Modeling of the Reverse Auction Scheme. Consider a computing task offloading scenario in an RCON. Since there are multiple buyers and sellers in the RCON, buyers will compete for the seller's computing resources to complete computing tasks faster. Therefore, this chapter will use the reverse auction method to match buyers and sellers to obtain the matching result that maximizes regional benefits. The actual meaning of the important parameters involved in the auction scheme is shown in Table 1.

Consider first the benefits of offloading the buyer's computing tasks. Since each seller's computing power is different, the utility benefits provided by each seller to the buyer are different. The benefit that the buyer b_i can get by offloading the unit calculation data to the seller s_j can be expressed by the following function:

$$\varphi_{ij} = \left(\frac{\delta}{c_{EC}} + \frac{1}{T_{EC}} + \theta \right) - \left(\frac{\delta}{c_j} + \frac{1}{T_{ij}} \right). \quad (1)$$

In formula (1), $(\delta/c_{EC} + 1/T_{EC} + \theta)$ represents the time for the buyer b_i to offload the unit computing task to the edge cloud server ECS, δ is the mapping of bits to CPU cycles, c_{EC} is the computing power of the edge cloud server, T_{EC} is the data transfer rate between the vehicle and the ECS, θ is the response delay due to network congestion or insufficient ECS performance, $\delta/c_j + 1/T_{ij}$ represents the time for the buyer b_i to offload the unit computing task to the seller s_j , and T_{ij} represents the data transmission speed between the buyer b_i and the seller s_j .

To sum up, the time saved by the buyer b_i offloading the unit computing task data to the seller s_j compared to the time saved by the buyer b_i offloading the unit computing task to the edge cloud server is the unit benefit of the buyer b_i .

Next, consider the overall benefit of RCON. For n buyers set $B = \{b_1, b_2, \dots, b_n\}$ and m seller set $S = \{s_1, s_2, \dots, s_m\}$ in RCON, the buyer's demand vector is $D = \{d_1, d_2, \dots, d_n\}$, and the seller's bidding vector for unit resources is $P = \{p_1, p_2, \dots, p_m\}$. Use R^{b_i} to denote a seller within the coverage of the buyer's b_i communication. Use R^{s_j} to represent buyers who are within the seller's s_j communication coverage. Then, in a time slot, through the calculation and offloading of buyers and sellers, the overall regional benefit that RCON can obtain can be expressed as

$$\begin{aligned} U(\eta_{ij}) &= \sum_{j=1}^m \sum_{i=1}^n \lambda_i \varphi_{ij} d_{ij} \eta_{ij} - \sum_{j=1}^m \sum_{i=1}^n p_j d_{ij} \eta_{ij} \\ &= \sum_{j=1}^m \sum_{i=1}^n (\lambda_i \varphi_{ij} - p_j) d_{ij} \eta_{ij} s.t. \eta_{ij} \\ &\in \{0, 1\} \sum_{j=1}^m \eta_{ij} \in \{0, 1\} \delta \sum_{i=1}^n d_{ij} \eta_{ij} \leq r_j, \\ d_{ij} &= \min(d_{ij}, \Delta t_{ij} T_{ij}). \end{aligned} \quad (2)$$

Here, η_{ij} is used to the nature of the task of calibrating the buyer b_i to the winning seller s_j . When $\eta_{ij} = 1$, the buyer

TABLE 1: Parameter correspondence table.

Parameter	Definition
d_{ij}	The amount of task data unloaded by buyer b_i to seller s_j
ϕ_{ij}	The benefit that buyer b_i can get by offloading unit calculation data to seller s_j
T_{ij}	Data transfer speed between buyer b_i and seller s_j
λ_i	Expected benefit for reconciling buyer b_i offloading unit data
η_{ij}	Used to calibrate whether buyer b_i can offload computing tasks to seller s_j
γ_j	Represents the idle computing resources of seller s_j virtualized into resource blocks (CPU cycles)
δ	A bit to CPU cycle mapping
T_{EC}	Data transfer rate between vehicle and edge server
θ	RCS response delay due to network congestion or insufficient ECS performance
$U_{\eta_{ij}}$	Overall regional benefits that RCON can achieve
C_j, C_{EC}	The computing power of seller s_j and edge server
P_j, P_{EC}	Bidding by seller s_j and edge server for unit offload task
L_{RSU}, L_{b_i}	List of preferred options between RSU and buyer b_i

b_i can unload its application data to the seller s_j through a one-hop V2V communication; otherwise, it cannot be uninstalled. For example, when the seller s_j is not within the communication coverage of the buyer b_i , or the seller s_j has exhausted its idle computing resources, the situation of $\eta_{ij} = 0$ will occur. d_{ij} represents the amount of task data unloaded by the buyer b_i to the seller s_j . λ_i is used to adjust the expected revenue of the buyer b_i unloading unit data. When the importance of the calculation task or the timeliness requirement is high, the value of λ_i is larger; this represents that the buyers are willing to pay a higher price to complete the current computing task faster.

Here, the limited value of constraint $\eta_{ij} \in \{0, 1\}$ can only be 0 or 1; that is, the unloading of computing tasks from buyer b_i to seller s_j has only two states of success and failure; $\sum_{j=1}^m \eta_{ij} \in \{0, 1\}$ represents that a buyer can only offload tasks to one seller; $\delta \sum_{i=1}^n d_{ij} \eta_{ij} \leq r_j$ is used to prevent the total workload offloaded from the buyer from exceeding the computing resources that the seller can provide; $d_{ij} = \min(d_{ij}, \Delta t_{ij} T_{ij})$ determines the actual uninstalled data from buyer b_i to seller s_j based on the smaller value between the two data, where Δt_{ij} represents the real transmission time of the buyer b_i offloading the computing task to the seller s_j .

4.2. Reverse Auction Solution Schemes. We will use the reverse auction method to solve the proposed computing task offloading problem and, at the same time, prove the authenticity of the seller's bid and the individual's rationality to verify the proposed scheme's rationality.

First, define a list of preferred options from the perspective of the administrator RSU and the buyer, respectively. For the auction manager RSU in RCON, according to the size of the value of formula (3), a list of its preference schemes is defined, and the list can be expressed by formula (4):

$$(\lambda_i \varphi_{ij} - p_j) d_{ij}, \{b_i \in B, s_j \in S\}, \quad (3)$$

$$L_{\text{RSU}} = \{((b_i, s_j) >_{\text{RSU}} (b_i, R^{b_i} \setminus \{s_j\})) | b_i \in B, s_j \in S\}, \quad (4)$$

where $>_{\text{RSU}}$ in formula (4) means that RSU is biased to match the buyer b_i with the seller s_j , rather than matching the buyer b_i with other sellers within its communication range; because scheme (b_i, s_j) can bring more benefits to RSU than other schemes, it maximizes the regional benefit of RCON.

Next, define a list of preferred options from the buyer's perspective. Also, according to the value of formula (3), the list of buyer's preference schemes defined here is

$$L_{b_i} = \{(s_j >_{b_i} s_k) | s_j, s_k \in R^{b_i}\}, \quad (5)$$

where $>_{b_i}$ in formula (5) means that the buyer b_i prefers to match the seller s_j rather than other sellers within its communication range, because the scheme (b_i, s_j) can make the buyer b_i obtain the maximum benefit.

In the following, the lists L_{RSU} and L_{b_i} are sorted in descending order according to the value of formula (3). At the same time, a virtual seller s'_j is added at the end of the list L_{b_i} as a critical indicator for the following algorithm to use. The virtual seller s'_j corresponds to the scheme of offloading computing tasks to ECS. The buyer b_i unloads the unit computing task revenue set to $\omega_i = (\lambda_i \varphi_{ij} - p_{\text{EC}}) d_{ij}$, where P_{EC} refers to the unit computing resources ECS price. Here, we consider that all sellers' vehicle bids are lower than P_{EC} , so sellers can attract buyers to offload computing tasks. The value of ω_i is smaller than $(\lambda_i \varphi_{ij} - p_j) d_{ij}$ for all real solutions in the list L_{b_i} . If no seller in the listing L_{b_i} wins the auction, the buyer b_i offloads its computation to ECS. On the other hand, when $(\lambda_i \varphi_{ij} - p_j) d_{ij} \leq 0$, it means that the buyer b_i cannot benefit from the offloading of computing tasks. At this time, $\eta_{ij} = 0$, the buyer b_i will not offload computing tasks to the seller s_j .

The reverse auction scheme proposed here consists of two parts, first, to determine the matching scheme of all buyers and sellers and, then, to determine the actual amount that the buyer should pay to the seller. In the matching process, the list L_{RSU} plays a leading role; that is, the scheme will prioritize the matching scheme that can maximize the regional benefit in the actual operation process, although this may sacrifice the interests of some buyers.

The auction algorithm is divided into three parts. The first is to set the algorithm's parameters, create lists L_{RSU} and L_{b_i} , and sort the two lists in descending order according to the size of the $(\lambda_i \varphi_{ij} - p_{\text{EC}}) d_{ij}$ value. This is followed by the matching phase, where buyers are matched with suitable sellers in the case of maximizing regional interest, based on listing L_{RSU} , until all buyers are matched, or sellers run out of free resources.

The last is the payment stage. For the matching scheme (b_i, s_j) , after determining the actual payment amount p_{s_j} that the buyer b_i should pay to the seller s_j , the next seller \hat{s}_j of s_j in the list L_{b_i} is selected as the critical reference payment indicator. At this time, the payment amount p_{s_j} can be expressed as

$$p_{s_j}^{\text{final}} = \sum_{b_i \in R^{s_j}} \left(\lambda_i \varphi_{ij} - \frac{(\lambda_i \hat{\varphi}_{ij} - \hat{p}_j) \hat{d}_{ij}}{d_{ij}} \right) \eta_{ij} d_{ij}. \quad (6)$$

When the seller \hat{s}_j is the last seller on the list L_{b_i} , the seller \hat{s}_j is the virtual seller s'_j at this time; we make $(\lambda_i \hat{\varphi}_{ij} - \hat{p}_j) \hat{d}_{ij} = \omega_i = (\lambda_i \varphi_{ij} - p_{\text{EC}}) d_{ij}$.

This scheme includes n buyers and m sellers. So, the computational complexity of auction is $O(n^2 m^2)$. The complexity of the algorithm is low, and the convergence can be achieved in a short time even when the scale of the vehicle network is large.

4.3. Consortium Blockchain Reward Modeling. In generating the consortium blockchain, the RSU as the consensus node will compete for the accounting right through the POCR consensus mechanism proposed above. The RSU that has obtained the accounting right can not only package the transaction records into blocks and link them to the blockchain but also be rewarded with resource coins distributed by the blockchain system. After RSU is rewarded with resource coins, it will distribute resource coins to sellers according to the ratio of the total amount of computing task data unloaded by buyers within a block generation interval to the total amount received by all sellers in RSU. Here, the total amount of buyer computing task data received by the seller is used to measure the computing resource contribution of the seller.

The generation of new blocks in the POCR consensus mechanism includes three stages: mining, consensus, and distribution of rewards. In this chapter, "mining" refers to how sellers provide computing resources to buyers for buyers to offload computing tasks. After the "mining" process, the system counts the buyers received by all sellers in the RCON area managed by each RSU. The total amount of unloaded computing task data and the RSU with the largest total amount are elected as the accounting node.

The next step is to enter the "consensus" stage. At this time, the accounting node packages part of the computing task by offloading records into a block and sending them to other RSU nodes for verification. After the verification is passed, the accounting node links the block to the blockchain. Next, in the "Distribute Rewards" stage, the system will distribute a certain amount of resource coins to the accounting node RSU as a reward. After RSU receives the resource currency distributed by the system, it will distribute resource currency rewards to each seller according to the number of computing resources contributed by each seller in RCON under its control to encourage sellers to continue to participate in computing resource scheduling.

The actual meanings of the important parameters are shown in Table 2.

The blockchain "distribute rewards" phase is modeled below. Assuming that there are z RCON areas in the current system, there are z consensus nodes RSU, the number of sellers' vehicles in the RSU numbered k , $k \in [1, z]$, is m_k , the seller numbered j , $j \in [1, m_k]$, in the RCON corresponding to this RSU at the amount of buyer calculation task data

TABLE 2: The actual meanings of the important parameters.

Parameter	Definition
τ_k^p	The propagation delay of RSU numbered k
τ_k^v	The verification time of the block of RSU numbered k
ϵ_k	The number of things in a block
γ	Parameters related to network size
μ	Average effective channel capacity per link
k	Parameters determined by network size and node verification speed
f_k^{RSU}	The probability that the RSU numbered k successfully obtains the accounting right
$P_o(\epsilon_k)$	The probability that a block generated by RSU number k will be orphaned
$P_k^{\text{RSU}}(\epsilon_k)$	The probability that the RSU numbered k is successfully elected as the accounting node and generates a block
U_k^{RSU}	The benefit function of the reward for the RSU numbered k
U_j^{vehicle}	The reward function that seller j should get

received in the current block generation time slot is d_j . The probability that the RSU number k successfully obtains the accounting right is

$$f_k^{\text{RSU}} = \frac{\sum_{j=1}^{m_k} d_j}{\sum_{k=1}^z \sum_{j=1}^{m_k} d_j}, \quad (7)$$

and there is $\sum_{k=1}^z f_k^{\text{RSU}} = 1$ here; that is, the sum of the probabilities of all RSUs being successfully elected as accounting nodes is 1. After RSU obtains the accounting rights and generates a block, it will immediately propagate the block on the network for verification to complete the consensus process. If the propagation and verification time is too long, the mined block becomes an orphan block and is abandoned by the blockchain. Here, the propagation delay of RSU number k as a “miner” is set to $\tau_k^p = \epsilon_k / \gamma \cdot \mu$, where ϵ_k is the number of transactions in a block, γ is a parameter related to network size, and μ is the average effective channel capacity per link. Since the verification of transactions requires a fixed amount of computation, this period is assumed to be linear with the number of transactions in the block; then this period can be expressed as $\tau_k^v = \kappa^* \epsilon_k$, where κ is a parameter determined by the size of the network and the average verification speed of nodes. Considering that the generation of new blocks follows a Poisson process, the probability that a block generated by a “miner” RSU _{k} is orphaned is approximate as

$$P_o(\epsilon_k) = 1 - e^{-\lambda((\epsilon_k/\gamma\mu) + \kappa\epsilon_k)}. \quad (8)$$

In the formula, the process parameter λ represents the complexity of the mining block. The probability that the “miner” RSU _{k} is successfully elected as a bookkeeping node and generates a block is

$$P_k^{\text{RSU}}(\epsilon_k) = f_k^{\text{RSU}} \times (1 - P_o(\epsilon_k)). \quad (9)$$

Assuming that the remuneration (reward rate) per unit transaction in the alliance blockchain system is r resource

coins, the reward obtained by generating a block with a transaction volume of ϵ_k is $r\epsilon_k$. Then the benefit function of the reward obtained by the “miner” RSU _{k} can be expressed as

$$\begin{aligned} U_k^{\text{RSU}} &= r\epsilon_k \times P_k^{\text{RSU}}(\epsilon_k) \\ &= r\epsilon_k \times f_k^{\text{RSU}} \times (1 - P_o(\epsilon_k)) \\ &= r\epsilon_k \times \frac{\sum_{j=1}^{m_k} d_j}{\sum_{k=1}^z \sum_{j=1}^{m_k} d_j} \times e^{-\lambda((\epsilon_k/\gamma\mu) + \kappa\epsilon_k)}. \end{aligned} \quad (10)$$

For the resource currency reward obtained by the “miner” RSU _{k} , the resource currency reward will be distributed to each seller according to the number of computing resources contributed by each seller in the RCON controlled by the RSU; then the seller j accepts the computing task unloading amount d_j . Then the reward function that seller j should get is expressed as

$$\begin{aligned} U_j^{\text{vehicle}} &= \frac{d_j}{\sum_{j=1}^{m_k} d_j} \times U_k^{\text{RSU}} \\ &= r\epsilon_k \times e^{-\lambda((\epsilon_k/\gamma\mu) + \kappa\epsilon_k)} \times \frac{d_j}{\sum_{j=1}^{m_k} d_j} \times \frac{\sum_{j=1}^{m_k} d_j}{\sum_{k=1}^z \sum_{j=1}^{m_k} d_j}. \end{aligned} \quad (11)$$

At this point, the blockchain reward model is established. In the next section, we will analyze the system’s performance through simulation.

5. Case Study

Here we will evaluate the performance of the proposed Internet of vehicles resource scheduling based on blockchain and game theory through simulation. First, we compare the proposed auction scheme with several types of baseline schemes to verify the scheme’s performance. Second, we conduct a simulation evaluation of the blockchain reward model to verify its effectiveness.

5.1. Simulation Setting. Since the calculation task offloading scheme using the reverse auction method applies to all RCONs, to simplify the discussion, we will first use an RCON as an example to conduct a simulation study on the reverse auction scheme. We use MATLAB2016A as the platform to simulate RCON with a network area of 500 m * 500 m, in which there are 5 roads in the east-west and north-south directions, and each road has 4 lanes. In RCON, an RSU is set up as the central broker, hosting and directing the auction process. On the other hand, this chapter also uses the blockchain open-source framework Hyperledger Fabric to write smart contracts to simulate the consortium blockchain system.

To evaluate the performance of the reverse auction scheme, the mobile vehicle computation offloading scheme based on consortium blockchain (scheme 0) is compared

with the following baseline schemes to evaluate the performance of scheme 0:

- (1) The fastest process scheme (scheme 1): in this scheme, assuming all sellers bid reasonably, buyers are always matched with the seller who can complete the application and calculate the offload fastest. If this seller runs out of idle resources, the buyer will be forced to find another seller for fast processing or offload computing tasks to edge cloud servers.
- (2) The lowest cost scheme (scheme 2): in this scheme, assuming that all sellers bid reasonably, buyers are always matched with the seller with the lowest asking price per unit calculation task. Similarly, when sellers run out of idle resources, buyers will be forced to find another low-priced seller or offload computing tasks to edge cloud servers.
- (3) First-come-first-served service (scheme 3): in this scheme, assuming that all sellers make reasonable bids, the buyer is always matched with the first seller to provide an offer. If this seller runs out of idle resources, the buyer will be forced to offload computing tasks to the edge cloud. Since the vehicles are randomly distributed in the simulation area, FCFS can be regarded as a random unloading scheme.
- (4) Offload to edge cloud scheme (scheme 4): buyers directly offload their computing tasks to edge cloud servers for processing.

In addition, for the proposed scheme, the function $\sigma_j = ac_j + e$ is used here to represent the most reasonable bid of the buyer s_j , where a and e are positive constants, and these two constants follow the unloading law of the market economy, which means that the buyer s_j provides that the more the computing power, the greater the reasonable bid. The settings of the relevant simulation parameters are shown in Table 3.

5.2. Simulation Analysis

5.2.1. Vehicle Density Analysis. We first analyze the impact of vehicle density within the RCON region on the overall benefit $U(\eta_{ij})$ of the region and on the average computing time of a single computing program (assuming that the computing task can be divided into computing programs with a fixed data size).

In the case of low and high vehicle flow levels, we simulated the scheme 50 times with different parameter values. We obtained the average value to cover various traffic conditions, making the conclusion more general.

Figures 2–5 show the changes of the average calculation time of a single calculation program and the regional overall benefit $U(\eta_{ij})$ with the number of sellers under low vehicle density (18 buyers and 22 buyers).

According to Figure 2 of Figure 3, we find that the average computing time of a single computing program in scheme 4 is always the highest. This is because when it is offloaded to the edge cloud, the edge cloud receives too many requests, resulting in that it cannot process the task of vehicle

TABLE 3: Simulation parameter settings.

Parameter	Value
c_j	$1 * 10^9 - 3 * 10^{10}$ (bit/s)
c_{EC}	$1 * 10^{11} - 7 * 10^{11}$ (bit/s)
r_i	$1.5 * 10^{11} - 3 * 10^{11}$ (CPU cycle)
a	$3 * 10^{-19}$
e	$1 * 10^{-8}$
δ	$1.8 * 10^4$
T_{ij}	5–8 (MB/s)
T_{EC}	5–6 (MB/s)
λ_i	0.7 – 0.9
d_{ij}	4 – 10 (MB)
Lane-width	4 m
θ	0.5 – 1 (s)
V_i^B, V_j^S	30 – 50 (km/h)
l_i^B, l_j^S	Random distribution
R^{RSU}	1200 m
R^V	500 m

unloading in time, which causes a large delay in unloading. The calculation time of a single calculation program of scheme 2 and scheme 3 gradually decreases with the increase of sellers because the buyer has more options at this time, and the buyer's task can be uninstalled faster. But these two schemes are still less efficient than scheme 0 and scheme 1. For scheme 0 and scheme 1 solutions, with the increase in the number of sellers, the computing resources are gradually sufficient, and the completion time of the unit calculation program gradually decreases. The performance of scheme 0 is close to scheme 1 of the fastest processing scheme, which reflects the superiority of the time performance of scheme 0.

According to Figures 4 and 5, it is found that, with the increase of the number of sellers, the overall regional benefit $U(\eta_{ij})$ of all schemes increases because with the rise in the number of sellers, more buyers can enjoy the calculation service and eventually reach relative stability where most buyers can be successfully matched to the right seller. At the same time, we found that, under low vehicle density, the $U(\eta_{ij})$ value of scheme 0 is higher than other schemes, the buyer's cost of scheme 1 is higher, and scheme 2 time cost is higher. However, the randomness of scheme 3 is high, and the performance level of these schemes is not high, which shows that scheme 0 can reasonably match buyers and sellers and maximize the regional benefits of RCON.

Figures 6–9 show the changes of the average calculation time of a single calculation program and the regional overall benefit $U(\eta_{ij})$ with the number of sellers under higher vehicle density (38 buyers and 42 buyers).

It can be seen from Figures 6 and 7 that the average calculation time of a single calculation program of scheme 4 is always the highest for the same reason as in the low flow case. For scheme 3 and scheme 2, the curve decreases slightly as more buyers access computing services as sellers increase. Likewise, the performance of scheme 0 is close to the time-optimal scheme 1, which verifies the superiority of the temporal performance of scheme 0. At the same time, the average calculation time of a single calculation program for scheme 0, scheme 3, scheme 2, and scheme 1 decreased compared to the low-traffic case; as buyers had more

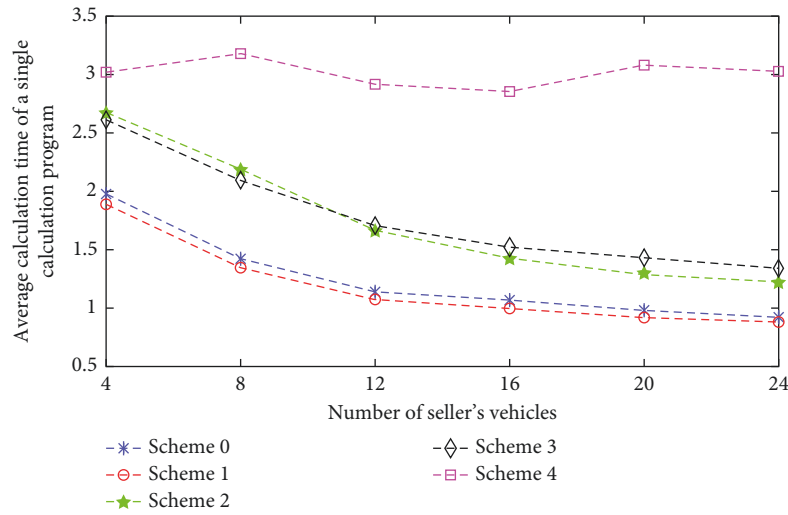


FIGURE 2: Change of average calculation time of a single calculation program with the number of sellers (18 buyers).

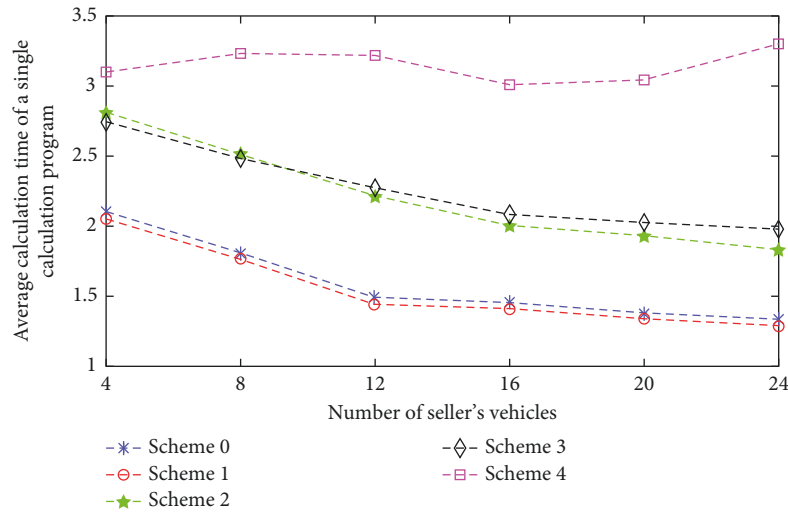


FIGURE 3: Change of average calculation time of a single calculation program with the number of sellers (22 buyers).

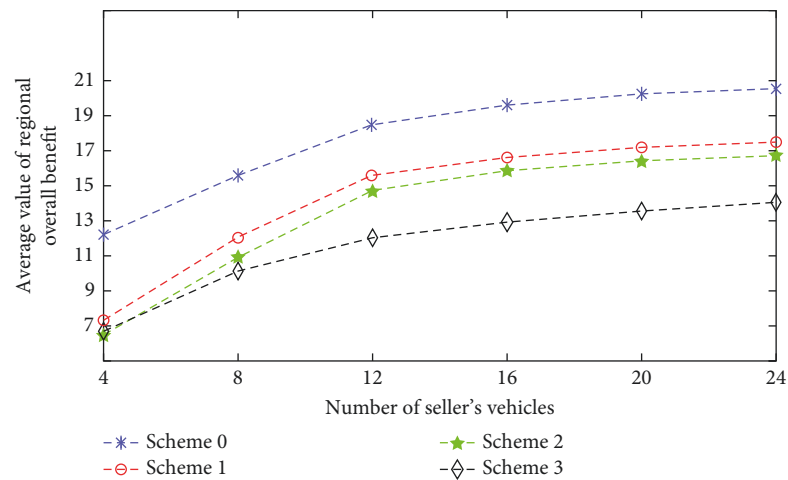


FIGURE 4: Change of average value of regional overall benefit with the number of sellers (18 buyers).

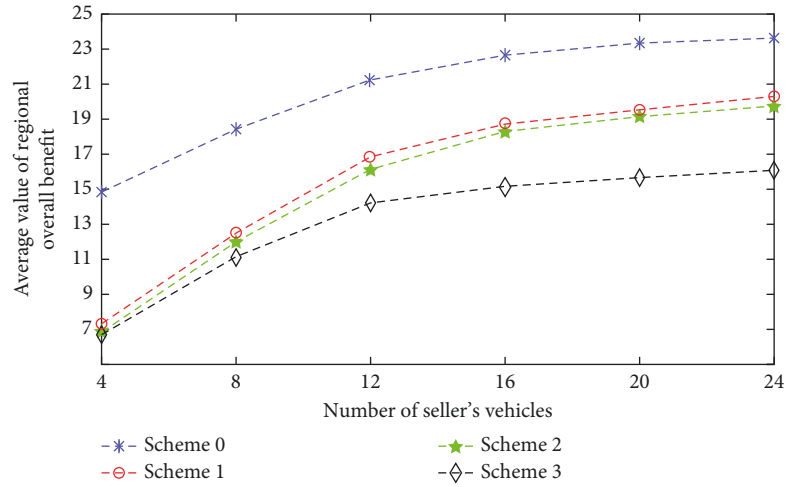


FIGURE 5: Change of average value of regional overall benefit with the number of sellers (22 buyers).

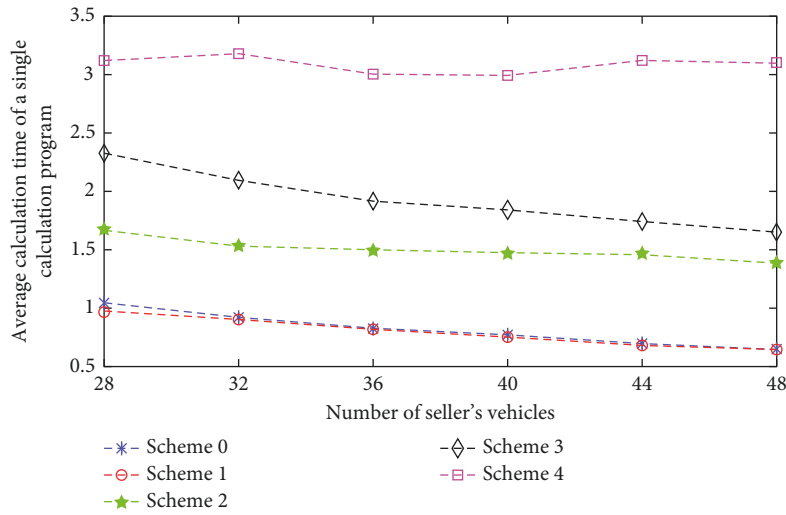


FIGURE 6: Change of average calculation time of a single calculation program with the number of sellers (38 buyers).

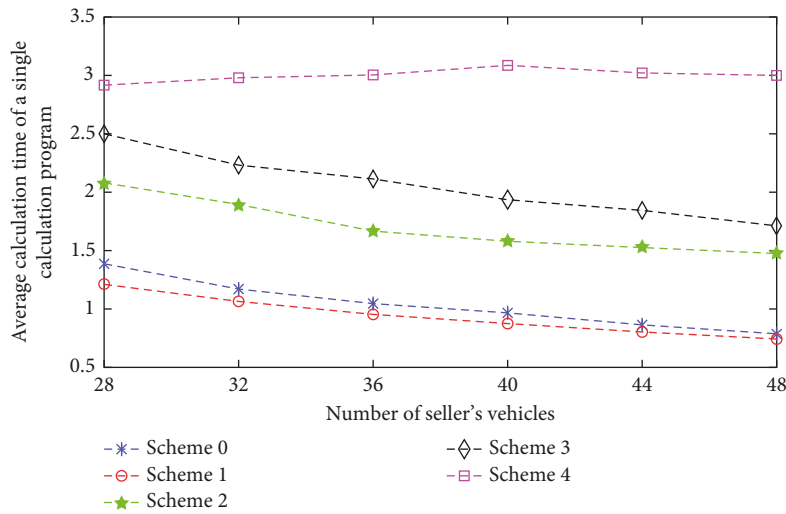


FIGURE 7: Change of average calculation time of a single calculation program with the number of sellers (42 buyers).

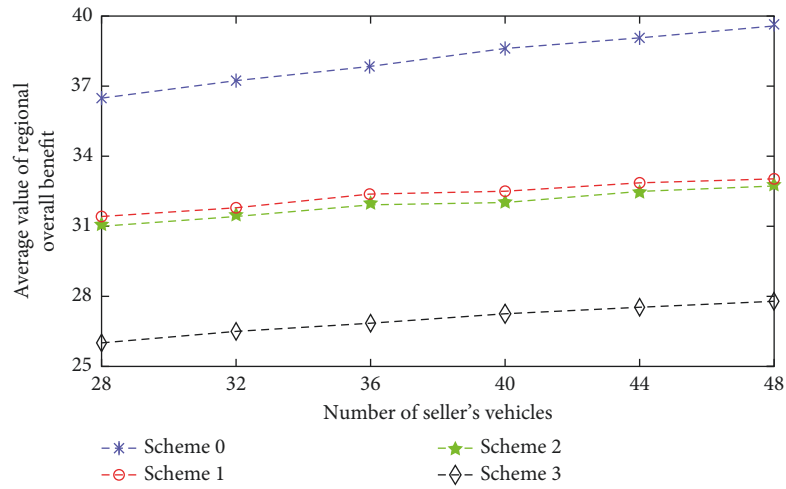


FIGURE 8: Change of average value of regional overall benefit with the number of sellers (38 buyers).

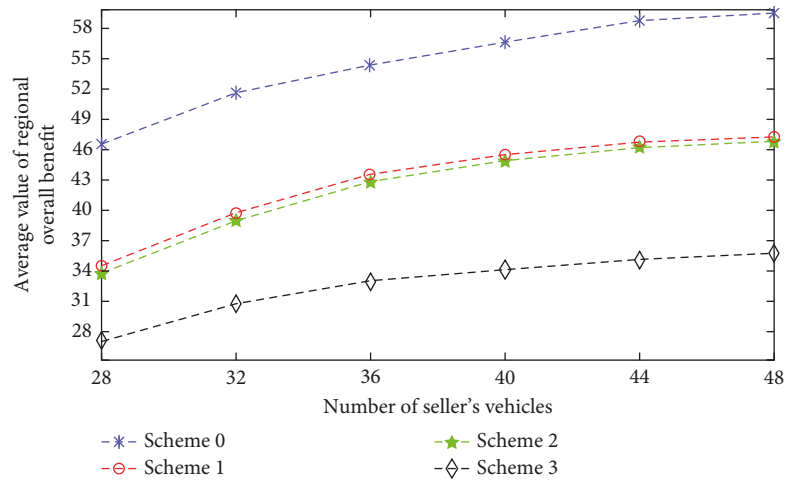


FIGURE 9: Change of average value of regional overall benefit with the number of sellers (42 buyers).

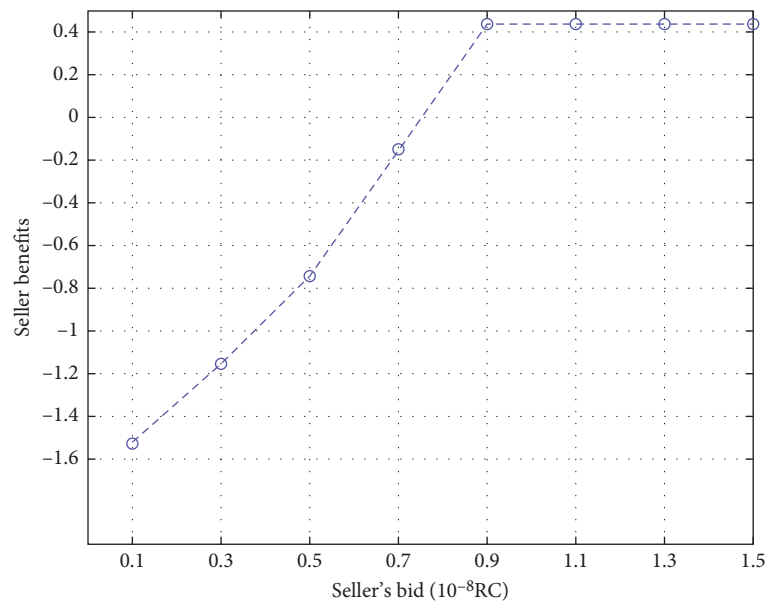


FIGURE 10: Authenticity verification of seller's bid.

offloading options at higher vehicle densities, the processing time of its task will be shortened.

Figures 8 and 9 compare the $U(\eta_{ij})$ values under each scheme. Considering various factors, the efficiency of scheme 0 maintains the highest level among multiple schemes. At the same time, compared with low-traffic scenarios, due to the increase in the number of vehicles, the total amount of unloading tasks increases, and the total regional benefit also increases.

To sum up, when considering the scenarios of low and high traffic flow, it can be seen that scheme 0 proposed in this chapter has a relatively high performance in the two performance indicators of task processing efficiency and overall regional benefit. This proves that the proposed reverse auction scheme can effectively match buyers and sellers.

5.2.2. Verification of the Authenticity of the Seller's Bid and the Rationality of the Individual. Here we will verify the authenticity and individual rationality of the seller's bids proposed. To verify the authenticity of the seller's bid, we simulate the behavior of the randomly selected seller S_{random} in reasonable and other unreasonable bids and calculate the graph of the seller's S_{random} revenue changing with its bid, as shown in Figure 10.

As shown in Figure 10, when the seller's S_{random} bid is less than its reasonable bid, the seller's S_{random} can never get the maximum benefit. On the other hand, when the seller's bid reaches a reasonable price, the benefit of the seller's S_{random} is maximized. Even if the seller's bid is greater than the reasonable price, its benefit will not increase. Therefore, it can be proved that the seller will provide a reasonable price to the buyer according to the computing resources and will not provide other quotes; that is, the seller's bid is authentic.

6. Conclusions

With the rapid development of the automotive industry, vehicles equipped with a variety of intelligent on-board equipment need more and more resources. On the one hand, a large number of driving data will be generated during the driving process of vehicles, which are useful in traffic situation analysis, automatic driving training, and other scenarios. On the other hand, due to the high mobility of vehicles and because their own computing resources are limited and the real-time distribution of computing resources is irregular, it is easy to see that some vehicles have insufficient computing resources while others have spare computing resources.

Through the scheduling of mobile vehicle data and computing resources, the data and computing resources can be shared to the subjects who need them, and both parties involved in the sharing can benefit. For the resource scheduling of Internet of vehicles based on blockchain and game theory, this paper proposes a mobile vehicle computing task unloading scheme based on alliance blockchain. In the simulation phase, the performance of the calculated unloading scheme and several baseline schemes under different traffic flows is compared. The results show that the

scheme in this paper has better performance than other schemes.

This research work still has many places that can be improved. For example, for the scheduling of data resources, artificial intelligence technology, big data, and other technologies can be used to filter vehicle data, reduce the proportion of duplicate or useless data in shared data, and improve the efficiency of data sharing. For the scheduling of computing resources, computing tasks can be unloaded to the edge cloud server and the surrounding mobile vehicles at the same time. How to reasonably control the amount of tasks unloaded to the edge cloud and mobile vehicles is also worth studying in the future.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Research on Model and Algorithm of Multiview and Multilabel Classification Based on Nearest-Neighbor Model

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In the field of machine learning, multilabel learning gradually evolved from the traditional text classification problem. In this study, a multiview multilabel via optimal classifier chain (MVMLOCC) algorithm based on the nearest-neighbor model is proposed. The algorithm model establishes a multilabel chain classifier for each view of the dataset and predicts unknown data samples by dynamically adjusting the weights of chain learners. When an unknown example is input, multiple chain classifier models are multiplied by corresponding weights to obtain the final tag set situation. The model makes full use of the relevance between multiple tags and the complementarity and integrity between multiple perspectives and can achieve better learning results. The final experimental results show that our proposed model can be applied to different multilabel classification tasks and has achieved excellent performance under different evaluation indicators. This study mainly studies the multiview and multilabel classification method and uses active learning technology to solve the problem of high label components in data collection.

1. Introduction

Machine learning is the key research direction in the field of artificial intelligence, and its application scope is more and more extensive. In real life, many fields have achieved good results by using machine learning technology [1]. In recent years, with the deepening of scholars' research, the research scope has expanded from traditional machine learning to deep learning, from binary classification model to multiclassification model, from single-label learning to multilabel learning, from simple single-view learning to multiview learning, and from machine learning to deep learning, and the research direction of machine learning has gradually met the needs of real life [2]. In essence, the classification problem belongs to the sample classification problem, and the traditional classification method mainly aims at learning single label, that is, each sample only needs to be described by one label [3, 4]. However, in practical applications, we will

encounter very complex classification problems, namely, multilabel classification, that is, a sample needs to be described by multiple labels. We can see that multilabel classification learning is more universal and more in line with practical applications, which has aroused the research interest of many scholars and become a research hotspot, and has been well applied in different fields such as images, video and audio, and informatics. Therefore, the exploration of multilabel classification learning has a very wide research significance and practical value.

Early research on multilabel learning is to transfer the original mature single-label learning model to multilabel learning. The binary correlation (BR) method is a relatively direct conversion method. Taking classification as an example, it converts multilabel learning problems into multiple single-label binary classification problems [5]. However, its shortcomings are also obvious. This method ignores the dependencies between tags and is prone to produce contradictory prediction results. Compared with

the BR method, the classifier chain can transfer label information among multiple binary classifiers and can use the dependency information between labels to make predictions. Moreover, this method still retains the advantages of simple and easy implementation of the BR method. However, this method also has some shortcomings [6]. In recent years, the study of multiperspective learning has gradually appeared in people's field of vision. People use the diversity brought by different perspectives to put forward multiperspective learning methods, which are widely used and have amazing performance. These views can be obtained from multiple sources or feature subsets.

In order to solve the disadvantage of the single association of traditional multilevel label classification algorithms in the knowledge base, this study will further study the multiview multilabel via optimal classifier chain (MVMLOCC) algorithm based on the nearest-neighbor model [7]. The algorithm can filter a large amount of data in a certain field in a short time, detect and summarize multiple related knowledge point tags of objects in a field, then analyze the features of the detected related knowledge point tags by the feature dimension reduction method, finally analyze the results according to the nearest-neighbor model, construct an association framework of all objects in the field, and complete the multilevel tag classification of knowledge base based on the nearest-neighbor model.

In this study, the formal definition of multiview and multilabel learning problem is given, and a new multilabel learning model is proposed for our multiview combined learning strategy. The innovation contribution is that the model not only combines the consistency of different view data under multiview data, but also combines the correlation between labels in multilabel data, and establishes a chain classifier for the data of each view. At the same time, considering the different prediction effects of each chain, the model gives each chain different weights, which better combines the complementarity and integrity of data from different angles. The experimental results show that the proposed model can be applied to different multilabel classification tasks and has achieved excellent performance under different evaluation indicators.

2. Related Work

2.1. Research Status of Single-Label Classification. The single-label classification is one of the most basic methods in data mining. In real-life applications, people are often faced with complicated things. A single tag can be understood as belonging to a large category, that is, a piece of data is classified and represented by a value. Then, there are two categories and multiple categories within a single label. We can classify some things with similar characteristics together, that is, into the same category by using some rules or standards, and classify very different things into other different categories, which provides convenience for people to analyze and study things, and can predict things more effectively [8, 9].

At present, the classical classification algorithms are naive Bayes classifier (NBC), support-vector machine, association rules, decision tree (DT), K-nearest neighbor, genetic algorithm, neural network, and so on [10–13].

The above classification algorithms have their own characteristics. Based on the practicality and value of these algorithms, they have been widely used in many different fields such as medical diagnosis and treatment, information processing, financial risk assessment, and so on.

2.2. Research Status of Multilabel Classification. In real-life applications, unlike single-label classification, multilabel learning is very common and complex, and it is more in line with the real situation, so it has aroused the research interest of researchers and has become a research hotspot. Up to now, scholars have learned multilabel data in two main ways: the problem transformation method and the algorithm adaptation method.

2.2.1. Problem Transformation Method. The main idea is to transform multilabel learning tasks into other typical tasks. Nowadays, a very common idea is to directly transform multilabel learning tasks into multiple single-label classification tasks. Then, the classical single-label classification algorithm is used to analyze each single-label learning problem, and then, the dataset is artificially classified. Finally, the results of each single-label classification are combined in order to obtain a label vector, and the final classification result is obtained.

2.2.2. Algorithm Adaptation Method. Its idea is to improve the existing classification algorithm, so that it can directly analyze and process multilabel datasets. For example, literature [14] puts forward the ML-KNN algorithm, which combines Bayesian theory with the nearest-neighbor idea to process multilabel datasets, and improves the classical K-nearest neighbor algorithm to get the multilabel classification algorithm ML-KNN, which can effectively solve the multilabel learning problem, and solve the problem of k neighbors, ML-A, and as far as the multilabel learning problem is concerned, a series of studies show that the labels contained in sample instances in the dataset do not exist alone but are related to each other in some form. Literature [15] puts forward the CC algorithm based on the BR classification algorithm, which transforms the multilabel learning task into D binary classification functions or classifiers. The main improvement lies in expanding the attribute space of each binary classification function or classifier, that is, adding some column vectors in the attribute space, which are related to labels. Literature [16] puts forward the Bayes chain classifier (BCC), which uses the Bayesian network to learn tags and then obtain the dependency relationship between tags. Although, theoretically, the model or classifier is obtained based on the related information between tags, it also greatly reduces the number of attributes to be extended by each base classifier. However, the disadvantage is that the complexity of constructing a Bayesian network between tags and tag variables will be different from that of tags.

2.3. Challenges Faced by Multilabel Classification Research. In recent years, with the gradual deepening of research, the proposed algorithm has become more efficient and accurate,

and the focus of research has gradually focused on the following points [17–19]:

- (1) In real life, there are various data sources in different scenarios, so it is more and more difficult to collect complete data, and the obtained data have the problem of incomplete labels. How to better deal with the problem of incomplete labels is the focus of research.
- (2) In the era of big data, multilabel data are growing exponentially, and labeling data are cumbersome. Manual labeling is not only time-consuming but also has certain deviations. How to label it efficiently has become an urgent problem to be solved. In view of this situation, unlabeled data are easier to obtain and will not be affected by incomplete labeling. How to design an algorithm to actively obtain the information of unlabeled data has become a research direction.
- (3) There are redundant features in many datasets, such as text and image. These datasets are often high- T -dimensional and may encounter dimensional disasters in the process of processing. Therefore, it is hoped that the algorithm can solve the problems caused by high-dimensional features and get the importance of features of each dimension in the training process, so as to screen and improve the classification effect of the algorithm.

3. Research Technique

3.1. Nearest-Neighbor Image Selection Method Based on Forward and Backward Filtering. The nearest-neighbor search is to find the most similar items from the database according to the similarity of data. This similarity is usually quantified by the distance between data in space. It can be considered that the closer the data are in space, the higher the similarity between data. Because the nonsemantic nearest-neighbor image contains a large number of noise labels unrelated to the image to be labeled, it is easy to introduce too many noise labels in the label propagation process of the nearest-neighbor image, which reduces the labeling accuracy. Therefore, considering the relationship between the sample to be labeled and the nearest-neighbor image, this study selects the nearest-neighbor sample of the image based on forward and backward filtering and uses it in the tag propagation process based on multi-NMF decomposition.

When calculating the distance between two images, different distance measures are used to calculate the subdistances on different visual features, and then, these subdistances are further merged into a global visual distance according to the relative importance of different features. Based on the dynamic distance fusion method [20], the visual distance between image A and image B is defined as follows:

$$D(A, B) = \frac{1}{R} \sum_{i=0}^R \frac{1}{\delta_i^2} d_i(A, B), \quad (1)$$

in which R is the number of visual features, $d_i(A, B)$ is the distance between image A and image B on the i th feature, δ_i^2 is the variance of the distance between all images in the dataset on the i th feature, $1/\delta_i^2$ represents the weight of the i th feature, and smaller δ_i^2 means that the images in the dataset are relatively close on the i th feature. On the contrary, it means that there is a big difference.

Due to the uneven distribution of image feature space, some images in the image library have a high probability of being selected as the nearest-neighbor images of other images, while others have a low probability of being selected as the nearest-neighbor images of other images, and some images cannot even be selected as the nearest-neighbor images by any other images, which often leads to the irreversible similarity between the images in the image library and their nearest neighbors.

Therefore, this study proposes a nearest-neighbor image selection method based on forward and backward filtering to select the nearest-neighbor image of the test sample. The so-called forward and backward screening process is the process of bidirectional nearest-neighbor image selection.

First, the image A to be labeled selects its first K visual nearest neighbors and then selects their first K visual nearest neighbors. For a certain nearest-neighbor image B of image A , if its nearest-neighbor image set contains image A , then image B can be regarded as the nearest-neighbor image of image A , that is, image A and image B are each other's nearest neighbors.

Through the abovementioned positive and negative screening methods, the nearest-neighbor images to be labeled are more in line with the image similarity in the actual situation, and the proportion of the nearest-neighbor images semantically related to the test samples will also increase.

3.2. Label-Specific Feature Transformation. For the multi-label classification algorithm, the algorithm can achieve better classification performance by effectively capturing the unique features of each label. In order to achieve this, it is necessary to study the intrinsic attributes of the labels corresponding to each training instance. There are some labeled data (e.g., training sets and historical test predictions) around the unlabeled data, and their classification results (correct/wrong classification) are known. If the unlabeled instance is close to the misclassified data, it may also be a model error under the local continuity attribute. This property enables us to extract the context properties of unlabeled instances from adjacent tagged data.

For each label l_k , in order to better understand its positive class instance set P_k and negative class instance set N_k , the multilabel classification algorithm chooses clustering technology, which has been widely used as an independent tool for data analysis.

As suggested in literature [21], based on the simplicity and high efficiency of k -means in clustering analysis, and the better clustering effect when clusters are close to Gaussian distribution, this study also uses the k -means algorithm to cluster the positive and negative instance sets of each label. In other words, for each label, it uses the k -means algorithm

to cluster P_k and N_k . In order to obtain the unique characteristics of tags, for each tag l_k , P_k and N_k are clustered by k -means, which is used to control the number of clusters. The number of clusters is defined as follows:

$$a = \lceil \gamma \times \min\{|P_k|, |N_k|\} \rceil. \quad (2)$$

Here, $|\cdot|$ represents the cardinality of the set, that is, the number of elements in the set $\lceil x \rceil$ represents the largest

integer not exceeding x , and $\gamma \in (0, 1)$ is the scale parameter to control the number of clusters.

For each label, l_k , a is a fixed value. P_k is clustered into a clusters, and the cluster center vector is $(p_1^k, p_2^k, \dots, p_a^k)$. Similarly, N_k is clustered into a clusters, and the cluster center vector is $(n_1^k, n_2^k, \dots, n_a^k)$. In order to obtain the unique features of labels l_k , for each instance x_i , the feature mapping function $\varphi_k(x_i)$ is defined as follows:

$$\varphi_k(x_i) = \{d(x_i, p_1^k), d(x_i, p_2^k), \dots, d(x_i, p_a^k), d(x_i, n_1^k), d(x_i, n_2^k), \dots, d(x_i, n_a^k)\}. \quad (3)$$

Here, the function $d(\cdot)$ represents the Euclidean distance between the instance and the cluster center.

After all instances are acted upon by the mapping function, we can get the unique feature set F_k of each tag as follows:

$$F_k = \{\varphi_k(x_i), y_i(k) | (x_i, y_i) \in D\}. \quad (4)$$

Next, for the above description of label-specific feature transformation, pseudocode is used for specific description, as shown in the following Algorithm 1:

3.3. Multiview and Multilabel Optimal Chain Learning Algorithm

3.3.1. Representation and Definition of Multiview and Multilabel Data. The multicategory problem indicates a classification problem with more than 2 categories. Multiclassification problem is to add categories on the basis of two classification problems. Such problems are based on the assumption that a sample belongs to only one category. Multilabel problem is as follows: the purpose of this kind of problem is to add a series of target labels to each sample. The important difference between this problem and multiclassification problem is that each tag is not mutually exclusive. Here, we first explain the formal definition of multiview and multilabel classification. The following definitions are applied to the whole study. In the multiview and multilabel classification problem, a given dataset contains n data samples, each of which has a subset of L category labels, which come from M different independent perspectives, and for each perspective, there will be an output space of n labels.

We use matrix $\{(X_1^m, y_1^m), (X_n^m, y_n^m)\}, X_i^m \in R^{dm}, i \in \{1, 2, \dots, n\}, m \in \{1, 2, \dots, M\}$ to represent the input dataset and $y_i^m \in \{-1, +1\}^L$ to represent the L possible labels of the output, where $y_i^m(l) = \{+1\}$ indicates that the sample corresponds to the l -th label, and if it is -1 , it means that the sample is irrelevant to the label. The following chapters are all expanded in the data form of this section.

3.3.2. Chain Classifier Algorithm. Many efficient models have been put forward for multilabel classification task after an in-depth study by scholars, among which the binary relevance (BR) algorithm is a typical method under the

problem transformation strategy. This algorithm model directly decomposes multilabel classification into several independent single-label classification problems. First, the dataset is decomposed to get the dataset for each label, and then, the classification learners corresponding to the labels are established, respectively.

Subsequently, the classifier chain method proposed by scholars was established on the basis of the BR method combined with the relevance of tags, and the classification effect of this model was improved to some extent [22, 23]. Classifier chain (CC), as a problem transformation strategy, is solved by designing a chain composed of multiple binary classifiers. In essence, the CC algorithm is an improvement of the BR method. When an unknown sample is input into the algorithm, the model first predicts the condition of the first label and then takes this sample example together with the predicted value of its corresponding label as the training set sample for predicting the next label. By analogy, the condition of each label will be obtained in turn, and the final output result will be obtained by synthesizing the results of each classifier.

3.3.3. Multilabel and Multiview Optimal Chain Algorithm.

The multilabel and multiview optimal chain algorithm originated from the abovementioned chain classifier idea. The labels around the classifier created each time in the classifier chain are randomly selected, which may bring prediction errors. In the field of machine learning, higher accuracy is always the theme of constant pursuit. To further improve the classification accuracy, we propose a multiview multilabel via optimal classifier chain (MVMLOCC) model to learn a set of classifier chains, and each chain classifier represents a learner learned from a corresponding perspective.

For the sake of simplicity, this study only introduces how to generate a chained multilabel classifier from multiple perspectives. Every M data example can be represented by feature sets of M perspectives. Each perspective corresponds to a representation form of data, and we train and learn an optimal chain classifier for each perspective, in which each base classifier is composed of a support-vector machine (SVM) [24]. At the same time, in order to verify the better effect of multiview learning, we splice the feature sets obtained from multiple views into a larger feature set and then

Input: training set D .
Output: dataset F_1, F_2, \dots, F_q obtained after label feature transformation
for $k = 1$ to q do
Classifying dataset D into P_k and N_k for label l_k ;
Executing k -means clustering on P_k and N_k , and clustering into a clusters according to formula (2);
Execute formula (3) to construct a mapping function k for each label l_k
Execute formula (4) to obtain the unique feature set F_k of each label l_k ;
end for

ALGORITHM 1: Pseudocode of label feature transformation.

build an optimal chain model based on this feature set for classification prediction.

In order to give a clearer representation of the model, the following forms are given:

$$H(x) = \sum_{m=1}^M \alpha_m h_m(x). \quad (5)$$

The basic function $h_m(x)$ in formula (5) is the output condition of each label of the m -th classifier chain for the position sample. $\alpha_m(l)$ is a weight factor, which represents a measuring factor for the output prediction result of the l -th label in the m -th classifier chain.

The classifier chain model trains and learns a binary classifier for each label according to the order of randomly selected labels. This order is randomly selected, which may bring poor prediction accuracy. We improve the performance of the model by designing an ordered sequence of labels sorted according to their relevance. Here, we define a weight network graph $G = (V, E, W)$ to describe the complex correlation, where V represents the node set (i.e., label set) of the network, E represents the connected edge of any two labels, and W represents any two label association weights (i.e., the correlation between labels) set.

Each category label is represented by a label vector, so the correlation between the two labels can be calculated by cosine similarity, that is, any two labels (i.e., two row vectors) are selected from the matrix to calculate cosine similarity, and the smaller the calculated value, the stronger the correlation between the two labels. Here, we use an $LL \times L$ matrix B to represent the correlation between two tags. Each element b_{ij} in the matrix represents the correlation between the corresponding A_i tag and A_j tag. The calculation formula (6) is as follows:

$$b_{ij} = \text{sim}(A_i, A_j) = \cos(\Theta_{ij}) = \frac{\sum_{n=1}^N a_{in} a_{jn}}{\sqrt{\sum_{n=1}^N a_{in}^2 \sum_{n=1}^N a_{jn}^2}}. \quad (6)$$

Therein, a_i^n represents the value in the i th row and n th column of the association matrix A , that is, the n th component element in the vector of the i th label. Here, we calculate the spatial distance between two row vectors to get the correlation between two labels.

Through formula (6), we can calculate the correlation between any two tags. Furthermore, we can get the network structure diagram $G = (V, E, W)$ of tag correlation, in which

the weight value of W is the correlation between any two tags calculated by us.

In the model, we use the training set to learn from M different perspectives to obtain M optimal classifier chains. Because different samples have different labels, the different correlations between the labels will affect the final model prediction effect. Here, we assign the corresponding weight value α_m to the prediction effect of M classifier chains.

$$Q(\alpha) = \sum_{m=1}^M \frac{1}{2} \{ \alpha_m^r \| \tilde{Y} - Y \|_F^2 \} s.t. \sum_{m=1}^M \alpha_m^r = 1, \alpha \geq 0. \quad (7)$$

The idea of determining the weight value of the multi-label classifier chain by training error is obtained from this study [25]. Here, we set $r > 1$ to avoid that the model only considers the output result of a single classifier chain due to a trivial solution, thus ensuring the complementarity of multiple classifier chains.

Algorithm 2 shows the specific implementation algorithm of the MVMLOCC model. After we get the weight vector, we can use formula (5) to predict the unknown samples and output the results.

4. Experimental Research

4.1. Experimental Setup

4.1.1. Dataset. In this experiment, two open multiview multilabel datasets (Core5K, ESP game, and PASCAL VOC) are used. The data come from many different fields. Each sample in the dataset is a multilabel image, and each image has a corresponding label subset based on its content. In the experiment, we use the standard training/test partition ratio, and the total number of labels in each dataset is different. The specific statistical information of the data used in the test is shown in Table 1. All the data are from Mulan, and more detailed information can be found here.

4.1.2. Contrast Algorithm. In order to test the performance of our method in multiclassification and multilabel classification, we will compare it with the multiview algorithm of multifeature level fusion and classifier-level fusion. The related comparison algorithm will be introduced first.

Input: training set data $X \in R^{n \times d}$, $Y \in R^{n \times m}$, the number of classifier chains M , and model parameters r

Step 1: Initialize parameter $\{\alpha_m = 1\}_{m=1}^M$.

Step 2: The following operations are repeated until the objective function can be minimized.

For each $m \in [1, M]$, first, the corresponding tag sequence is generated according to the algorithm (5), and then, the chain model learning and training are carried out according to the tag sequence by using the dataset from the corresponding perspective; the parameter α_m of the minimized objective function is obtained.

Output: the whole model framework includes m optimal chain classifiers and corresponding weight vectors α_m .

ALGORITHM 2: Multiview and multilabel optimal chain classifier learning algorithm.

(1) *SVM*. We use standard SVM to deal with every single perspective data and all data from different perspectives. In other words, we use each single perspective feature to train different SVM, and after all features are spliced together, we train to be a SVM.

(2) *GP-PMK*. GP-PMK adopts the Gaussian process method and pyramid matching kernel function to improve the classification effect.

(3) *ML-KNN*. Multilabel nearest-neighbor (ML-KNN) is proposed to solve the problem of multilabel classification from a single perspective. The ML-KNN algorithm obtains the statistical information from the neighbor samples of unknown samples and determines which categories the unknown samples belong to by using the method of maximum a posteriori probability.

(4) *Hierarchical SVM*. The algorithm belongs to the multiview algorithm of classifier-level fusion. First, each view feature is used to train an independent SVM, and then, the prediction result is used as the input of another SVM. In our experiment, we realize hierarchical SVM by using standard SVM.

4.2. Analysis and Discussion

4.2.1. Verification Experiment of the Number of Nearest-Neighbor Images. In order to select the appropriate number of nearest-neighbor images, this study makes corresponding verification experiments under the condition that the number K of nearest-neighbor images is different. During the experiment, the weight parameters of the image visual feature angle are all set to 0.01, the weight parameters of the tag feature angle are set to 1, the number of tag allocation is set to 5, and the number of potential topics is set to 150, as shown in Figure 1.

With the increase in the number K of the nearest-neighbor images of the target image, the performance indexes of the image annotation method based on multi-NMF decomposition generally show a trend of increasing at first and then tending to be stable. Taking the curve of average recall obtained from the experiment in the Corel 5K database as an example, when the value of K is less than 50, the value

TABLE 1: Basic information of the experimental dataset.

Dataset	Corel5K	ESP game	PASCAL VOC
Total samples	4999	20770	10000
Number of training samples	4500	18689	5011
Number of test samples	499	2081	4952
Total tags	266	268	20

of average recall gradually increases with the increasing number of nearest-neighbor images K .

When the value of K is greater than 50, with the value of K increasing, the value of average recall has not significantly increased but has remained relatively stable. Therefore, when the number K of nearest-neighbor images is not large, the value of the average recall rate will remain stable. Therefore, due to the compromise between labeling accuracy and processing time, the number K of nearest-neighbor images is generally set to 50.

4.2.2. Performance Comparison. In the MVMLOCC model, we set up an optimal classifier chain for data subsets from each perspective. In the experiment, we selected two different perspectives from the data for the experiment.

The data in Table 2–Table 6 are the prediction effect evaluation of each algorithm in two datasets under different evaluation standards. The specific sample numbers of the training set and the test set used in the experiment are randomly divided.

Based on the above experimental results, we can observe the following:

- (1) Compared with other methods, the performance of our proposed algorithm model on two datasets has certain advantages, which proves the efficiency of our method.
- (2) As mentioned earlier, the BR method assumes that labels are independent of each other, so each category label is treated as a separate classification problem, and the performance advantage obtained in the experiment is not obvious.
- (3) Compared with the hierarchical SVM multilabel classification algorithm, our algorithm model performs slightly worse on a given dataset, but our method shows better stability when all datasets are

TABLE 2: Ranking loss performance comparison.

Dataset	Algorithm									
	SVM		GP-PMK		ML-KNN		Hierarchical SVM		MVMLOCC	
	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV
Corel5K	0.936	0.205	0.236	0.205	0.125	0.147	0.105	0.963	0.891	0.087
ESP game	0.114	0.244	0.337	0.217	0.102	0.336	0.287	0.214	0.245	0.226
PASCAL VOC	0.201	0.336	0.174	0.225	0.107	0.258	0.306	0.147	0.228	0.308

TABLE 3: Average precision performance comparison.

Dataset	Algorithm									
	SVM		GP-PMK		ML-KNN		Hierarchical SVM		MVMLOCC	
	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV
Corel5K	0.305	0.302	0.487	0.325	0.225	0.279	0.257	0.241	0.259	0.244
ESP game	0.647	0.335	0.776	0.741	0.617	0.654	0.776	0.706	0.745	0.639
PASCAL VOC	0.120	0.207	0.174	0.281	0.217	0.369	0.247	0.501	0.774	0.208

TABLE 4: Hamming loss performance comparison.

Dataset	Algorithm									
	SVM		GP-PMK		ML-KNN		Hierarchical SVM		MVMLOCC	
	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV
Corel5K0	0.063	0.066	0.225	0.147	0.001	0.716	0.633	0.057	0.568	0.336
ESP game	0.147	0.125	0.417	0.263	0.201	0.124	0.327	0.023	0.174	0.012
PASCAL VOC	0.301	0.147	0.228	0.247	0.144	0.177	0.219	0.325	0.118	0.201

TABLE 5: Comparison of one-error performance.

Dataset	Algorithm									
	SVM		GP-PMK		ML-KNN		Hierarchical SVM		MVMLOCC	
	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV
Corel5K0	0.174	0.225	0.258	0.201	0.201	0.336	0.178	0.147	0.214	0.089
ESP game	0.136	0.174	0.206	0.307	0.013	0.124	0.259	0.339	0.144	0.122
PASCAL VOC	0.217	0.228	0.146	0.528	0.392	0.417	0.208	0.136	0.218	0.152

TABLE 6: Comparison of coverage performance.

Dataset	Algorithm									
	SVM		GP-PMK		ML-KNN		Hierarchical SVM		MVMLOCC	
	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV	Best SV	Con SV
Corel5K0	0.302	0.307	0.471	0.336	0.021	0.269	0.277	0.245	0.244	0.241
ESP game	0.335	0.322	0.258	0.205	0.217	0.358	0.308	0.279	0.752	0.609
PASCAL VOC	0.014	0.724	0.218	0.258	0.326	0.224	0.563	0.745	0.281	0.159

integrated. To sum up, the experimental results can prove the efficiency of our method.

4.2.3. Runtime Analysis and Convergence Analysis. In order to evaluate the performance of the MVMLOCC algorithm, we select some comparison algorithms to compare their running time. The comparison algorithms include linear SVM using all features, GP-PMK using all features, ML-KNN, and hierarchical SVM. In Figure 2, we show the running time of different algorithms based on a different number of samples.

As shown in Figure 2, the methods based on SVM and MVMLOCC combined with different norm constraints are all nonlinear methods, while our method has linear computational time complexity. When dealing with large-scale multiview data, the difference in running time between nonlinear and linear methods will be particularly large. In addition, it is worth noting that the parallel version of MVMLOCC has a lower running time on different data than linear SVM and ML-KNN methods, which further proves that our method is suitable for processing large-scale multiview data.

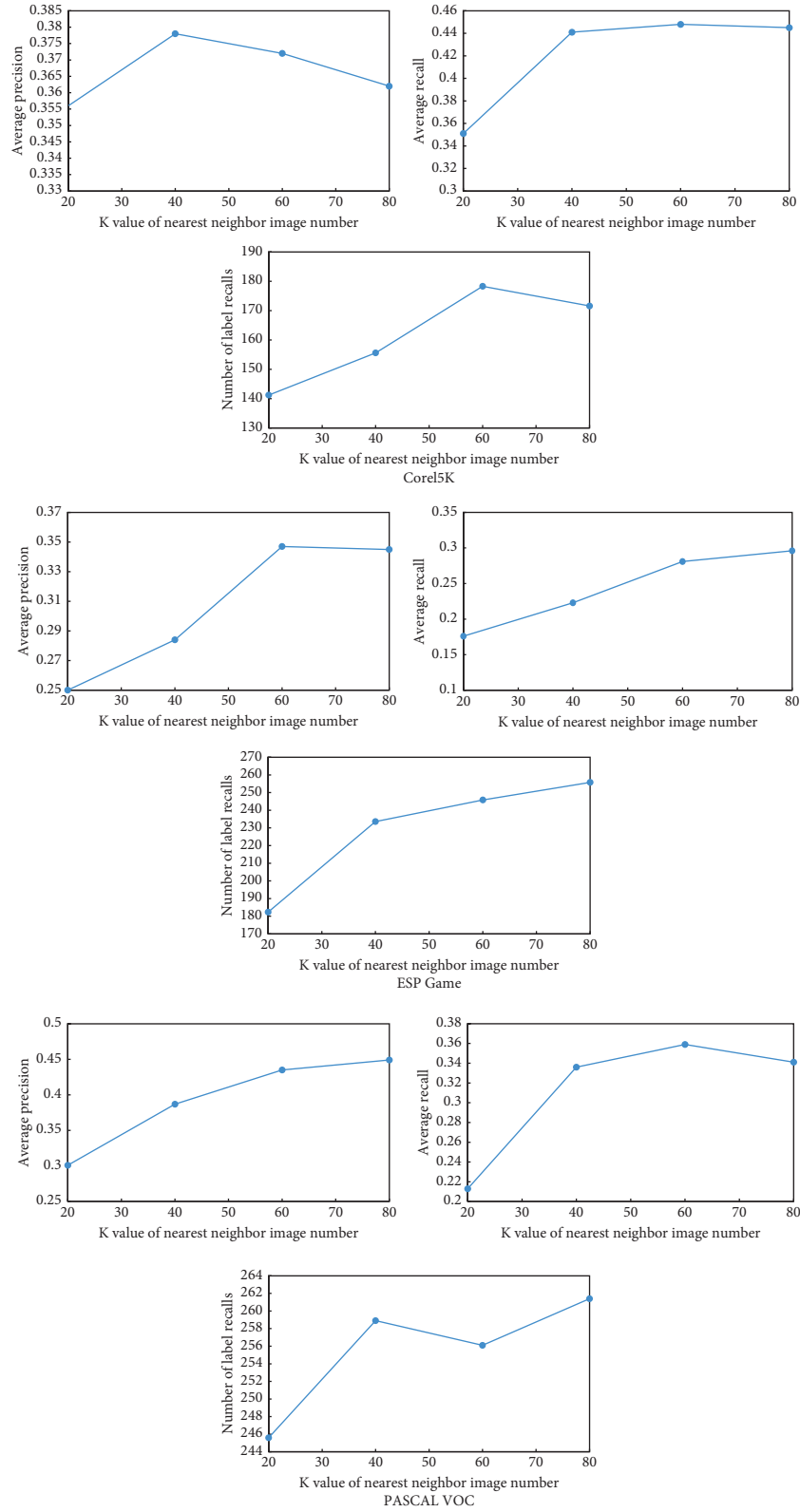


FIGURE 1: Labeling performance curves with a different number of nearest-neighbor images.

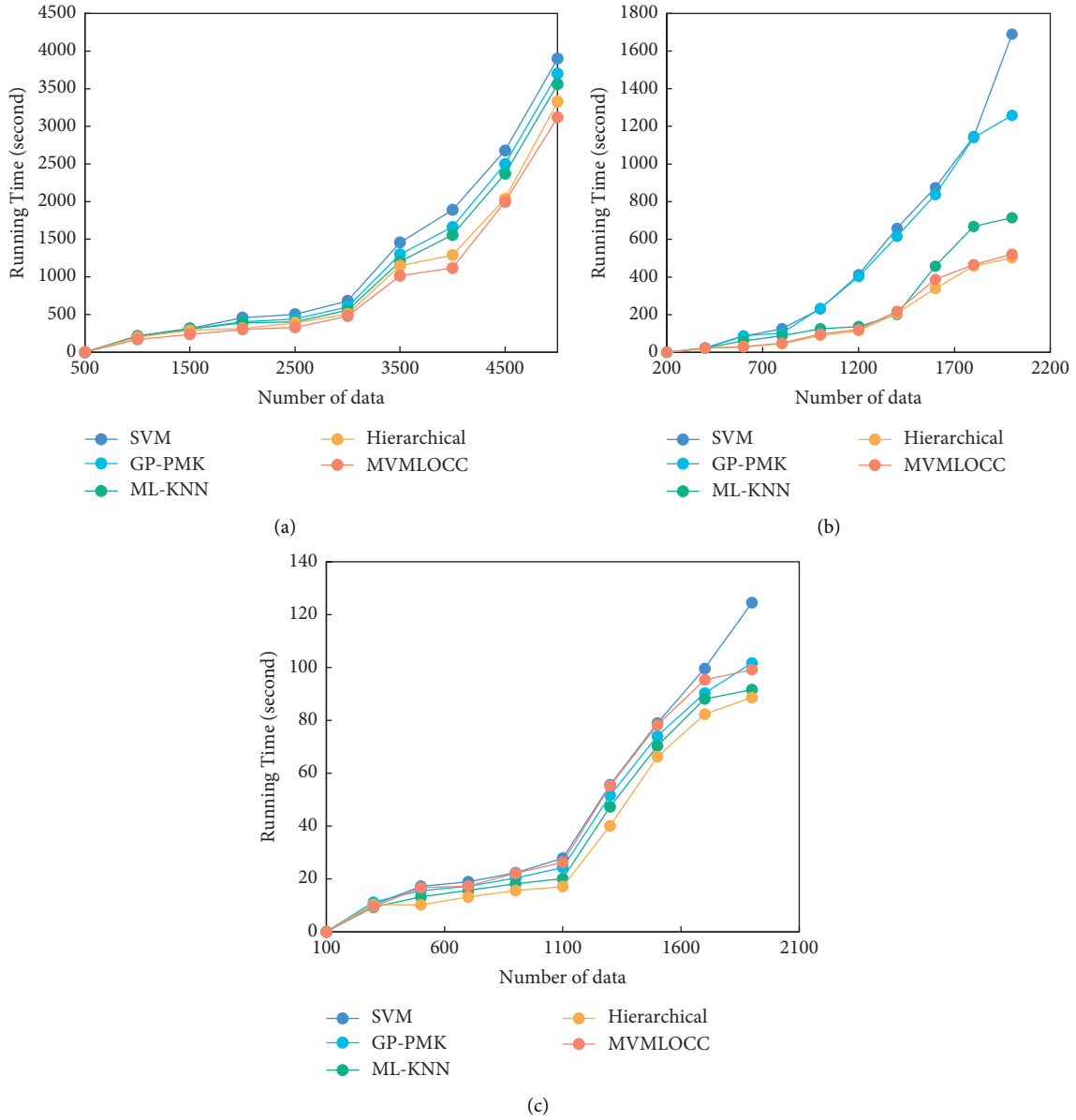


FIGURE 2: Based on the training time corresponding to different numbers of samples. (a) Corel5K. (b) ESP game. (c) PASCAL VOC.

5. Conclusions

This model not only combines the consistency of different view data under multiview data, but also combines the correlation between labels in multilabel data, and establishes a chain classifier for each view data. Considering the different prediction effects of each chain, the model gives each chain different weights, which better combines the complementarity and integrity of data from different angles. When dealing with large-scale multiview data, the running time difference between nonlinear methods and linear methods will be particularly large. In addition, it is worth noting that compared with linear SVM and ML-KNN methods, the parallel version of MVMLOCC has a

shorter running time on different data, which further proves that our method is suitable for processing large-scale multiview data. Experiments show that the performance of the multiview and multilabel learning method is far better than that of the traditional multilabel algorithm. This method provides a new strategy for solving multilabel classification problems from multiple perspectives [26].

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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Research Article

The Effectiveness Evaluation Method of Regional Digital Economy Innovation Model Based on Intelligent Computing

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Digitalization is a long-standing concern in modern industrial engineering. At present, there is no widely recognized standard for the connotation and definition of digital economy, the scope of digital economy is difficult to be defined. This paper conducts an evaluation study on the development level of the digital economy, which mainly contains two parts: first, a comprehensive digital economy; second, a study on the influencing factors. This paper first summarizes the connotation of the digital economy and digital economy evaluation-related research, extracts the influencing factors of digital economy development, and adopts partial least squares (PLS) path model to verify the hypotheses from five dimensions: basic resources, integration development, innovation capacity, social benefits, and network security. It also has an indirect impact on integrated development by influencing innovation ability; innovation capability has a significant positive impact on convergence development; convergence development has a significant positive impact on social benefits; both convergence development and social benefits have a significant negative impact on cybersecurity. Finally, based on the above research results, corresponding countermeasures and suggestions are proposed for the development of the regional digital economy.

1. Introduction

As a product of Internet technology, the digital economy has brought great changes to the socio-economic production and life styles, and a number of related research results have emerged in the academic field [1]. For the emerging digital economy, more scholars have focused on its development status, connotation and extension, and accounting issues. For example, Litvinenko [2] compared the concept of the digital economy in various countries and found that although the concept has been around for a long time, its connotation has been enriched over time and the boundaries have become more and more blurred, while the understanding of the digital economy is divided and the focus of each country is different.

Digital enabling services, industry and agriculture, and 44 digital economy projects have been implemented to boost the development of high-end, green, intelligent, and

integrated industries. The digital energy attached service industry has been upgraded. We will implement projects such as the Xinhua Department Store smart mall, e-commerce live broadcast base of the four shopping malls, and tourism big data platform, promote the in-depth application of information technology in the service industry, and comprehensively improve the intelligence level of the service industry, and promote industrial scientific and technological innovation. We will implement projects, such as Wolong green energy-saving transformer manufacturing plant, Zhongli new plate smart home manufacturing plant, and Internet + smart water, speed up the upgrading of control systems and technological transformation of energy conservation, consumption reduction, and emission reduction, and promote the transformation of old and new industrial kinetic energy. Efficient development of digital-enabled agriculture. We will implement projects, such as the Wantou intelligent organic pasture of Junhua company, the

e-commerce agricultural products exhibition center in Yueyahu township, and the construction of the national digital agriculture innovation and application base, promote the popularization and application of data collection, measurement, and analysis technologies in the agricultural industry, and accelerate the digital transformation of agricultural production and operation.

The digital economy is a kind of innovation, but it is different from innovation in the traditional sense [3]. Traditional innovation is the result of the systematic combination of production factors, the integration of the capabilities of a series of enterprise research and development, production, and manufacturing, and the focus is on technological innovation with independent intellectual property rights [4]. The digital economy, on the other hand, reflects an economic and social form that goes beyond the realm of information industry and Internet technology and transforms the organization of production by digitizing production factors [5]. For example, e-commerce, a model of digital economy, is an innovation of business model, which integrates information flow, capital flow, logistics, and commercial flow through the use of network technology to generate value-added. Some literature points out that the digital economy reconstructs the relationship between consumers and enterprises, leads to personalized and immediate demand for R&D and design, integrates R&D resources of enterprises, and promotes collaborative innovation [6]. In the era of digital economy, the integrated sharing of information resources will accelerate knowledge diffusion and promote innovation acceleration in the whole economic and social fields [7].

Taken together, the digital economy is recognized as a driver of innovation. However, most of these analyses remain in the logical explanation. In addition, the key elements of the development of the digital economy are information and data, and the characteristics of information sharing can easily lead to data and information leakage and misuse, make intellectual property protection more difficult, and affect the incentive of enterprises to innovate, which may also affect the development of innovation. So, what kind of impact will the digital economy have on innovation capability? How much impact will it have? How does it affect? These questions have not been well documented and need to be answered by empirical analysis [8]. Therefore, this research can provide a theoretical basis for exploring new innovation influencing factors and provide better ideas for the implementation of national innovation-driven development strategy.

Starting from the abovementioned issues and practical implications, this paper will study the impact of digital economy on the improvement of innovation capability. Compared with the existing studies, the innovations of this paper are as follows: first, we try to examine the influence of innovation from a new perspective. In order to comprehensively analyze the innovation impact of digital economy, this paper expands the sample as much as possible and selects 287 prefecture-level cities in China for regression analysis and verification of the impact of digital economy on innovation capability, trying to explore and find more factors that can promote innovation development; second, due to the lack of unified standards for accounting indicators of the digital

economy and the difficulty of obtaining data, the existing literature on the measurement of the digital economy has the width and narrowness of the digital economy [9].

1.1. Related Work. As for the research on the measurement of digital economy, due to the characteristics of digital economy such as virtual nature, high penetration, and external economy, accounting for digital economy should therefore reflect its penetration in various industries to provide policy makers with a basis for decision making, but there is no unified caliber on accounting for digital economy internationally [10]. In fact, in the early stage of digital economy development, ICT was mainly concentrated in the field of e-commerce, so most of the measurements of digital economy were basically centered on e-commerce. Using a comparative approach, [11] constructed a model for measuring the development level of the digital economy, incorporating factors such as smart infrastructure, promoting growth-led employment, and enhancing social vitality [12]. Suggested that two conventional value-added accounting methods, namely, the production method and the expenditure method, could be used to account for the size of the digital economy, but the study only proposed an idea and did not have a specific measurement framework. Asheim [13] explained the impact brought by AI technology from three aspects: total employment, employment population structure, and employment time series. Simmie and Martin [14] explained that in the digital economy, the value chain as well as the way of value creation has changed, and the supply-oriented business model is gradually shifting to a demand-oriented business model, where customers and vendors create value together. Baldwin and Von Hippel [15] have disrupted the R&D model of manufacturing, which can break the bottleneck of the innovation chain, improve the quality of the manufacturing chain, and optimize the efficiency of the supply chain. Khamparia et al. [16, 17] analysed that the digital economy can drive the expansion of China's economy and that its impact on employment in technology-intensive manufacturing is stronger than that on labor-intensive and capital-intensive and that China's digital transformation will lead to productivity gains and a speed-up in innovation. From a micro perspective, [18] argues that network resources in the digital economy have a positive impact on firm value and competitive advantage [19]. Found that B2C-type e-commerce platforms open channels for customers to participate in the manufacturing process of firms and trigger the codevelopment of new products between customers and firms. It was also verified in [20] that customer participation under the moderating effect of interface management contributes to the smooth development of an enterprise's autonomous R&D activities.

2. Comprehensive Evaluation of the Development Level of Regional Digital Economy

Regional cities and municipalities and the evaluation process are shown in Figure 1.

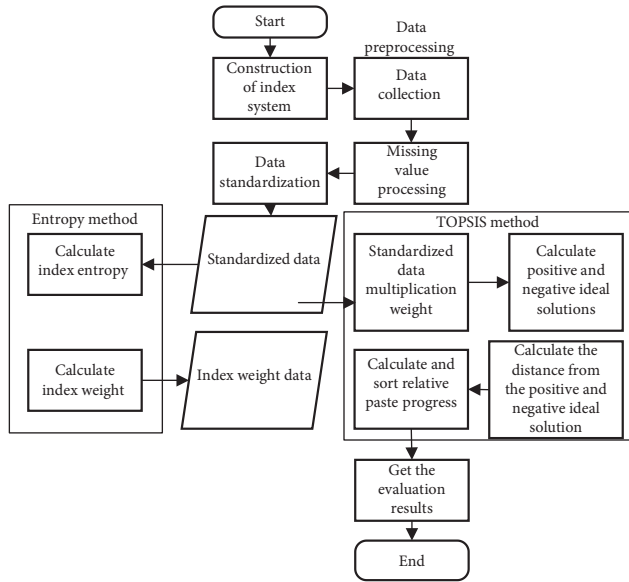


FIGURE 1: Comprehensive evaluation process.

People's risk refers to the risk of loss caused by people due to their own behavioral faults or improper self-management. In this paper, people's risk is divided into two parts: people's action behavior risk and people's self-management risk. Sports venue risk refers to the risk of loss caused by people due to improper organization and maintenance or poor execution of sports venues. In this paper, sports venue risk is divided into two parts: sports venue safety management risk and sports venue medical supervision risk. Site equipment risk refers to the risk of loss caused by unfavorable factors in the object that objectively exists. In this paper, the risk of venue equipment is divided into two parts: the risk of activity venue and the risk of sports equipment. In this paper, the external environment risk is divided into two parts: natural environment risk and man-made environment risk.

Combined whitening is a common form of surface injury caused by external forces resulting in loss between normal connections as shown in Figure 2. It is divided into semi-dislocation and complete dislocation. The former is the surface portion of the dislocated joint, while the latter joint surface is completely dislocated from its original position. The main cause of joint dislocation is an incorrect landing position after a fall [20]. The first treatment is analgesic and antishock should require the injured person to remain quiet and not move. Fracture is the destruction of the integrity and continuity of the bone, local swelling, pain, and functional impairment when fractured. There are two types of fractures: one is without skin injury, and the other is open fracture. The upper and lower joints of such fracture sites can be fixed with plastic, wood, etc. In the case of cervical fractures, the fracture should be fixed in the postinjury position and should not be bent, stretched, or rotated. Several people work together to bring the injured person to the plank, fix both sides of the head with sandbags or rolled-up clothes,

and tie the injured person to several broadband planks. The analysis of the steps to prevent the risk of injury in sports is shown in Figure 3.

In order to establish a systematic risk assessment system for sports injuries, it is necessary to decompose the decision object based on the idea of decomposition method, and build a hierarchical model accordingly. The basic level of the model: decision target refers to the final derived result; criterion layer is the criteria for the model judgment to make a decision; program layer refers to each specific program limited by the decision target and criterion layer. According to the above, the hierarchical analysis model is constructed as shown in Figure 4.

The relative importance of the above four factors was compared between two under the constraints of the criterion level. The importance ratings of coaches and athletes on the seven major exposures of the four risk categories were first arithmetically averaged in terms of categories and then weighted in terms of the ratio of the number of coaches and athletes participating in the study to obtain the final values of the matrix factors.

2.1. Indicator Data Collection and Pre-Processing. Based on the constructed comprehensive evaluation index system, the regional statistical yearbook, regional prefecture-level cities' statistical yearbook, regional Internet development report, regional Internet security report, regional intellectual property annual report, regional municipal governments' information disclosure annual report, and other reports were widely consulted and combined with the data from the website of the Alliance for the Development of Integration of Two Systems; four years of data from 2014 to 2017 were selected from regional municipalities.

After the data collection was completed, the data of the number of government information disclosure in Suzhou from 2014–2016 and 2018 were used for fitting. The comparison of the results of multiple fitting methods is shown in Table 1.

According to the fitting results, R^2 is used as the judging criterion, and because the binomial fit has the largest R^2 , the binomial fit result is selected as the indicator data of the number of government public information in Suzhou in 2017.

Since each indicator data have different levels and orders of magnitude, the original data of the indicators are standardized in the paper, and the original data are converted to values between 0 and 1. The standardization method uses linear maximum-minimum standardization. Since the index system contains negative indicators, a different approach is used for standardization.

With y years, n evaluation objects, and m evaluation indicators, $x_{\theta ij}^*$, the original values of the indicators are used; the standardized values of the indicators are denoted by $x_{\theta ij}$; in all y years is denoted by x_j^{\min} , where θ denotes the year ($\theta = 1, 2, \dots, y$), j denotes the evaluation index ($j = 1, 2, \dots, m$).

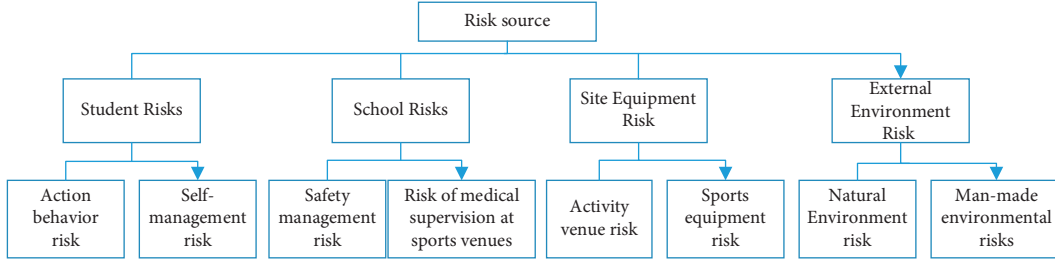


FIGURE 2: Sports training risk factors classification chart.

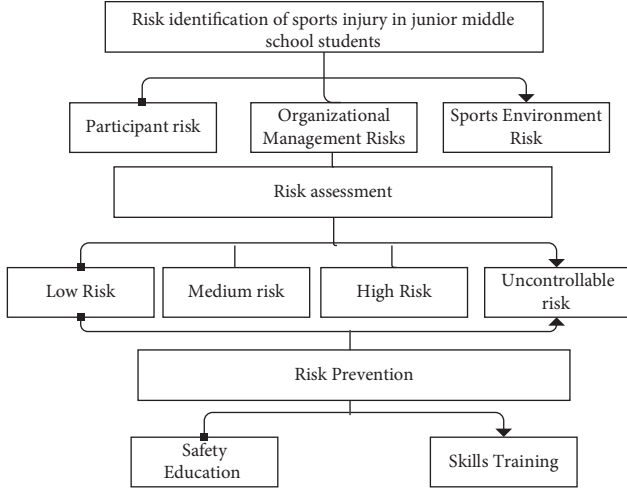


FIGURE 3: Risk prevention chart for sports injuries.

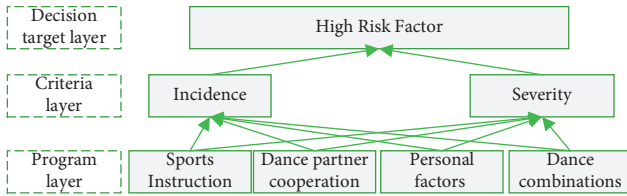


FIGURE 4: Hierarchical decision model for high risk factors.

TABLE 1: Fitting results of the data of the number of government public information in Suzhou in 2017.

Fitting method	R^2	Formula	Estimate
Index	0.8887	$y = 258855e0.0777x$	369949
Linear	0.8922	$y = 29428x + 254303$	368811
Logarithmic	0.9455	$y = 76107 \ln(x) + 269656$	375055
Binomial	0.9633	$y = -6968x^2 + 73351x + 204542$	382224
Power	0.9501	$y = 272756x^{0.225}$	375029

$$\begin{aligned} x_j^{\max} &= \max(x_{\theta ij}^* | 1 \leq \theta \leq y, 1 \leq i \leq n), \\ x_j^{\min} &= \min(x_{\theta ij}^* | 1 \leq \theta \leq y, 1 \leq i \leq n). \end{aligned} \quad (1)$$

Most of the indicators in the indicator system are positive indicators, and the larger the value of these indicators, the better. x denotes the standardized value, and the formula used to standardize the positive indicators is.

$$x_{\theta ij} = \frac{x_{\theta ij}^* - x_j^{\min}}{x_j^{\max} - x_j^{\min}}. \quad (2)$$

The network security indicators in the indicator system are all negative indicators, and the smaller the value of such indicators, the better, so the negative indicators are standardized using the following formula:

$$x_{\theta ij} = \frac{x_j^{\max} - x_{\theta ij}^*}{x_j^{\max} - x_j^{\min}}. \quad (3)$$

3. Entropy Weighting

In information theory, information and entropy are measures of the degree of order and disorder of a system, respectively. Applied to evaluation, the greater the entropy value of an indicator, the greater the amount of information the indicator can provide, and the indicator should be given a higher weight. The entropy method is an objective assignment method, which has a stronger mathematical theoretical basis than the subjective assignment method, excludes the subjective interference of the evaluator, and is more accurate and scientific.

This paper studies the comprehensive evaluation of multiple indicators for multiple objects and years. In order to make the evaluation results of each year comparable with each other, time variables are added when using the entropy weighting method to calculate the index weights.

3.1. Entropy Weighting Method Calculation Process. Let there be y years, n evaluation objects, and m evaluation indicators, and use $x_{\theta ij}$ to denote the standardized indicator values, where θ denotes the year ($\theta = 1, 2, \dots, y$).

(1) The i th evaluation object

$$p_{\theta ij} = \frac{x_{\theta ij}}{\sum_{\theta=1}^y \sum_{i=1}^n x_{\theta ij}}. \quad (4)$$

(2) Calculate the entropy value e_j

$$e_j = \sum_{\theta=1}^y \sum_{i=1}^n p_{\theta ij} \ln(p_{\theta ij}), \text{ among then, } k = \ln(yn). \quad (5)$$

$$d_j = 1 - e_j.$$

(3) The j th indicator w_j

$$w_j = \frac{d_j}{\sum_{j=1}^m d_j} = \frac{1 - e_j}{m - \sum_{j=1}^m e_j}. \quad (6)$$

From this, the weights of each indicator can be calculated $W = [w_1, w_2, \dots, w_m]$.

3.2. Comprehensive Evaluation of Digital Economy. The TOPSIS is a multiobjective decision making method proposed by C. L. Hwang and K. Yoon, and the TOPSIS method was fused with the entropy method by [12].

The TOPSIS evaluation method is applied in this evaluation study as follows:

- (1) Determine ideal solution

$$\begin{aligned} x^+ &= \{x_1^+, x_2^+, \dots, x_m^+\} \\ &= \{(\max(x_{\theta ij} | j \in J_1), \min(x_{\theta ij} | j \in J_2)) | 1 \leq \theta \leq y, 1 \leq i \leq n\}, \\ x^- &= \{x_1^-, x_2^-, \dots, x_m^-\} \\ &= \{(\min(x_{\theta ij} | j \in J_1), \max(x_{\theta ij} | j \in J_2)) | 1 \leq \theta \leq y, 1 \leq i \leq n\}. \end{aligned} \quad (7)$$

Among them, J_1 is the positive indicator and J_2 is the negative indicator.

Since the original data have been standardized, the maximum value is 1 and the minimum value is 0 after the standardization of positive indicators; the minimum value is normalized to 1 and the maximum value is normalized to 0 after the standardization of negative indicators.

- (2) Calculate the distance D_i^+ of the evaluation object to the positive ideal solution x^+ and the distance D_i^- of the negative ideal solution x^- , respectively,

$$D_i^+ = \sqrt{\sum_{\theta=1}^y \sum_{j=1}^m (w_j (x_{\theta ij} - x^+))^2}, \quad i = 1, 2, \dots, n, \quad (8)$$

$$D_i^- = \sqrt{\sum_{\theta=1}^y \sum_{j=1}^m (w_j (x_{\theta ij} - x^-))^2}, \quad i = 1, 2, \dots, n, \quad (9)$$

where w_j is the weight of the j th indicator calculated by the entropy weighting method.

- (3) Calculate the relative posting progress of each evaluation object C_i^* .

$$C_i^* = \frac{D_i^-}{D_i^+ + D_i^-}, \quad i = 1, 2, \dots, n. \quad (10)$$

Among them, $C_i^* \in [0, 1]$.

According to equations (8) to (10), the relative fit of each evaluation object can be obtained.

The final posting degree as the evaluation result of digital economy development level ranges from 0 to 1, and the larger the value, the higher the digital economy development level.

3.3. Comprehensive Evaluation Results. The evaluation results of digital economy development level can rank the evaluation objects, and the evaluation results are shown in Table 2 and Figure 5.

The comprehensive evaluation results show that the regional digital economy development level is relatively obvious, which shows that four cities are in a relatively backward position. The relatively large gap between the evaluation results of the digital economy in different cities and regions indicates that the unbalanced development of digital economy in the region is relatively serious.

According to the evaluation results, the regional digital economy development level can be divided into three levels, as shown in Table 3, the first echelon is the high-level cities whose four year average exceeds 0.2236 (i.e., the average of all cities); the second echelon is the medium level cities whose average is less than 0.2236 but more than 0.15; and the third echelon is other lower level cities.

The radar diagram of the evaluation results of the five first-level indicators for each city in the high-level region is shown in Figure 6. Where BR indicates basic resources; ID indicates integration development; SB indicates social benefits; IA indicates innovation capacity; and CS indicates cyber security.

From the perspective of basic resources dimension, Nanjing, Suzhou, Wuxi, and Changzhou are decreasing in order, but the evaluation results of each city are improving year by year, Wuxi and Changzhou have relatively lower scores in basic resources, and the progress is not as obvious as Nanjing and Suzhou; from the perspective of integration development, all cities are improving and the progress is gradually increasing, and Nanjing is still the leader of integration development with the latest data. From the social benefit dimension, Nanjing is in the absolute lead, which should be attributed to the fact that Nanjing has created more jobs in the information industry, while the social benefit dimension of Suzhou and Wuxi is not outstanding and is the lowest level among the five dimensions of their own development, which has become an obvious disadvantage to Changzhou; from the viewpoint of innovation capability, Suzhou is in the absolute lead and the other three cities are at similar levels, the same is true in terms of innovation capability; all cities have not improved significantly and are in a relatively stable state; in the cyber security dimension, Changzhou Wuxi is relatively high and stable, while Nanjing Suzhou has relatively low and unstable evaluation results, indicating that Nanjing Suzhou has relatively more unstable factors in the cyber security dimension. In general, the high-level regions have better digital economy development, and the characteristics of their respective development are relatively obvious.

The radar chart of the medium level regional level indicators is shown in Figure 7. Among them, the basic resource dimension is not outstanding and the progress is not significant, relatively speaking, the progress of Nantong is relatively large; from the perspective of integration development, all four cities have progressed and the progress is relatively obvious, Yangzhou and Taizhou are obviously better than Nantong and Zhenjiang; from the social benefit

TABLE 2: Comprehensive evaluation results of regional digital economy development level.

City	2014	2015	2016	2017	Average
Nanjing	0.5556	0.5587	0.6402	0.7598	0.6301
Suzhou	0.4115	0.4447	0.4889	0.5829	0.4820
Wuxi	0.2707	0.2886	0.3224	0.4055	0.3355
CHangzhou	0.1981	0.2131	0.2877	0.3929	0.2731
Yangzhou	0.1155	0.1335	0.2501	0.3622	0.2155
Nantong	0.1515	0.1502	0.1859	0.2668	0.1931
Zhenjiang	0.1465	0.1531	0.1987	0.2511	0.1907
Taizhou	0.0897	0.1055	0.1509	0.2544	0.1511
Xuzhou	0.0766	0.0828	0.1716	0.2221	0.1355
Yancheng	0.0658	0.0755	0.1143	0.1598	0.1031
Suqian	0.0722	0.1051	0.0688	0.1325	0.0933
Huai'an	0.0521	0.0611	0.0705	0.0988	0.0801
Lianyungang	0.0499	0.1866	0.2418	0.0815	0.2239
Average	0.1739	0.1866	0.2422	0.3839	0.2273

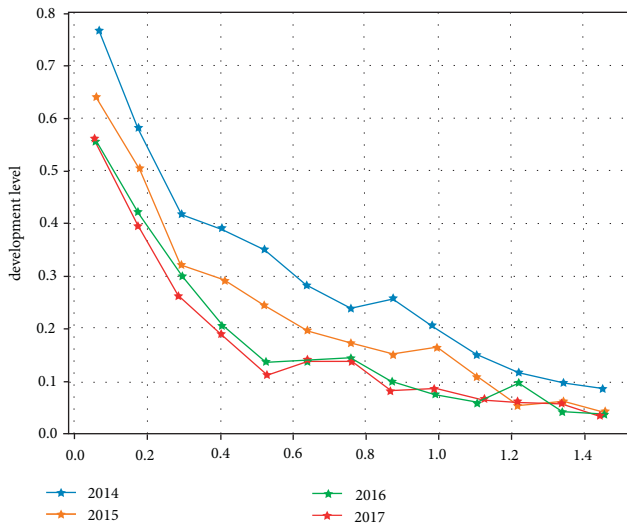


FIGURE 5: Line graph of the regional digital economy development level.

TABLE 3: Regional digital economy development level echelon.

Echelons	Including cities
High level	Nanjing, Suzhou, Wuxi, and CHangzhou
Medium level	Yangzhou, Nantong, Zhenjiang, and Taizhou
Low level	Xuzhou, Yancheng, Suqian, Huai'an, and Lianyungang

dimension, the development level of all four cities is not high, and the progress is not significant between four years and is in a relatively stable state; from the perspective of innovation capacity, all four cities are basically in the same level range. In addition to Yangzhou, Taizhou is slightly worse, and the other three cities have almost no significant progress; network security dimension, the evaluation results of the four cities in the medium level area are relatively high, but there is a certain regressive trend when the other dimensions grow, the network security evaluation results are declining.

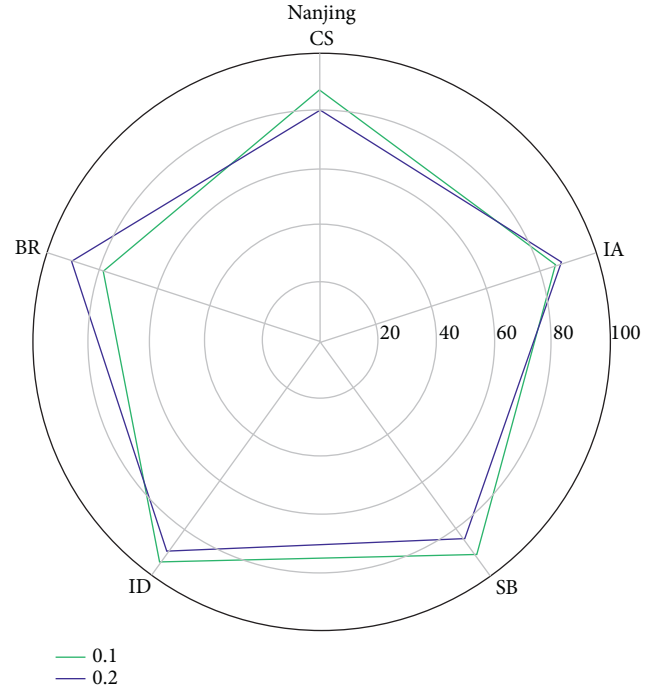


FIGURE 6: Radar chart of indicators at the level of high-level regions.



FIGURE 7: Radar map of indicators at the medium level.

The radar diagram of the first-level indicators for low-level regions is shown in Figure 8. Except for the relatively high evaluation results of the network security dimension, the scores of the other four dimensions are low, among which the shortcomings common to the five cities of basic resources and integration development, Xuzhou's scores in the other four dimensions belong to the higher level in this

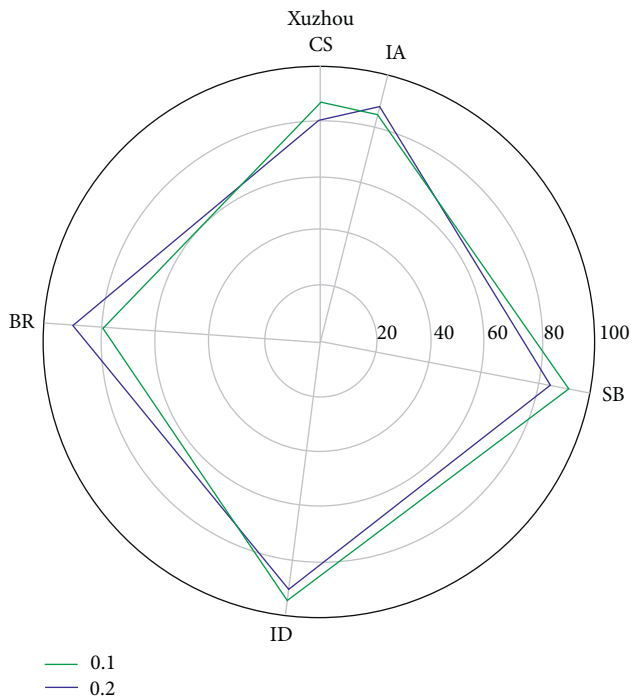


FIGURE 8: Radar map of indicators at the low-level area level.

echelon, but it is obvious that Xuzhou's network security score is significantly regressed. The level of innovation capacity of all cities is not high, but Yancheng city has grown significantly.

4. Conclusion

In this paper, we evaluate the level of digital economy development research, first summarize the connotation of the digital economy and digital economy evaluation-related research, distill the influence factors of digital economy development, use PLS to verify the hypothesis analysis, and the research results show that the basic resources have a large impact on integration development, not only has a direct positive impact but also has an indirect impact on integration development by affecting the innovation capacity.

Data Availability

The dataset used in this paper is available from the corresponding author upon request.

Conflicts of Interest

The authors declared that they have no conflicts of interest regarding this work.

Acknowledgments

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Retraction

Retracted: Evaluating and Exploring the Effectiveness of Journalism and Communication Discipline Construction in the Context of Smart Era

Mathematical Problems in Engineering

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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.

References

- [1] Y. Li, "Evaluating and Exploring the Effectiveness of Journalism and Communication Discipline Construction in the Context of Smart Era," *Mathematical Problems in Engineering*, vol. 2022, Article ID 2899128, 6 pages, 2022.

Research Article

Evaluating and Exploring the Effectiveness of Journalism and Communication Discipline Construction in the Context of Smart Era

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In today's intelligent era, the talent training mode of traditional journalism and communication discipline cannot keep up with the pace of the times. Under the background of intelligent era, the cultivation of compound talents in journalism and communication discipline is not only in line with the direction of education reform in journalism and communication discipline, but also in line with the objective requirements of economic and social development. Based on this, this paper puts forward three suggestions: improve the discipline layout of "smart age + journalism and communication discipline" and strengthen professional construction; enrich the textbook resources in the era of wisdom and promote smart teaching.

1. Introduction

Guided by the goal of educational modernization and building China into an educational power by 2035, the discipline of communication in China has updated the concept of liberal arts education in national universities and outlined a new picture of the construction of Johnson & Johnson discipline with Chinese characteristics, practicality, and interdisciplinary nature [1]. Johnson & Johnson discipline is a strategic measure to cultivate new liberal arts talents in China. "The core significance is to base on the new era, respond to the new needs of society, and promote the integration, modernization, sinicization, and internationalization of liberal arts [2].

Intelligent education is an intelligent concept and educational method developed and perfected with the development of intelligent technology. This is an effective way to establish Johnson & Johnson discipline [3–5]. The discipline of Johnson & Johnson can make use of intelligent education to break the shackles of Johnson & Johnson education in teaching methods, educational resources, educational objectives, and other aspects so as to strengthen the discipline function and social function of the specialty [6].

As the saying goes, "if you don't keep justice, you won't know the way to the future; if you don't innovate, there will be no way out." We must follow and inherit the humanistic tradition and the basic laws of liberal arts, such as following the basic laws of liberal arts education and personnel training, and inheriting China's excellent traditional culture. Innovation lies in that it must improve itself in the contemporary era. Its main characteristics are the docking with the new information technology in the 21st century, the cross integration with similar majors and other disciplines, and the integration with the social life and students' psychology in the new era. We must take this discipline authorization as the most basic starting point.

2. Related Work

Technology is the basic element of news communication, which determines the basic form and function of news communication. As a science that studies the phenomena and laws of news communication activities in human society, the development of J & C has always been branded with the first marks of technology, and its theory and discipline system have often undergone profound changes due

to the evolution of media technology, such as the development of printing technology and radio and television technology, which not only supported the theoretical development of the Western school of media criticism and the school of media experience, but also directly contributed to the development of the school of media technology (the development of print and broadcast technologies not only supported the theoretical development of the Western media critical school and the media empirical school, but also directly contributed to the formation of the media technology school (media environment school)). With the emergence of new technologies, J&C are inevitably ushering in a kind of disruptive revolution in the face of the richness and complexity of new communication activities and phenomena, and to a certain extent, its disciplinary system and attributes will be redefined due to technology [7–9].

As China enters a new era, people have higher and higher requirements for news. The greatest expectation of the public for news is to enrich people's spiritual world and tell a good Chinese story. News practice reflects the characteristics of the times of "writing news on the Earth and in the hearts of the people." This authorization is also reflected in the new practice part of the course teaching, which should be strengthened by seizing the opportunity of in-depth media integration [10]. The design and teaching of Johnson & Johnson courses should not only focus on the classroom but also break the physical space-time constraints in the classroom, constantly broaden the vision of teaching and learning, integrate (academic circles), industry and society, practical courses, professional practice, base construction and media technology, media ecology, media production and even daily life, and not only develop and update the courses on the basis of joint discussion and consultation. We should also jointly undertake the design and teaching of practical courses. They shall not only formulate and update the training plan on the basis of joint discussion and consultation but also jointly undertake the design and teaching of practical courses [11]. In particular, China Johnson & Johnson urgently needs to promote the training of all media talents by strengthening all media practical teaching activities, and improve students' basic professional abilities, such as all media reporting ability. Through diversified practical training and media experience, they have the ability of comprehensive media expression and cross media cooperation.

Finally, practice empowerment is also reflected in the international perspective of strengthening curriculum practice. Under the historical background of building a community with a shared future for mankind, the education and teaching of this discipline should be combined with the global vision and China's position [12], clearly explain China's position and philosophy, and cultivate outstanding news reserve talents who can speak Chinese logic and are good at spreading Chinese views.

3. Methods

Based on the above compilation of policies, issues, and trends of J&C discipline talent training, the development

trend of J&C discipline environment in the age of intelligence is analyzed, and the factors influencing the competence of J&C discipline are compiled and analyzed (see Figure 1).

In the era of intelligence, which is deeply rooted in the hearts of the people, the educational concept, model, and governance will be reshaped. The discipline construction of Johnson & Johnson under the background of the wisdom era is a reform project for the reconstruction of the discipline education of Johnson & Johnson. "Smart age + Johnson & Johnson discipline" is based on a new educational concept (moderate education, not optimal education), with the goal of people's all-round development (not just employment oriented), rethinking, and designing new talent training mode, new curriculum system, new teaching mode, and new teaching platform to cultivate innovative Johnson & Johnson discipline talents. Therefore, Johnson & Johnson discipline is comprehensively and fundamentally reconstructing a new set of Johnson & Johnson discipline education concepts, systems, mechanisms, methods, evaluation, etc., and a new reform of Johnson & Johnson discipline education governance has taken place [13–16].

The curriculum training objectives should be combined with students' learning needs to jointly serve the creation of an efficient foreign language learning ecology. As shown in Figure 2, the curriculum of Johnson & Johnson discipline is based on the needs of language use and defines the dual goals of "promoting learning" and "educating people" of Johnson & Johnson discipline, as well as the knowledge, ability, and political goals of foreign language courses.

On the basis of fully investigating the international evaluation paradigm and combining with the actual situation of the University, the international evaluation work innovates the evaluation concepts and methods, pays more attention to the organic unity of discipline construction objective evaluation, process evaluation, and result evaluation, pays more attention to the connection and integration of problem orientation and result sharing, and pays more attention to the design of the closed-loop system and long-term mechanism of "evaluation optimization and re evaluation." The work plan of the discipline international evaluation model is formed by designing a closed-loop system and a long-term mechanism. One of the main links is shown in Figure 2.

Local governments and education departments will take the lead in formulating supporting policies and measures to guide schools, vocational training institutions, enterprises, and other institutions to jointly build an intelligent education ecosystem of industrial Johnson and Johnson disciplines in the smart era, realize the integration of industry and education and the linkage between government and enterprises, and build a diversified and collaborative intelligent education ecosystem. As shown in Table 1, "teacher" has the highest word frequency of 88, followed by "talent training" and "scientific research," with word frequencies of 81 and 71, respectively. "Planning initiative," "discipline reputation and cultural construction," and "international cooperation" have more than 20 keywords [17].

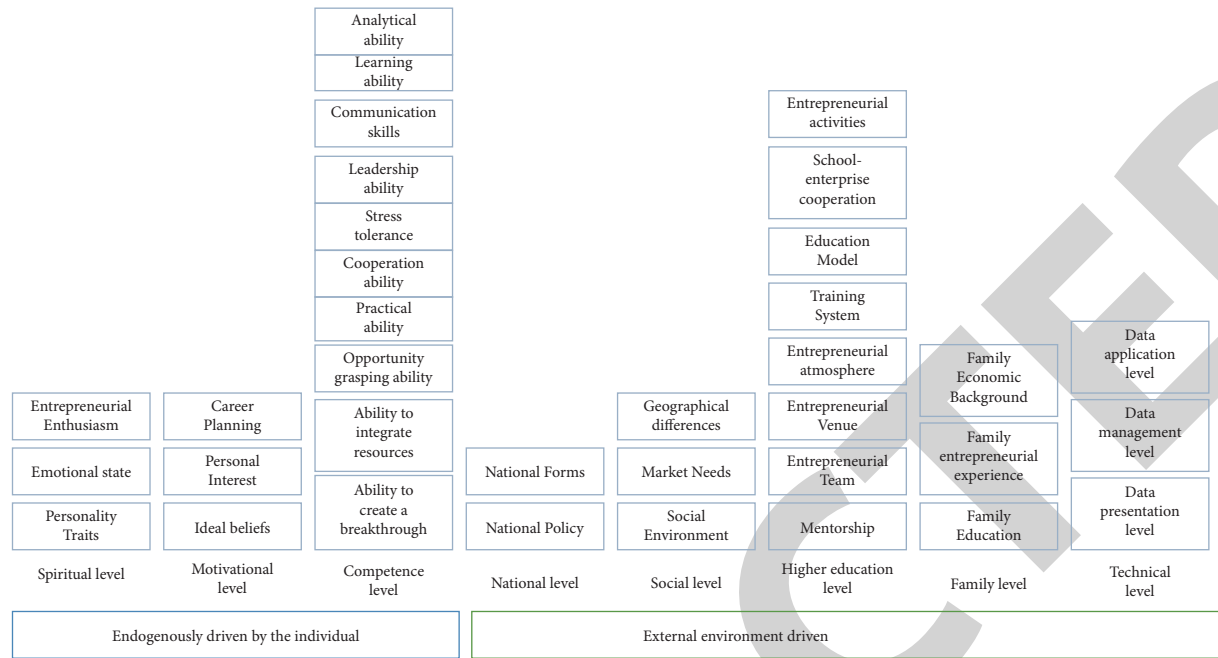


FIGURE 1: Factors influencing competence in J&C disciplines.

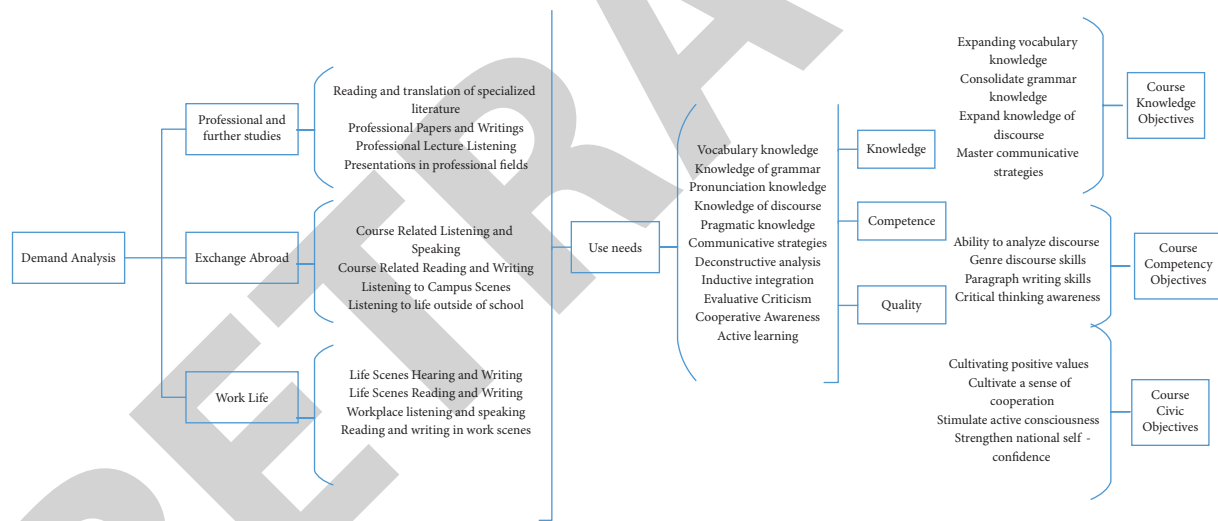


FIGURE 2: Analysis of curriculum needs and teaching objectives of J&C disciplines.

TABLE 1: High-frequency key words in the expert evaluation report.

Keywords	Word frequency	Keywords	Word frequency
Faculty	88	Interdisciplinary research	8
Talent cultivation	81	Young faculty	8
Scientific research	71	Developing a plan	7
Planning initiatives	45	Building initiatives	7
Academic reputation and culture building	31	International exchange opportunities	7
International cooperation	26	International impact	7
Cultivation system	19	Social service	7
Research quality	11	Adjunct faculty	6
Academic backbone	10	International cooperation in scientific research	6
Research direction	8	Culture building	5
Student quality	9	International evaluation	5
Comprehensive ability	7	International cooperation in teaching	5

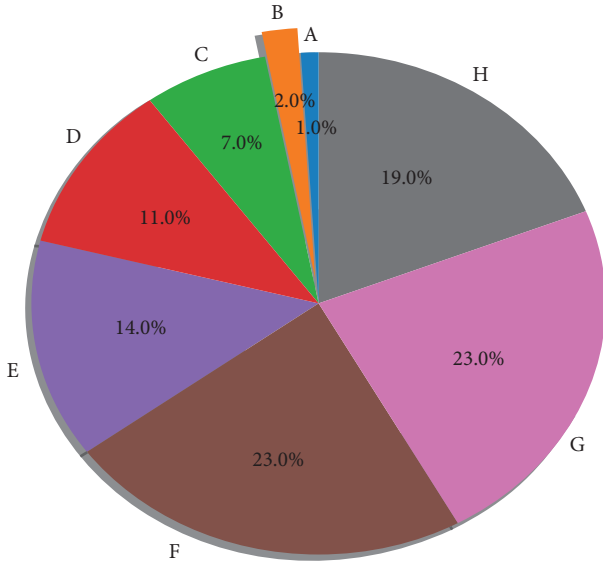


FIGURE 3: Percentage of disciplines above category C in the fourth round of national discipline evaluation.

In order to cultivate the compound ability required by the “intelligent era + Johnson & Johnson era,” it is necessary to cultivate students’ compound ability through school enterprise cooperation and engineering combination so that students’ knowledge application ability, engineering practice ability, management practice ability, professional development ability, and innovation and entrepreneurship ability can be exercised in the real work practice and business environment [12, 18–20]; Johnson has certain compound knowledge. Professional development ability and innovation and entrepreneurship ability are exercised in the actual work practice and business environment. The integration of talent training and innovation research bases are strengthened, the multidisciplinary collaborative education mechanism is improved in the field of the intelligent age, and multilevel talents are cultivated in the field of the intelligent age in various forms.

4. Experiments

In the discipline evaluation, there are 278 first-level disciplines in 17 higher education institutions, accounting for 4% of all the disciplines evaluated. According to the evaluation results, there are 159 disciplines above category C. There are 4 A subjects, accounting for 0.56% of 710 A subjects, 53 B subjects, accounting for 2.42% of 2,187 B subjects, and 102 C subjects, accounting for 4.60% of 2,215 C subjects, as shown in Figures 3 and 4.

As the saying goes, “classroom is the main channel and position of education and teaching,” the realization of subject empowerment takes classroom teaching as the basic path. Classroom teaching is the basic organizational form of human education and teaching since modern times. With the popularization of higher education in China, classroom teaching will still be the leading form of education and teaching in our country in the future [12].

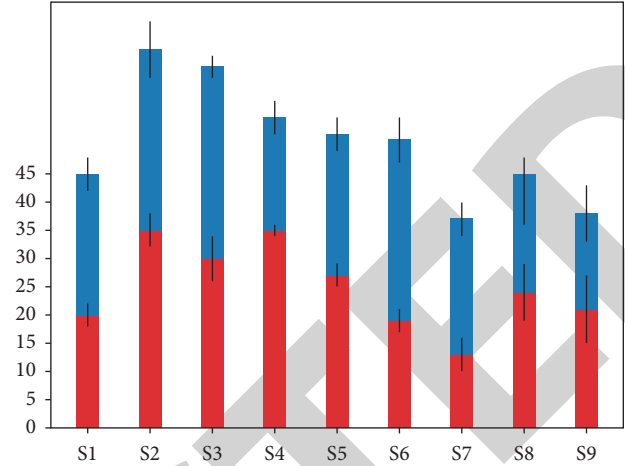


FIGURE 4: The fourth round of national discipline evaluation of higher education institutions above category C.

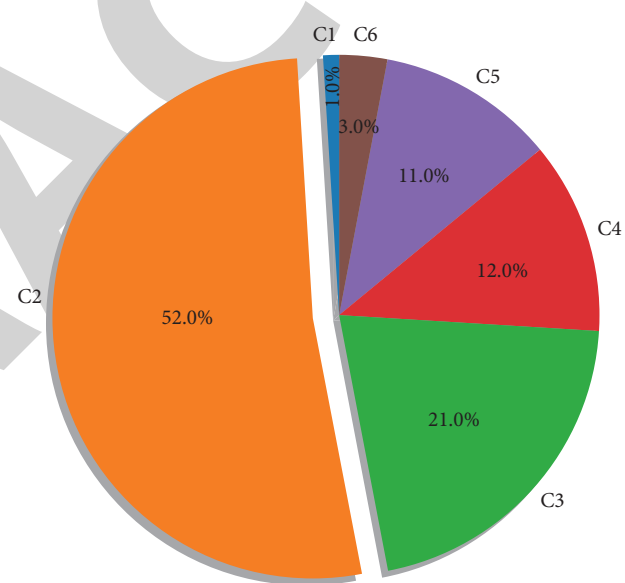


FIGURE 5: Number and percentage of disciplines with category C.

Creating a classroom of “love, righteousness, warmth, and love” needs systematic support. Educators should naturally take classroom empowerment as a breakthrough to leverage the chain effect of discipline construction and further promote professional optimization, including course objective design, course system setting, syllabus approval, textbook review and selection, teaching plan and courseware production, practice base selection and collaborative education, degree setting and certificate issuance, teaching and management personnel evaluation, and even international exchange and transnational training [14]. It runs through the course arrangement, classroom teaching, teaching seminars, experimental training, assignments and papers, examination and assessment, salary incentive and management system and mechanism, and is finally unified in the discipline construction. Finally, it is unified in the complete discipline construction system. The speciality construction layout is

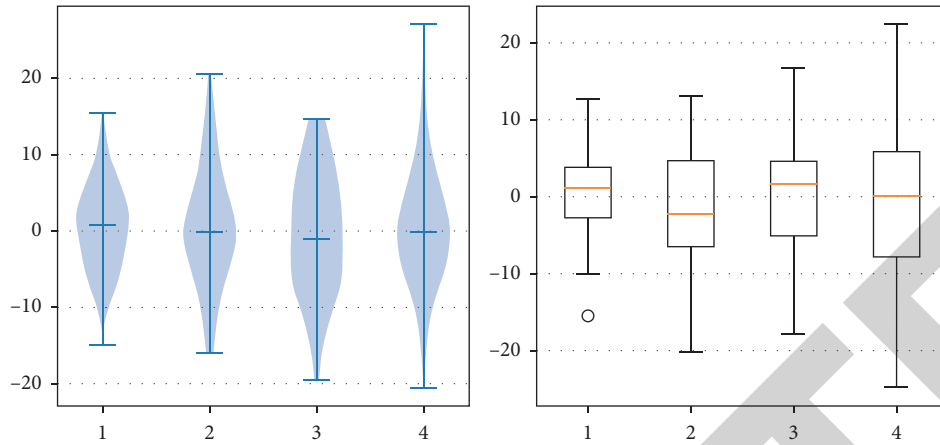


FIGURE 6: Comparison results of evaluation schemes.

TABLE 2: Distribution of indicators judged by the degree of concentration of indicators.

Concentration judgment index	Round 1			Round 2		
	Minimum value	Maximum value	$\bar{x} \pm s$	Minimum value	Maximum value	$\bar{x} \pm s$
Mean	3.835	5.000	4.658 ± 0.315	4.185	5.000	4.758 ± 0.162
Standard deviation	0	1.288	0.598 ± 0.199	0.0000	1.135	0.526 ± 0.229
Entry selection rate (%)	55.568	100.000	90.289 ± 12.325	70.598	10.000	95.012 ± 6.315

TABLE 3: Kendall's W harmony coefficients and significance tests for 2 rounds of expert opinions.

Projects	Importance of level 2, level 2 and level 3 indicators			Reasonableness assignment of the scoring method of the three levels of indicators		
	No. of entries	Kendall's W	P	No. of entries	Kendall's W	P
Round 1	62	0.255	<0.001	45	0.388	<0.001
Round 2	65	0.365	<0.001	46	0.386	<0.001

closely related to the cities where the 15 specialties above class C are located, as shown in Figure 5.

The degree of concentration of experts' opinions is measured by the mean, standard deviation, and selection rate of each indicator's importance score. The whole process of classroom teaching and all its effects and internal and external links will be reflected. This process is also the process of promoting discipline construction by taking discipline empowerment as the logical starting point, and the empowerment of the construction of J&C disciplines in the new era in China can take classroom teaching as the main grasp and breakthrough point, as shown in Figure 6.

As shown in Table 2, the overall importance is 0.301, 0.362, 0.275, and 0.253, respectively, and the Kendall coordination coefficient of the operability of the three-level indicators is 0.378. Kendall coordination coefficient and overall importance are 0.360, 0.298, 0.456, and 0.335, respectively. Kendall coordination coefficient for operability of Kendall coordination coefficient of level III indicators is 0.380. The significance test is statistically significant (<0.05), as shown in Table 3.

The cut-off values for the mean, perfect score, and coefficient of variation of each item in the two rounds of

TABLE 4: Threshold values for screening indicators.

Projects	Mean		Standard deviation		Boundary value	
	1	2	1	2	1	2
K	68.55	76.15	17.55	10.18	50.87	65.89
M	4.65	4.78	0.33	0.17	4.32	4.55
CV	0.11	0.13	0.08	0.04	0.23	0.19

Note. K refers to the perfect score rate (%) of each index, M refers to the mean of each index, both of which are high-performing indicators; CV refers to the coefficient of variation, which is a low-performing indicator.

consultation were calculated according to the "cut-off value method," as shown in Table 4.

5. Conclusion

Talent cultivation of J&C disciplines based on the intelligent era is not only a trend of educational reform of J&C disciplines but also an inevitable requirement of economic and social development. Through this mode of talent cultivation, students can improve comprehensive quality while learning theoretical knowledge systematically and closely integrate with corresponding industries, which can also better support the cultivation of cross-border talents in universities. In

Retraction

Retracted: Exploring the Hot News on the Internet Based on Recommendation Algorithm for College Students' Ideological and Political Education

Mathematical Problems in Engineering

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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.

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- [1] Y. Su and Z. Lv, "Exploring the Hot News on the Internet Based on Recommendation Algorithm for College Students' Ideological and Political Education," *Mathematical Problems in Engineering*, vol. 2022, Article ID 5855328, 7 pages, 2022.

Research Article

Exploring the Hot News on the Internet Based on Recommendation Algorithm for College Students' Ideological and Political Education

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College students are the main group of Internet users. With the development of electronic technology and mobile communication technology in China, most college students can easily use computers to access the Internet, and almost all college students use mobile phones, and using mobile phones to access the Internet has become very common in Colleges and universities. The effect is more obvious, and it is easier for ideological and political educators to understand the real situation. In order to further improve the performance of the interest point recommendation algorithm, this paper proposes a time feature-oriented interest point recommendation algorithm. The basic methods of user-based collaborative filtering are given, the functions of spatio-temporal features are described, respectively, the corresponding model representation is given to fuse spatio-temporal features, and a joint recommendation algorithm is proposed. Experiments show that compared with other related algorithms, this algorithm has higher accuracy and recall and is more suitable for the recommendation service of points of interest.

1. Introduction

With the development of electronic technology and mobile communication technology in China, most college students can easily use computers to access the Internet, and almost all of them use cell phones, and using cell phones to access the Internet is very common in colleges and universities [1]. The Internet brings college students into a wonderful virtual world, in which they can understand the culture of the world and grasp the current world events [2]. The means and methods are more modern and diversified, the form and content are more attractive, the effect is more obvious, and the ideological and political education workers can more easily understand the real college students' ideological dynamics and psychological problems [3][4].

Ideological and political education, as a discipline closely combining theory with practice, has always been the focus of academic attention and the forefront of research. At present,

network technology is developing rapidly. By studying the development trend of network ideological and political education, this study aims to put forward some theoretical thinking on how to carry out ideological and political education, so as to guide practice more effectively [5].

In recent years, location-based social networks have developed rapidly and attracted more and more users. Point of interest recommendation has been widely studied in location-based services and recommendation systems [6]. Among these methods, the collaborative filtering method based on user similarity is not only efficient but also has good recommendation performance, so it is often used by service providers. In the point of interest recommendation, the item set is the point of interest in the system. The user login record constitutes the user's evaluation matrix for the item. The elements in the evaluation matrix represent the user's access times or evaluation values for the corresponding point of interest [7].

In the real society, time factor plays a very important role in people's daily life. In lbsn, the time characteristics of user behavior are included in the time records of user access points of interest. Therefore, the time characteristics of user behavior can be found by analyzing user check-in records and using them to recommend points of interest to users [8]. For example, if many people go to the bar at midnight and only a small number of people go to the library at this time, the weight of the bar is greater than that of the library when recommending points of interest to users. In lbsn, in order to further analyze the importance of temporal features in user interest point recommendation, a temporal feature-oriented interest point recommendation algorithm is proposed.

2. Related Work

According to the author's search, there is no monograph on online ideological [9]. For example, the approach and methods adopted are different from the explicit approach in China, which is the implicit education approach. The authors of [10] discuss the recent status of various aspects of educational research and development in the United States, with specific science as the main line, make a more in-depth review of the frontier hotspots, and present in detail the research development of educational theory in the United States as well as the challenges and development trends and main measures faced by ideological and political education in the United States in recent years.

For the research related to the network and ideological and political education, the authors of [11] regard the network as a cyberspace corresponding to the physical space, a completely simulated environment, and a virtual real world, and the main research involves the influence of the network on people's ideology, way of thinking, value orientation, psychological and behavioral styles, and social market. The authors of [12] argue that colleges and universities, because of the existence of the network, thus making ideological education with high cultural and technological content, can implicitly include the essence of ideological education content in various cultural knowledge and technological information knowledge, so that students can be inculcated and infected in a subtle way.

The authors of [13] have conducted a more systematic research work on the online Internet, and people began to study network culture and its influence on ideological and political education from various different perspectives, such as communication, education, political science, and sociology. The authors of [14] focus on the relationship between network culture and college students from the perspective of communication science, and the theoretical research results are quite rich. The authors of [15] systematically expound the opportunities and challenges brought by the network culture to emphasize the necessity of combining "rule by law" and "rule by morality" [16, 17].

Regarding the research on countermeasures to strengthen ideological and political education in the network environment, scholars have proposed response strategies from different perspectives to provide theoretical guidance. The authors of [18, 19] believe that under the influence of

new media such as the Internet, the traditional indoctrination mode of ideological and political education has obviously failed to keep up with the development of the times, and it is necessary to innovate educational concepts, focus on ideological guidance, and build an interactive platform. In his doctoral dissertation, the authors of [20] proposed five methods in the context of globalization, such as combining indoctrination with two-way communication, explicit education with implicit education, differentiating levels and teaching according to the material, optimizing information and practicality, and spiritual communication and mutual feeling of ideas.

3. Opportunities in the Network Environment

3.1. Breakthrough of Ideological and Political Education in Time and Space. Traditional ideological and political education is often restricted by time, place, venue, and language and is a kind of "face-to-face" education. In contrast, online ideological and political education has broken the limitations of time and space, and students no longer have to be restricted by time and place to receive education. No matter teachers as educators or college students as educated people, as long as they have a connected network and a computer, they can go online 24/7 to publish and get all kinds of information; no matter where they are, they can learn about the political, economic, and cultural situations happening at home and abroad through the network; college students from different countries, different regions, and different universities can share resources through the network, and students from different countries, regions, and universities can share resources, consult on problems, and exchange study experience.

3.2. Enrichment of Ideological and Political Education Contents. The traditional ideological and political education contents are chosen by educators according to the established cultivation goals and programs, some of which are monotonous and old-fashioned; influenced by the limitation of the traditional media of accommodating little information and the insufficient knowledge reserve of ideological and political education workers themselves, the amount of information received by college students is relatively small and cannot meet the needs of college students' growth and success.

3.3. Strengthening the Relevance. Because the network is virtual, equal, and anonymous, many college students can leave behind the constraints and worries of reality in the network world, open their hearts, and reveal their real inner world, and ideological and political education workers can understand students' ideological dynamics and interests more realistically and accurately through students' QQ space, microblog space, and WeChat messages, so as to carry out targeted individual ideological education or formulate targeted education policies. At the same time, through the network, it also shortens the psychological distance between teachers and students, and the things that college students

cannot say in person can be boldly revealed to teachers online; teachers can also put down the “teacher” frame, and discuss with students in a more close to life, witty, and humorous language, and become friends with students, so the interaction greatly improves the effectiveness of education. This interaction greatly improves the effectiveness of education.

4. Recommendation Algorithms Combining Spatio-Temporal Features

4.1. User-Based Collaborative Filtering Method. In predicting the probability of a user’s visit to a certain point of interest, the user-based collaborative filtering method first calculates the similarity between the user and other users based on the sequence of the user’s point of interest visits, then selects a number of most similar users, and weights the sum of the visit record values of these similar users to the specified point of interest.

Let U be the set of users, L be the set of interest points, and the user’s access matrix to interest points be c , where user $c_{u,l} = 1$ means that user $u \in U$ has accessed interest point $l \in L$ and $c_{u,l} = 0$ means that u has not accessed interest point l . Given user u , if the user has not accessed interest point l , then the probability that u will access l in the future is

$$\hat{c}_{u,l} = \frac{\sum_v w_{u,v} c_{v,l}}{\sum_v w_{u,v}}. \quad (1)$$

In equation (1), the similarity weight between users can be derived by various methods, and in this paper, we apply cosine similarity to calculate the similarity of the check-in records between two users. For users v and u , the formula for calculating the cosine similarity is

$$w_{u,v} = \frac{\sum_l c_{u,l} c_{v,l}}{\sqrt{\sum_l c_{u,l}^2} \sqrt{\sum_l c_{v,l}^2}}. \quad (2)$$

4.2. Introducing Temporal Features. In this paper, time is divided into equal time segments, and each time segment is one hour. Therefore, the user’s behavior can be represented as the user’s visit to a specific interest point in a specific time slice, that is, the check-in information. In order to represent the temporal characteristics of the user’s check-in behavior, this paper introduces a temporal dimension to the traditional user-a-point-of-interest check-in matrix, that is, a three-dimensional cube composed of user \sim time \sim point-of-interest. In this three-dimensional cube, each element $c_{u,t,l}$ represents the behavior of user u about interest point l at time segment t . $c_{u,t,l} = 1$ means that u has visited l at t , and $c_{u,t,l} = 0$ means that u has not visited l at t .

To consider the role of temporal features in interest point recommendation, the collaborative filtering method of equation (1) is modified as follows: (a) includes temporal features in calculating the similarity between users; (b) applies the user’s check-in records on a time slice instead of all check-ins on the timeline in the recommendation process. Given a user u and a time segment t and an interest

point l that has not been visited, the probability that the user visits the interest point l is as follows:

$$\hat{c}_{u,t,l} = \frac{\sum_v w_{u,t}^{(t)} c_{v,t,l}}{\sum_v w_{u,t}^{(t)}}, \quad (3)$$

where $w_{u,t}^{(t)}$ is the temporal similarity of users u, v at time segment t . After considering the temporal characteristics, the cosine similarity shown in equation (2) is expressed as

$$w_{u,t}^{(t)} = \frac{\sum_{t=1}^T \sum_{l=1}^L c_{u,t,l} \times c_{v,t,l}}{\sqrt{\sum_{t=1}^T \sum_{l=1}^L c_{u,t,l}^2} \sqrt{\sum_{t=1}^T \sum_{l=1}^L c_{v,t,l}^2}}. \quad (4)$$

4.3. Introducing Spatial Features. The literature [2] shows that the geographical location of interest points largely influences users’ check-in behavior. Based on the analysis of the relationship between users’ check-in behavior and distance, this paper concludes that users prefer to visit those interest points near the interest points they have visited before, and this tendency decreases with the increase of the distance of candidate interest points.

In order to introduce spatial features in interest point recommendation, this paper uses power rate distribution to represent the relationship between users’ tendency to visit interest points and the distance between interest points and known interest points. Let dis be the distance of the interest point to be estimated, and a and k be the parameters of the power rate distribution, respectively, and then, the propensity of the user to visit the interest point can be calculated by the following equation:

$$wi(dis) = a \cdot dis^k. \quad (5)$$

In this paper, we apply the great likelihood estimation method to estimate the parameters a and k in equation (5). Taking logarithms of both sides of equation (5) yields the following equation:

$$\ln wi(dis) = \ln a + k \ln dis. \quad (6)$$

Let the user’s current interest point be l_i and the distance between the candidate interest point l_i, l_j and l_j be $dis(l_i, l_j)$, then the conditional probability $p(l_j | l_i)$ that the user visits l_j in the next time segment is the proportion of the user’s propensity to visit interest point l_j to all interest points, which is defined as shown in the following equation:

$$p(l_j | l_i) = \frac{wi(dis(l_i, l_j))}{\sum_{l_k \in L, l_k \neq l_i} wi(dis(l_i, l_k))}. \quad (7)$$

Equation (5) shows that as the distance of the point of interest increases, the user’s propensity to visit the point of interest decreases; as the user’s propensity to visit the point of interest decreases, the conditional probability of the user visiting the point of interest shown in equation (7) also decreases. Thus, it can be assumed that the probability of a user visiting a distant interest point is small. Given a user u and its historical check-in records L_u , the conditional

TABLE 1: Descriptive analysis of political socialization status of college students.

Topic category	Average	Range of possible scores	Average score by percentage*
Political knowledge	3.77	0~5	75.5
Current affairs	1.62	0~2	81.5
Institutions	2.14	0~3	71.68
Political value tendencies	40.32	12~60	67.25
National identity	11.16	3~15	74.35
Institutional identity	5.57	2~10	55.62
Policy identity	10.68	3~15	71.15
Political rationality	2.85	1~5	56.55
Western values	6.59	1~10	65.62
Democracy and the rule of law	3.51	1~5	71.25
Political participation tendency	29.10	9~45	64.76
Political effectiveness	10.22	3~15	68.12
Participatory attitudes	7.08	2~10	70.72
Citizenship	5.42	2~10	54.5
Expression channels	6.45	2~10	64.45

*The following data are calculated by the formula (mean/score out of 100) \times 100.

probability of that user visiting l in the next time segment can be obtained based on Bayes' rule as $P(l|L_u)$.

$$\hat{c}_{u,l}^{(s)} = P(l|L_u) \propto P(l)P(L_u|l) =, \quad (8)$$

$$P(l) \prod_{l' \in L_u} P(l'|l).$$

5. Empirical Study

5.1. Experimental Setup. The experiments compare the algorithm proposed in this paper with other related algorithms. The interest point recommendation algorithm for temporal features proposed in this paper is denoted as UTE + SE and user-based collaborative filtering algorithm considering spatial features (U + SB).

5.2. Experimental Results. We can see the scores of the subjects in the three dimensions of political socialization in Table 1. By converting the average score percentage, we can better understand and compare them. We can see that the average score of the students' political knowledge is 75.5, and the average correct answer to the political and current affairs questions is 81.5%; the average correct rate of answering questions about political system knowledge was 71.68%. This is closely related to China's good and systematic education level.

In general, the frequency of Internet access determines the extent to which they are affected by Internet communications. The higher the frequency of Internet use, the greater the impact of network communication on them, and the more obvious the political socialization function of network media. According to the actual situation, college students are divided into three classes according to the frequency of surfing the Internet: low-frequency Internet users who surf the Internet less than or equal to 1 day a day, medium-frequency Internet users who surf the Internet 2–3 days a week, and high-frequency Internet users who surf the Internet more than 4 days a week. The percentage of college students with different surfing frequencies is shown in Figure 1.

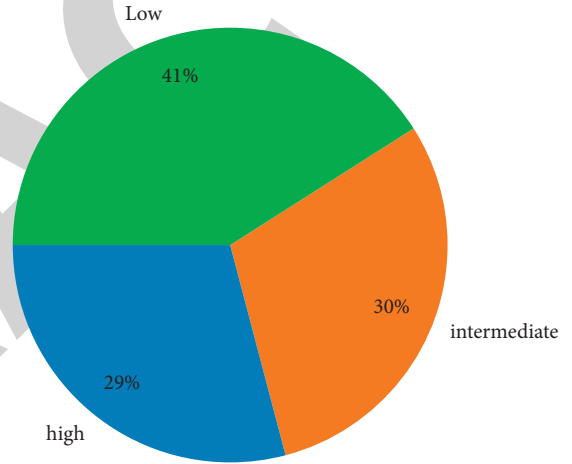


FIGURE 1: The proportion of college students with different Internet access frequencies.

According to statistics, among the 550 valid questionnaires collected, 20 (3.64% of the total) used low-frequency Internet, 91 (16.55% of the total) used medium frequency Internet, and 439 (79.81% of the total) used high-frequency Internet. It can be seen that the number of high-frequency Internet users accounts for the vast majority of college students, which indicates that this group has a high Internet utilization rate.

In this survey, we studied the political socialization of college students in the network environment. Information exchange, communication, entertainment, and frequent Internet access are not necessarily for browsing political information. Therefore, it is not comprehensive to only consider the Internet access frequency in the analysis. In the questionnaire, two questions were added: "how often do you browse the political information on the Internet." Only 17.7% of college students chose "never," "4–5 days a week," and "every day." The number of people who choose "4–5 days a week" and "every day" is as high as 34.55%; the results of the question "how many times do you participate in online political discussions" show that more than 60% of the

TABLE 2: Descriptive analysis of college students' political socialization status.

Topic category	High frequency M_1	Low frequency M_2	Medium frequency M_3	Range of possible scores
Political knowledge	3.98	3.52	3.78	0~5
Current affairs	1.85	1.65	1.62	0~2
Institutions	2.18	1.88	1.99	0~3
Political value tendencies	39.32	40.03	40.31	12~60
National identity	11.38	9.45	8.46	3~15
Institutional identity	5.49	6.43	6.35	2~10
Policy identity	9.38	9.97	9.90	3~15
Political rationality	1.19	0.48	3.88	1~5
Western values	6.47	6.58	7.69	1~10
Democracy and the rule of law	3.45	4.02	4.13	1~5
Political participation tendency	27.85	29.11	29.19	9~45
Political effectiveness	9.91	10.02	10.01	3~15
Participatory attitudes	6.65	7.11	6.89	2~10
Citizenship	5.10	5.52	5.63	2~10
Expression channels	6.20	6.48	6.31	2~10

people have never participated in online political discussions, and 7.27% of the people have participated in online political discussions. 7.27% of college students have participated in it for 3–4 times, which indicates that college students often study political information online, but the proportion of real political participation is low, indicating that the high frequency of Internet access and the socialized function of the Internet have a certain impact on them.

In the specific measurement of the impact of the Internet on various dimensions, the frequency of Internet access was used as a single factor, and the frequency of Internet access frequency as a single factor and the frequency of Internet access as the independent variable, the differences in political knowledge, political value tendency, and political participation tendency of Internet users with different frequency of Internet access were measured. The results are shown in Table 2.

- (1) The relationship between the frequency of Internet access and the level of political knowledge is shown in Figure 2.

College students learn rich political knowledge and accelerate the process of their own political socialization through the political information obtained and disseminated through the Internet. The above figure shows that people with different frequencies of Internet users have different effects on political knowledge ($M_1 > M_3 > M_2$), and in terms of the total mean score of political knowledge, those with higher frequencies are 0.48 points higher than those with lower frequencies.

The mean scores of the two subcategories of basic political institutional knowledge and current affairs are higher for those with high frequency of Internet access than those with low frequency of Internet access, 0.2 and 0.28 points higher, respectively. From the findings, we can see that the use of the Internet has improved the level of political knowledge of the subjects, but the difference is not significant.

The above situation occurs for the following reasons, in my opinion.

First, the Internet, because of its own characteristics, can quickly and conveniently provide rich political information

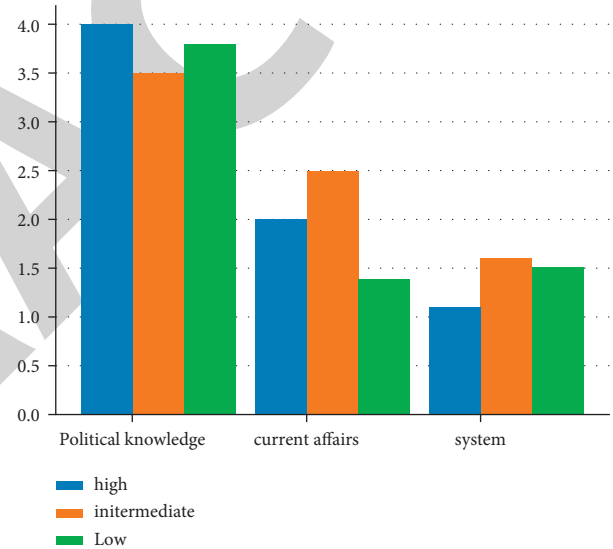


FIGURE 2: Comparison of mean scores of political knowledge among people with different frequencies of Internet access.

and a wide range of political culture, and those who go online frequently have the opportunity to get more updated political knowledge.

Second, due to the systematic ideological and political education system in China, college students have received a good education from childhood to adulthood. In addition, they have acquired certain political knowledge through communication with peer groups and reading traditional media; therefore, there is not much difference in the scores of political knowledge among different groups with different Internet access frequency in the Internet environment.

- (2) The relationship between the frequency of Internet access and political value tendency is shown in Figure 3.

From the above figure, it can be seen that there is a significant difference in the political value tendency of

different Internet access frequency groups, and the score of high-frequency Internet users is only 38.3, which is lower than the scores of low and medium frequency Internet users, so it can be seen that the political values of high-frequency Internet users are more deviated from the mainstream direction of society. The scores of high-frequency Internet users are significantly lower than those of other Internet users in all five categories except for the subcategory of national identity. The use of the Internet tends to have a negative impact on the political values of high-frequency Internet users.

I believe that the above situation occurs for the following reasons.

First, the network information is mixed, and the network itself is confidential, open, and autonomous. Compared with the positive publicity of traditional media, netizens can evaluate the current government in various forms. If college students are exposed to this negative information for a long time and lack mature political judgment, it will inevitably lead to a reduction in their recognition of the government.

Second, people with high Internet frequency are dependent on the use of the Internet and over-dependent on the Internet environment, their political thinking ability is weakened, they lack rational judgment on political events and are prone to impulse, and their political rationality scores are low, which shows this problem.

Third, the sovereignty of Internet information is in the hands of western countries. Long-term access to Internet information is easy to be confused by some superficial things, resulting in ideological confusion. While Western values and concepts are widely spread, college students with high frequency of Internet access are easily affected by these values and concepts.

Fourth, a healthy network culture is conducive to the improvement of college students' ideological and political levels. Groups with different Internet access frequencies do not have the same problems as those studied by previous scholars: "in the Internet environment, diversified political culture and virtual political activities often lead to the expansion of individual liberalism and the weakening of national consciousness in the process of political socialization of young people," while groups with high Internet access frequency score higher in the national identity subitem than those with low or medium Internet access frequency. It can be seen that the network environment does not affect the patriotic enthusiasm of college students, but it is easy to stimulate a stronger sense of patriotism and national consciousness.

- (3) The relationship between the frequency of Internet access and the tendency of political participation is shown in Figure 4.

The Internet not only provides an exchange platform for college students' political participation but also brings diversified online information to college students. Whether the high frequency of surfing the Internet will affect the political participation tendency of college students? From the survey results, it can be seen that the total

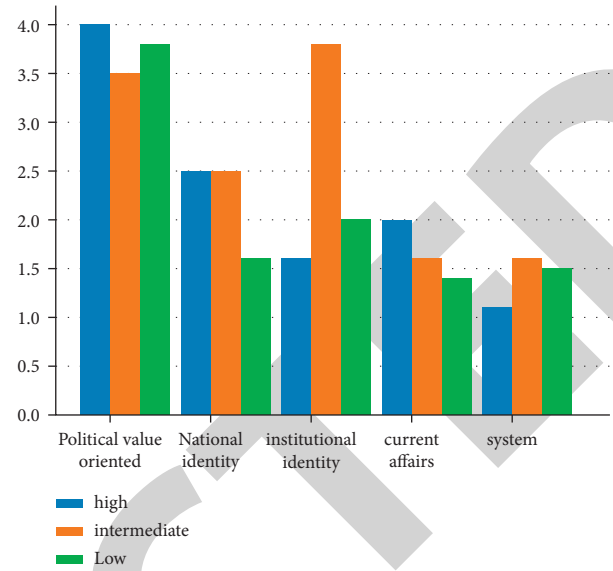


FIGURE 3: Comparison of the mean scores of political value tendency among people with different Internet access frequencies.

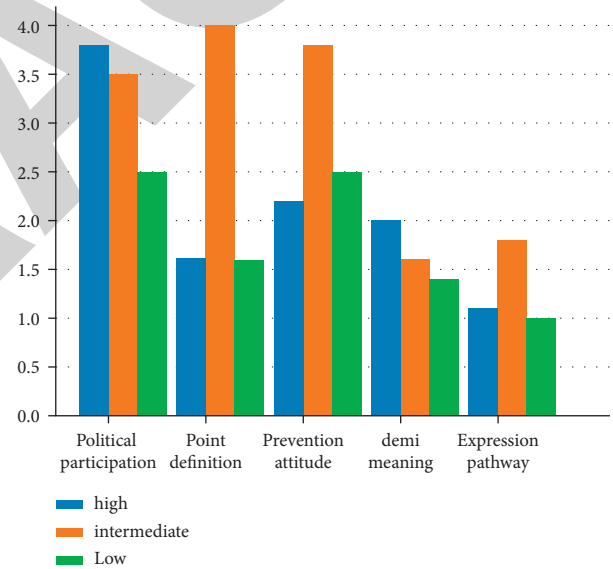


FIGURE 4: Comparison of the mean scores of political participation tendency among people with different frequencies of Internet access.

score of political participation tendency of college students with a high frequency of surfing the Internet is lower than that of other college students with a high frequency of surfing the Internet. In the subcategories of political participation tendency, such as political efficacy, participation attitude, civic awareness, and expression, the score is slightly lower than that of the low and middle Internet users. It can be seen that the use of the Internet has a negative impact on those who surf the Internet more frequently, while those who surf the Internet more frequently have a less positive attitude towards political participation, poor political efficiency, and poor understanding of civil rights and biased expression.

Research Article

Bank Credit Structure Model Based on Big Data Financial Technology Innovation

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The credit business is the primary source of income for commercial banks, and the quality of credit business directly affects the operating efficiency and sustainable development of commercial banks. Constructing an evaluation model that can accurately measure the credit quality of commercial banks and then systematically analyze the distribution and evolution of credit quality is of great significance for judging the operating situation and pattern of credit assets of commercial banks in our country. This paper analyzes the credit asset quality of our country's commercial banks from five aspects: credit asset scale, profitability, risk security, liquidity, and expansion capability, and uses computer extensive data analysis and structural equation model to analyze the 20 representative banks in our country. An empirical analysis is conducted in a commercial bank.

1. Introduction

The interest rate difference between deposits and loans is one of the primary profit sources of commercial banks in our country [1, 2]. Once there is a problem with credit assets, it will significantly impact the entire economic system. Therefore, it is necessary to continuously adjust and optimize the establishment of an evaluation index system for the quality of credit assets of commercial banks in our country and to evaluate and analyze the operating conditions of credit assets. As an intangible product of a country's economic development, science and technology finance is inseparable from improving the level of science and technology. As a systematic, innovative, and holistic institutional arrangement for scientific and technological innovation activities and financial resource allocation, science and technology finance is vital to promoting our country's economic restructuring and industrial transformation. Our country's science and technology finance has developed rapidly in recent years. The government has issued a series of policy support, theoretical research has been deepened, and practical innovation has continued to innovate [1–5].

2. Definition of the Concept of Financial Technology

First, fintech is a combination of “finance” and “technology.” Since financial technology is currently in a stage of continuous development and a unified standard has not yet been formed in academia, the definition of financial technology is also completely open. According to the official definition of the Global Financial Stability Board, fintech refers to a series of innovations in the financial field; these innovative products can meet the new needs of customers or provide convenient services for the financial industry. This will drive the growth of financial institutions and affect the way financial institutions and markets serve consumers. Fintech is the product of combining a series of powerful technologies and financial demand scenarios. Its development not only involves many fundamental technologies, such as big data, mobile Internet, biometrics, and so on, but also involves digital twins, edge computing, human brain, and cutting-edge technologies such as machine combinations. In addition, a new generation of distributed technologies, such as directed acyclic graph, etc., will be included. From the definition of the above authoritative unit, it is easy to see that fintech is an innovation in the financial field which will bring

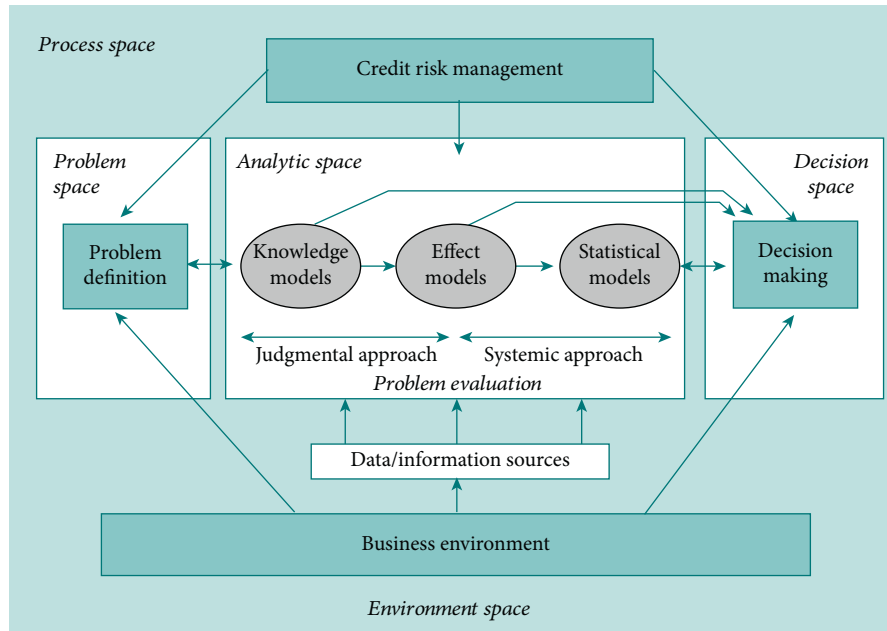


FIGURE 1: Classification and influencing factors of bank credit structure.

fundamental changes to financial institutions and even the entire financial industry.

3. Classification of Bank Credit Structure and Analysis of Influencing Factors

3.1. Analysis of the Connotation of Credit Structure. Credit is a credit activity for commercial banks and other financial institutions to issue monetary funds to the outside world. It is premised on specific borrowing rates and repayment conditions. Banks lend monetary funds in the financial market to the outside world in the form of loans. On the one hand, they can ensure the monetary funds needed for colonial expansion and reproduction, thereby promoting the healthy development of the national economy; at the same time, banks can also earn a certain amount of money from them, thereby ensuring the accumulation of its capital. As the pillar business of commercial banks, the credit business is an essential means for banks to make profits and an essential basis for adjusting the internal structure of banks. According to the nature of the loan, bank credit can be divided into a mortgage loan, secured loan, and credit loan. Among them, mortgage loans refer to the commercial bank's right to control part of the enterprise's property to a certain extent, and the secured loan is the right of the bank to recourse to the guarantor of the loan. A credit loan is a form in which a company obtains a loan based on its credit status (see Figure 1).

3.2. Classification of Credit Structure. From the perspective of bank operation development and social performance, the credit structure can be divided into multiple levels. Credit structure is generally divided into customer structure (personal loan and corporate loan), credit structure (credit

loan and secured loan), and term structure (short-term loan and medium and long-term loans).

3.3. Research on Factors Affecting Credit Structure.

Through the analysis of the credit structure, the characteristics of the bank's loan business can be grasped, such as the main investment direction of the loan, the positioning of the customer group, and the regional distribution of the loan market [6, 7]. The credit structure of different banks varies due to the influence of internal and external factors.

- (1) The credit structure of banks is greatly affected by the local economic structure. The regional economic structure determines the credit structure of commercial banks. However, the loan business of commercial banks is not limited to the location of banking institutions, but also can cooperate with foreign banks to jointly issue loans to foreign enterprises with good reputation through joint loans or purchase loans from foreign commercial banks [6–11]. Therefore, the geographical distribution of banking institutions does not limit the regional distribution of bank loans..
- (2) Loan interest rate structure: the loan yield structure refers to different loan yields, and banks are always willing to issue high-yield loans. With the help of the bank accounting costing software system, the bank can quickly calculate the rate of return of different types of loans to determine the critical loan types of the bank.
- (3) Loan scale: the scale of bank loan funds is different, the loan strength is different, and the bank credit structure is also different. Commercial banks with larger loan scales mainly extend credit to large and

mature enterprises, while the credit structure of SMEs is mainly personal loans and SME loans.

- (4) Personnel composition: the credit structure of commercial banks is affected by the experience and quality of the credit personnel. Commercial banks must be equipped with credit management personnel in line with the local economic structure to meet the needs of business development.

4. Determination of Evaluation Indicators of Bank Credit Structure Model

4.1. Author's Definition of Credit Quality. The quality of commercial bank credit assets is a relatively comprehensive concept that includes dynamic elements. It needs to consider the performance of the traditional "three characteristics" during the evaluation period and take into account the ability and trend of credit asset operation in the future period. Therefore, the quality of credit assets should be reflected in the profitability of credit assets and take into account the control of risk levels, the structural allocation of terms and objects, asset liquidity, and the ability to expand and develop. This paper will define and evaluate the quality of commercial banks' credit assets from the aspects of credit asset scale, profitability, risk security, asset liquidity, and expansion capability and establish a more comprehensive credit quality evaluation system.

4.2. Credit Quality Evaluation Indicators. Based on the understanding of the quality of commercial banks' credit assets, 21 indicators were selected, including scale, profitability, risk safety, asset liquidity, and expansion capacity. A comprehensive and scientific evaluation index system was established.

4.2.1. Scale Level. This paper selects two indicators of commercial banks' scale of credit assets: the total amount of loans Q1 and the proportion of credit assets Q2 [12–19]. It is generally believed that a particular scale of credit is a necessary basis for quality. Taking the profitability of a commercial bank's credit assets as an indicator, select loan profit rate Q3, asset profit rate Q4, net interest margin Q5, net interest margin Q6, interest income ratio Q7, and cost-to-income ratio Q8. There is a significant positive correlation between Q3~Q7 and the credit quality of commercial banks; Q8 reflects the cost of bank unit income and expenditure, and Q8 is negatively correlated with the credit quality of commercial banks.

4.2.2. Security Risks. From the perspective of credit asset risk level and risk control capability, seven indicators are selected, namely, non-performing loan ratio Q9, overdue loan ratio Q10, reserve coverage ratio Q11, loan loss reserve adequacy ratio Q12, loan provisioning ratio Q13, the largest customer loan ratio Q14, and capital adequacy ratio Q15. Q9 and Q10 are negatively correlated with the credit quality of commercial banks; Q11~Q15 have a significant positive

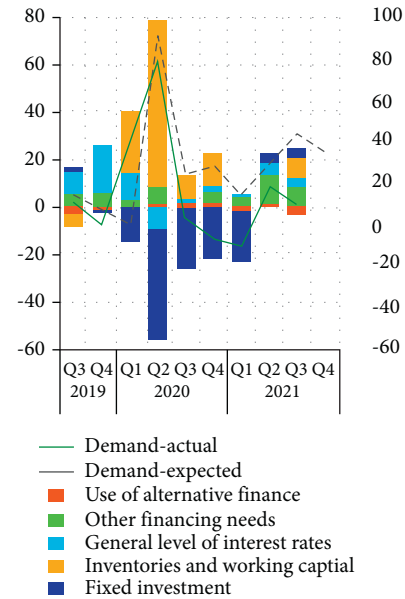


FIGURE 2: Evaluation index of domestic bank credit structure model.

correlation with credit quality. From the perspective of the liquidity level of commercial banks' credit assets, two indicators are selected, namely, the loan-to-deposit ratio Q16 and the liquidity ratio Q17. Commercial bank credit quality is negatively correlated with Q16, and Q17 is positively correlated with commercial bank credit quality (see Figure 2).

4.2.3. Capacity Expansion. Taking the expansion capability of the commercial bank's credit assets as an indicator, select the loan growth rate Q18, the deposit growth rate Q19, the net profit growth rate Q20, and the interest income growth rate Q21. There is a significant positive correlation between Q18~Q21 and the credit quality of commercial banks. The meaning and calculation method of the above indicators are shown in Figure 1.

5. Data Sources and Processing of Bank Credit Structure Models

This paper selects the 2010–2017 data of 20 commercial banks with assets exceeding one trillion in 2017. According to the data of the total assets of financial institutions of 252 trillion yuan in 2019, the assets of these 20 banks account for about 60% of the total assets of the banking industry. Their types include large state-owned, national, joint-stock, and city commercial banks [20–23]. Strong representation is seen in Figure 2. In order to facilitate comparison, the data are firstly processed without dimension.

Then, the original data are uniformly converted into standardized data in the range of [0, 100] by the extreme value method.

Exploratory factor analysis shows that the theoretical index of commercial banks' credit quality evaluation index system is $KMO = 0.702 > 0.6$, and the Bartlett sphericity test

TABLE 1: Analysis of the evaluation indicators of credit quality of commercial banks.

Index	Components			
	1	2	3	4
Deposit growth rate	0.877	−0.135	0.083	−0.064
Loan growth rate	0.832	0.017	−0.049	−0.056
Net profit growth rate	0.729	−0.413	0.222	0.228
Interest income growth rate	0.729	−0.294	0.30	0.317
Loan provision ratio	0.157	0.794	−0.047	0.025
Overdue loan ratio	−0.424	0.644	−0.047	−0.002
Provision coverage ratio	0.497	−0.612	0.209	−0.161
Loan ratio of the top ten customers	−0.493	0.608	−0.334	−0.283
Net interest margin	0.405	−0.537	−0.238	0.277
Return on assets	−0.318	−0.032	0.674	−0.230

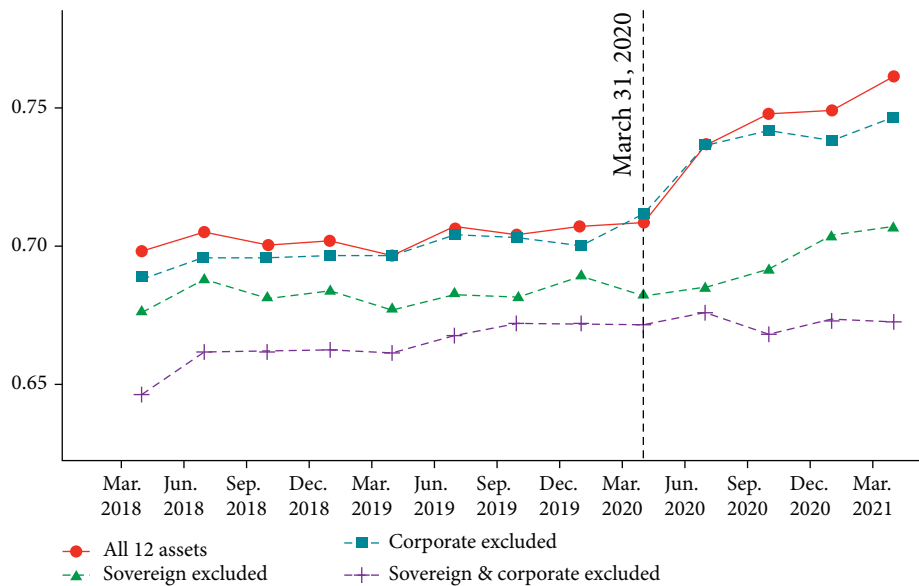


FIGURE 3: Effectiveness index factor analysis of evaluation index system rotation component matrix.

has a significant level of $\text{Sig.} = 0.00 < 0.05$. The principal component analysis method was used to reduce the data dimension, and three common factors were selected under the condition that the eigenvalue was more significant than 1, and the cumulative variance contribution rate reached 73.069% (see Table 1).

The first common factor includes deposit growth rate, loan growth rate, net profit growth rate, and interest income growth rate, which generally reflects the expansion of credit assets. The second public factor, net interest spread and asset return rate, generally reflects the profitability of credit assets. The third common factor includes the liquidity ratio and the loan-to-deposit ratio, which generally reflects the liquidity of credit assets. The analysis results are shown in Figure 3.

The above analysis shows that the credit quality of commercial banks in our country has prominent structural characteristics. Different types of commercial banks have different credit quality performances. At the same time, the changes in the time dimension of the overall commercial bank credit quality deserve attention. Although the accuracy

of the analysis conclusion is affected by research methods, index comprehensiveness, data accuracy, cycle, and other factors, in view of the consistency and corresponding comparability of the above factors to the evaluation objects, it is still necessary to make an in-depth and systematic analysis on the reasons for the differences and dynamic changes of bank credit quality structure, so as to improve the efficiency of financial resource allocation and prevent the breeding of financial risks.

In recent years, due to the large-scale operation of banks and the need to maximize shareholders' wealth, the development of credit asset optimization models has shown a trend of diversification. As can also be seen from the above, the objective function can minimize unexpected losses, optimize capital use, and maximize the Sharpe ratio. To a certain extent, the design of the objective function reflects the different understandings of relevant parties on credit risk, large-scale operation, and target management. The second data source is different, such as default probability, correlation, and so on. Risk exposure El, probability of

default, specific loss given default, El period, and the correlation between different risk exposures are the main contents of credit portfolio credit risk management. There is a common trend in the collection and use of these data, that is, the consistency and continuity of data and the sensitivity to credit risk measurement, which is obvious in the Basel agreement. The credit transfer matrix is different until the asset is transferred to the final state (e.g., loan maturity, refinance, default, and so on). Many rating agencies currently provide credit asset credit quality transition matrices, such as Moody's, Standard & Poor's, KVM, and so on. Although the specific results of various rating agencies on the relevant indicators are not the same, the conclusions are the same [24–30].

6. Conclusions

In short, the bank credit structure model based on big data financial technology innovation has made valuable explorations in optimizing loan portfolios, both in theory and in practice. However, its shortcoming is that it is impossible to give the best or most appropriate credit asset allocation conclusion based on the basic requirements of the Basel Capital Accord and the characteristics of bank risk management. Therefore, the practical basis of the bank credit structure model of big data financial technology innovation needs to be further enriched, but it is also challenging to have a relatively general guiding significance for the specific business operations of commercial banks.

Data Availability

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

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Effect Analysis of Carbon Information on Enterprise Value Based on Big Data

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An effect analysis approach of carbon information on enterprise value based on big data is proposed. This study first systematically expounds on the sources of research data and data collection methods and then comprehensively analyzes corporate carbon information disclosure status and characteristics. It also conducts an empirical study on the short-term impact of carbon information disclosure on corporate value creation and draws the following conclusions. Industry classification has an important impact on corporate carbon information disclosure in terms of the status and characteristics of corporate carbon information disclosure. Except for the financial and insurance industry, the average amount of carbon information disclosure in susceptible sectors such as the extractive industry and construction industry is relatively high. In terms of carbon information disclosure content, the carbon information disclosed by enterprises is mainly related to low-carbon technology and low-carbon product plans. Through empirical analysis of the impact of carbon information disclosure on short-term stock market performance and investor returns, it is found that the trading volume and value of stocks in the 5 trading days after the information event were higher than those in the previous 5 trading days. Still, the increase in the overall stock market value was not significant. This shows that the occurrence of carbon information disclosure events can improve the liquidity and trading activity of the stock market, trigger the stock market's market response to carbon information disclosure, and enable investors to obtain more abnormal returns among short-term investors. It has a certain impact on short-term enterprise value creation.

1. Introduction

As the world enters the era of low-carbon economy, the impact of enterprise carbon emission activities on human survival and development has attracted more and more attention from all walks of life. As a way and tool for enterprises to talk with the outside world about their carbon emission management, carbon information disclosure has been highly valued by enterprise regulators, stakeholders, and the public, and has become an important practical problem [1–9].

Whether carbon information disclosure contributes to enterprise value creation is a highly controversial issue, which needs to be further studied. Especially in China, in the face of huge pressure on emission reduction and the absence of a unified regulation on carbon information disclosure

management, actively encouraging enterprises to practice carbon emission reduction and disclose carbon information will effectively promote the realization of the government's emission reduction target. At the same time, in the domestic research on the impact of carbon information disclosure on enterprise value creation, a few relevant studies have not found that the carbon information disclosure has a significant impact on market performance and enterprise value creation.

Therefore, what impact will carbon information disclosure have on the formation and creation of enterprise value in China? What is the path through which this impact is realized? These important questions have not been well answered. We need to further explore the impact mechanism and path of carbon information disclosure on enterprise value creation in theory and practice, and test the actual

effect of carbon information disclosure on enterprise value creation. We will conduct research on the impact of carbon information disclosure on enterprise value creation.

This study mainly explores the dynamic process and internal mechanism of carbon information disclosure affecting enterprise value creation, verifies the short-term impact, long-term impact, and lagging impact of carbon information disclosure on enterprise value creation through empirical research, and answers the question of whether carbon information disclosure is conducive to enterprise value creation. This study can not only enrich the theoretical and empirical research in the field of carbon information disclosure in China, but also provide a theoretical basis for enterprises to strengthen the management and governance of carbon information disclosure, and provide an important reference for the government to supervise enterprise carbon information disclosure and relevant policy-making.

2. Data Collection

2.1. Data Collection Design Based on Web Crawler. We will take 2012 Chinese A-share listed companies as research samples, use web crawler technology to collect carbon information disclosed by companies through non-annual report channels, reprocess the information, and finally form the research database of this paper. This data collection method is inspired by Lee et al [1]; when they studied the frequency of corporate carbon information disclosure, they used web crawler technology to measure the number of carbon information reported by companies through the media. The specific data collection idea mainly includes the following three steps:

The first step is to determine the data source. The company website, media reports, and carbon information released by the company based on other web forms are selected as data sources. The company website and the media are the two most important channels. This is mainly because: First, under the unique domestic institutional background, the amount of carbon information disclosed by my country's listed companies through annual financial reports is small, and no company has disclosed it through independent reports (except social responsibility reports and environmental reports). Second, scholars such as Isenmann and Lenz [2], Adams and Fros [3] have confirmed in their research on environmental information disclosure that with the development of network technology, more and more enterprises will use the website to publish the information related to business operations. When companies use websites and independent annual reports to disclose information, the relevant information disclosed in the annual reports will be reduced, thereby reducing the value of the annual report as a source of information [4]. Scholars such as Frost [5], Clarkson et al. [6], and Aerts and Cormier [7] also confirmed that the media is another critical channel for corporate information disclosure. The research of Pellegrino and Lodhia [8] further confirmed that corporate websites and media are essential channels for companies to disclose carbon information.

The second step is data collection based on a web crawler. To collect information comprehensively, this paper will use JAVA language to write a web crawler program and use a web crawler to automatically crawl information, respectively, to crawl carbon information disclosed by enterprises through company websites, media, and other web-based forms. The carbon information disclosed by the enterprise in this paper refers to any information related to the enterprise's GHG emission reduction disclosed by the enterprise to its stakeholders, which includes the enterprise's carbon emission, carbon emission reduction plan, and implementation of the carbon emission reduction plan. After clarifying the connotation of corporate carbon information disclosure, based on web crawler technology, "company name + keywords" are used to crawl, and the database of this paper is initially formed. Lee et al. [1] used keywords such as climate change and business, greenhouse gas emissions, low carbon, green development, green management, environmental management, and carbon management when collecting carbon information disclosed that topics related to carbon disclosure and the definition of news coverage. Since the corporate carbon information disclosure in my country has just started, the carbon information disclosed by enterprises is relatively small, and the subject is single. To improve the relevance of the collected data, this paper only selects low-carbon, emission reduction of 2 keywords to capture information, and improve the quality of information collection.

The third step, data preprocessing, mainly includes two aspects of data deduplication and classification. The first is to deduplicate the data. Since the sources of information obtained through web crawlers are multi-channel, there is some duplication of information, and further deduplication processing is required for the received information. This paper adopts data mining technology, sorts the total amount of information each enterprise obtains according to the information title, automatically deletes the duplicated information title, and retains all non-duplicated information. Then, the collected data is processed by text classification, etc., to lay the foundation for the subsequent carbon information disclosure level calculation.

The essence of a web crawler is algorithm-based information crawling program. The information crawling workflow is: firstly, initialize a URL set, build a waiting queue that meets the information crawling requirements, and then the crawler starts from the waiting queue and uses the waiting queue in turn. The URL in the line is used to crawl web pages and page information, and a new URL is obtained. In contrast, the URL in the waiting queue is used to crawl the data so that the original URL queue is updated, and a new waiting line is formed to guide the crawler to continue crawling and repeat this process.

To collect carbon information disclosed by enterprises in a targeted manner, the information crawling is limited by a specific theme, so in the process of crawler program design, a theme-oriented crawler program [2, 5, 6], that is, a theme web crawler, should be designed. The main difference between the theme crawlers and general crawlers is that available crawlers follow the principle of random crawling

when crawling web pages, while theme crawlers are limited by themes when crawling web pages. Therefore, the direction of the theme crawler is based on the simple crawler, crawling more targeted content, crawling more accurate information in a particular field, for example, using a web crawler to crawl agricultural and financial information, etc. [9–11]. In a specific program operation, the topic web crawler will receive program instructions related to the topic before crawling the data. According to this instruction, the irrelevant web pages will be excluded to retain the web pages closely related to the subject, that is, form a waiting queue for URLs related to the case, and then the crawler starts to crawl information from this waiting queue, and repeats the above process until it stops when the preset conditions are met [12–14].

To collect the information disclosed by enterprises on the specific topic of low carbon and emission reduction, it is necessary to add requirements to the general web crawler design program so that the web crawler can only crawl the subject-related information during work—information search strategy, rather than a system of crawling a web page when it encounters it. In the program design process, a calculation module for the relevance of each URL and page theme is added. This module judges whether the read information relates to the theme. Crawl and record information if relevant; discard and re-crawl if irrelevant. In this way, crawlers can only process web pages about low-carbon fields, significantly reducing the search scale and improving the search efficiency.

The theme crawler indicates the direction of crawler information collection through the two keywords of “low carbon/emission reduction” during information crawling. When designing the crawler program, the researchers collected the company websites of A-share listed companies and made a “seed set” of the theme crawler. In this paper, we check all the information disclosed by A-share listed companies in the Huike news database and build a “seed set” of the theme crawler with a single enterprise as a unit. After the two “seed sets” are aggregated, the theme crawler program “seed set” is formed, and the theme crawler will start from this “seed set” to crawl carbon information.

2.2. Implementation of Web Crawler Data Collection.

Based on the subject crawler, the general steps for collecting carbon information disclosed by each enterprise are information collection and preprocessing. Information collection is to download the web page information captured by the web crawler to the local; information preprocessing deals with the noise and other problems in the collected information to prepare for the subsequent data analysis. In this paper, through the operation of the theme crawler, the web pages and text information extracted by the crawler are stored in the database for subsequent research. In the actual crawled data, we can see the amount of carbon information disclosed by each enterprise, the time of disclosure, and the number of words in each disclosed information. At the same time, this program also deduplicates the captured data, records the same information only once, and displays the number of times the information is repeated.

The information collected in the above way will be automatically stored in txt format with the name of the stock symbol. The content of the file storage includes the title of each piece of carbon information disclosed by the enterprise, the time of disclosure, and the specific content of the disclosure. When opening each text, the text first records the total number of information collected this time. It displays the link of each piece of data, the specific text content captured, the number of text and the source of the text, and other information. In addition, data preprocessing mainly uses text mining technology (Text Mining) to separate the collected text data. Since the web crawler collects data by putting the collected information into a text with a single enterprise as a unit, it is necessary to use text separation technology to separate the carbon information disclosed by a single enterprise as a unit to separate the texts to prepare for the later carbon information classification and calculation. The separation of text data is essentially a process of knowledge discovery. First, all the data received from the data are deduplicated and preprocessed, and then the Chinese text data is formed, followed by knowledge mining.

3. Research Hypothesis

The information asymmetry theory believes that information asymmetry exists in the capital market. In terms of corporate carbon information disclosure, there are mainly two scenarios for information asymmetry between companies and investors: First, the information about corporate carbon emissions and carbon trading is unevenly distributed between companies and investors, and companies possess more information than investors possess. This directly leads to an increase in the investors’ demand for information, making investors obtain information through various channels. Different information acquisition methods have different costs. The cost of receiving information from the enterprise is low for investors. The price of searching for information from other channels is high for investors, making it difficult to get information. The ease of access to information varies. In this context, information disclosure effectively alleviates the degree of information asymmetry between the two parties. Based on the theory of information asymmetry, corporate carbon information disclosure will help solve the problem of information asymmetry between companies and stakeholders.

At the same time, efficient market theory believes that the market and information are inseparable, the stock price integrates the expectations and information of all market participants, and the stock price is unpredictable. The market price is the reasonable expected value of the intrinsic value of the stock [15]. Investors’ investment behavior is a systematic information processing process, which is affected by many factors (such as information factors and environmental factors) in the investment decision-making process of measuring risks and returns. The information factor is necessary for investors to make decisions. Investors will pay attention to different stocks because of the difference in the amount of information on other stocks, which will eventually lead to changes in investor behavior, leading to

changes in stock market performance, and induce changes in stock market performance and volatility in investor returns.

The disclosure of carbon information by companies is conducive to eliminating investors' hesitation and worry when purchasing stocks due to insufficient information, promoting traders to conduct transactions quickly, and shortening the transaction time so that the stock price, transaction volume, and transaction amount fluctuate on the day when the information event occurs and during the event window. At the same time, when traders have sufficient information in the market and the transaction cost is relatively small, traders can conduct free transactions. The trading market activity can be effectively improved, thereby promoting many transactions and transactions quotas, increasing stock liquidity and investor interest in investing [16]. In addition, in an active market with a short trading time and large trading volume, even if there are many transactions, the security price can still reproduce the equilibrium price in a short period, making the trading market elastic.

Some empirical studies have also confirmed the impact of carbon disclosure on short-term stock market performance and investor returns. For example, Antoine [17] used European listed companies in the Dow Jones Index as a research sample and used regression analysis to test the relationship between the climate change crisis and stock market prices; it was found that there is a certain correlation between climate change exposure and stock returns. Griffin et al. [18] systematically analyzed whether the stock market would respond to climate change-related news reports using the S&P500 and TSE200 companies that participated in the CDP project from 2006 to 2009. The stock price and market trading volume will fluctuate significantly on the day or the next day when the relevant emission reduction information is disclosed, which means that investors' value judgment will be affected by the company's GHG emission information. Company stock market performance can also fluctuate based on carbon disclosures. Elias [19] further found in the survey and interview of investment companies, individual investors, and fund managers in South Asia that fund managers are very concerned about the carbon information disclosed by enterprises and other non-financial information and believe that such information will affect the short-term performance of a company's stock price. Haigh and Shapiro [20] surveyed 30 financial institutions in the United States, Europe, and Australia in 2010. They found that carbon emission reports will affect investors' evaluation and investment decisions on corporate investment projects, affecting investors' stock purchase behavior.

This paper believes that carbon information disclosure will affect investors' decision-making, leading to changes in stock market performance, which affects investors' short-term returns, and ultimately affects corporate value creation. Based on the above discussion, this paper proposes the following assumptions:

Hypothesis 1. Carbon information disclosure will have a short-term impact on corporate value creation.

The short-term impact of carbon information disclosure on corporate value creation is mainly manifested in the

difference in investors' attention and understanding of different stocks due to the carbon information disclosed by enterprises, thereby affecting investors' investment decisions and stock purchase preferences. Differences in buying preferences and changes in stock behavior will cause fluctuations in the performance of the entire stock market and ultimately affect investors' profits. Based on this, this paper proposes the following two sub-hypotheses:

Hypothesis a: The stock market performance will fluctuate before and after the carbon information disclosure event.

Hypothesis b: Investor returns will fluctuate before and after the carbon information disclosure event.

4. Research Design

We use the entire fiscal year from January 1, 2012, to December 31, 2012, as the time of information collection in the interval, the carbon information disclosed by enterprises based on non-annual report channels is collected through web crawler technology as the data source, and other financial data are from the Guotaiminan Economic and Financial Research Database. The software used in the data processing is SPSS17.0.

4.1. Determination of Information Events. When examining the short-term impact of carbon information disclosure on corporate value creation and verifying the "disclosure effect" of carbon information, the primary research method used in the existing empirical research is the event study method. The event research method is a standard practical analysis method in finance. It is a research method that reflects the stock market's response to information by observing the cumulative abnormal returns and fluctuations of abnormal returns during the event window period [21].

Event research begins with the definition of an information event, i.e., the determination of the information event's estimated window, event window, and information event occurrence date. Information event day generally takes the day when the event occurs as the event day. Therefore, the information event must be determined first before selecting the event day. Foreign researchers mainly use specific corporate environmental events to determine events such as corporate environmental accidents, corporate environmental penalties, and environmental report disclosure events.

It can be seen that the existing research mainly focuses on the specific environmental accidents of individual enterprises as information events because typical environmental accidents have a significant impact on the stock market performance of enterprises, and the effect on the creation of enterprise value is more important. Since this paper examines the short-term impact of carbon information disclosure on corporate value creation, it focuses on the differences in stock market performance before and after the corporate carbon disclosure event. As far as corporate carbon information disclosure is concerned, the carbon information disclosed by enterprises is mainly positive information, and there is less disclosure of negative information and major corporate

carbon emissions pollution accidents. For this reason, this paper draws on the research method in Reference [22]. It does not use specific events as the basis for judgment when determining information events. Still, it determines the information events by examining the amount of carbon information disclosed by enterprises on the information disclosure day. That is, if the value of the carbon information disclosure amount of stock i on a certain day deviates from the mean by 2 times the standard deviation, it is considered that the carbon information disclosure amount of stock i is higher than its average level, and an information disclosure event occurs. That is:

For the carbon information disclosure amount CIQ_{it} related to stock i , if there is a situation like a formula (1), it is considered that an information event has occurred.

$$CIQ_{it} \geq \mu + 2\sigma. \quad (1)$$

In financial research, researchers mainly conduct research by observing market changes caused by information events within a certain window period. The selected event window period is five trading days before and after the occurrence of the information event; that is, the window period is $[-5, 5]$. After the initial determination of information events based on the above methods, the events of step screening are processed as follows, and the following observations are eliminated:

- (1) During the event window period, the company disclosed other significant events (such as allotment of shares, dividends, mergers and acquisitions, and other events);
- (2) Disclosure of annual financial report, social responsibility report, and environmental report during the event window;
- (3) During the event window, companies with incomplete individual stock income data or trading suspension;
- (4) Companies that have continuously disclosed information multiple times within an event window. Based on the above principles, 89 information events were finally identified as research events. The content analysis found that the information events were all positive information disclosure, so there was no need to distinguish between positive and negative events in later empirical studies.

4.2. Selection of Measure Indicators for Short-Term Enterprise Value Creation. Based on the research assumptions of this paper, this paper chooses the short-term performance of the stock market and investor returns during the carbon disclosure event window to reflect its short-term impact on corporate value creation. On the short-term performance measure of the stock market, this paper chooses to describe the trading volume, trading volume, stock price fluctuation, and stock market value fluctuation before and after the occurrence of information events.

In terms of the short-term benefits of carbon information disclosure to investors, this paper measures the

abnormal return rate and the cumulative abnormal return rate. Returns can be divided into normal returns and abnormal returns. Normal returns refer to the expected and reasonable returns that investors can obtain under normal circumstances. Abnormal returns are the portion of investment returns that exceed normal returns, i.e., abnormal returns are equal to the actual rate of return minus the expected rate of return. It is necessary to calculate normal return before calculating abnormal return and cumulative abnormal return. Its calculation methods mainly include the following four: the first is the constant income model method, the second is the market adjustment model method, the third is the constant mean model method, and the fourth is the market model method.

This paper uses the market adjustment model method to measure the standard rate of return, measured by the average market rate of return. Since this paper analyzes the short-term impact of corporate carbon information disclosure on corporate value creation, this paper chooses the market monthly average rate of return weighted by the circulating market value as the market rate of return. Based on this, the abnormal return of stock i in period t during the event window is obtained as:

$$AR_{it} = R_{it} - R_{mt}. \quad (2)$$

In formula (2), AR_{it} represents the abnormal return rate of stock i in period t , R_{it} represents the rate of return of stock i in period t considering cash dividend reinvestment, and R_{mt} represents the market rate of return in period t . This paper uses the average monthly market return weighted by the float market capitalization.

By summing and averaging the abnormal returns of individual stocks, the average abnormal returns of all sample stocks in period t are

$$AAR_t = \frac{1}{N} \sum_{i=1}^N AR_{it}. \quad (3)$$

In formula (3), AAR_t represents the average abnormal return of all sample stocks in period t , and N represents the number of sample stocks in period t . Therefore, the average cumulative abnormal return can be recorded as:

$$ACAR(t_1, t_2) = \sum_{t=t_1}^{t_2} AAR_t. \quad (4)$$

In formula (4), $ACAR(t_1, t_2)$ represents the average cumulative abnormal return in the event window period $[t_1, t_2]$.

4.3. Analysis Model of Emotion Cognition Based on Regular Semantic Analysis

4.3.1. Emotion Dictionary in Semantic Analysis Model of User Emotion Cognition. Emotion dictionary can distinguish special information elements separately in emotion dictionary. Therefore, the quality and quantity of constructing effective emotion dictionary will also affect consumers' emotion judgment. Applying more characteristic elements

of consumer news to the establishment of emotion dictionary can effectively improve the accuracy of emotion analysis of consumer news. Figure 1 describes in detail the formulation method of emotional cognition in this paper.

The emotion classification in the text is to complete the emotion analysis according to the characteristic words. Among them, the core is feature extraction, and the quality of features has a great impact on the accuracy of emotion analysis. Therefore, constructing the characteristics of emotional dictionary is an important link in this paper. We will build relevant dictionaries based on the characteristics of diversified information elements and flexible language of consumer messages.

(1) *Basic Emotional Dictionary of Consumer Words*. Emotion dictionary is composed of a large number of words expressing emotion. The construction of emotion dictionary is the main way to obtain the characteristics of emotion words. There are two methods to construct emotion Dictionary: manual construction and automatic generation. This paper synthesizes the above two methods, and then uses the semiautomatic construction method to complete the construction of the dictionary.

Word2vec is an implementation of word vectorization. Through word vectorization, the synonyms of emotional word features or words with similar context are calculated, and the dimensions are set to add emotional word features.

In order to get a more comprehensive and accurate emotional dictionary, this paper uses word2vec to cluster the labeled emotional words, and selects the synonyms to complete the expansion function of the dictionary. At the same time, through the discovery of new words, this paper completes the extraction of consumer emotional words.

(2) *Degree Adverb Dictionary*. According to How Net dictionary, the degree adverbs in the dictionary are weighted, and these degree adverbs are divided into six levels. They are super, extremely, very, relatively, slightly, and under and negative adverbs, but they do not give the weight of degree. Therefore, combined with Chinese semantic rules, this paper expands the emotional intensity of the modified emotional words according to the six levels of adverbs, and sets the multiples as 2 times, 1.75 times, 1.5 times, 1.25 times, 0.5 times, and 0.25 times, respectively. The dictionary is shown in Table 1.

(3) *Dictionary of Network Terms*. After investigation and research, it shows that most consumers like to use online language. Network words have the characteristics of gradually increasing with the passage of time.

Words are often used as the smallest processing unit in natural language processing. Moreover, different meanings can be expressed by different words. Words with emotion are usually defined as emotional words. Emotional words are used to describe people's feelings for things, such as "happy," "sad," and "happy". The emotional classification of words is the basis for judging the overall emotion of the text. For example, there are a large number of words representing positive emotional bias in an article, but few words showing

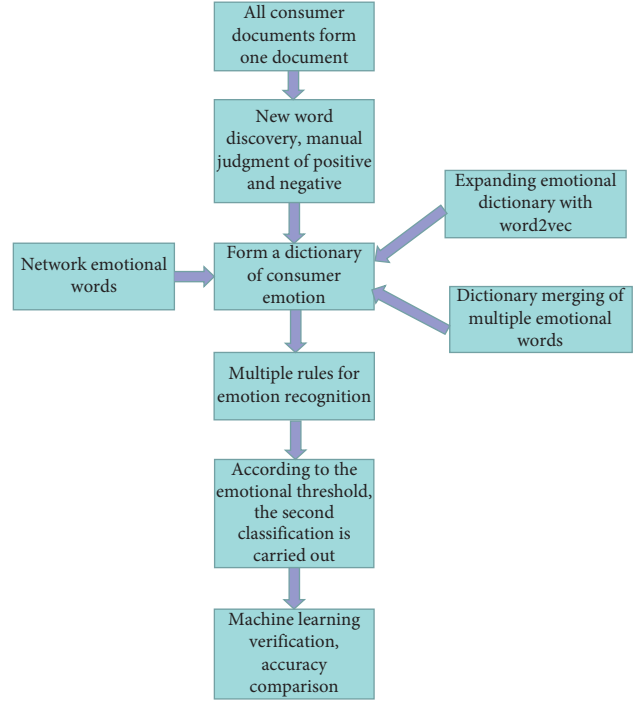


FIGURE 1: Affective cognitive recognition method framework.

TABLE 1: Degree adverb dictionary.

Degree adverb	Level	Weight multiple	Number
Super, too much...	Over	2	31
One hundred percent, doubly, extremely...	Most	1.75	83
Not a few, mostly...	Very	1.5	39
More, comparatively, further...	More	1.25	37
More or less, a little, slightly...	Ish	0.5	30
Very small or short...	Ishufficient	0.25	12
No, none...	Inverse	-1	50

negative emotional bias. This article is usually judged to express relatively positive emotions, which is also the basis for general emotional analysis and judgment. Emotional analysis at the sentence level is conducive to preserving the integrity of the sentence. Emotional words are used as the characteristic basis for the classification of sentence level by characteristic words. In this paper, the definition rules are applied to calculate the comprehensive emotion of sentence level text, which can not only ensure the integrity of sentences, but also realize the calculation of a small number of sentence level emotional texts.

4.3.2. *Semantic Cognitive Rule Algorithm for Emotion Cognition*. In order to ensure the semantic analysis of sentence level and small quantity level, when emotional words are matched through emotional dictionary, corresponding strategies are made for the possible combination of a sentence according to the law of general sentences.

Addition is the method of weighting emotional words or expressions; multiplication is the method of weighting emotional words of modifiers, and finally additive weighting.

This paper defines six rules, including: rules that rely only on basic emotional vocabulary, the calculation rules of the expression in the text, rules that rely on Network Vocabulary weighting, the rule of negative words in front of emotional words, the rules of degree adverbs in front of emotional words, and rules of negative adverbs in front of emotional words. We use *O* to represent the emotion value of the corresponding sentence combination, *A* to represent each basic emotion word, *Q* to represent each degree adverb, *C* to represent each network word, and *E* to represent each emoticon. The emotional cognitive rules are shown in Table 2.

5. Analysis of Empirical Results

5.1. Analysis of Stock Market Performance before and after the Carbon Information Disclosure Event. According to the occurrence time of the information event, the event research method is used to analyze the data reflecting the stock market performance, such as the stock trading volume, trading volume, bid-ask spread, standard return rate, and stock market value during the window period of each information event, to fully understand the short-term impact of carbon information disclosure on corporate value creation.

Figure 2 depicts the distribution of average transaction volume and transaction value before and after the information event. In Figure 2, the vertical axis represents the quantity, and the horizontal axis represents the number of days before and after the information event.

Figure 2 shows that before the information event occurs, the stock trading volume fluctuates, and there is a phenomenon of one day high and one day low. The average trading volume of stocks was the largest on the day when the information event occurred. The trading volume of stocks began to decline in the next 4 trading days after the information was disclosed, and the trading volume of stocks increased on the fifth trading day. In general, the average stock trading volume in the 5 trading days after the information event is higher than the average stock trading volume in the 5 trading days before the information event occurs. From Figure 2, it is not difficult to find that the fluctuation and change trend of stock trading volume and the changing trend of stock trading volume converge during the event window period. When the information event occurs, the stock trading volume reaches the maximum value. On the whole, the transaction volume of the five trading days before the occurrence of the information event is smaller than the transaction volume of the five trading days after the occurrence of the information event. Moreover, the trading volume fluctuated wildly on the day when the information event occurred, which increased significantly compared with the previous trading day and began to decline on the first trading day after the information event occurred.

Figure 3 shows the distribution of the average bid-ask spread before and after the information event. In Figure 3,

the vertical axis represents the average bid-ask spread and the horizontal axis represents the number of days before and after the information event. As shown in Figure 3, the average bid-ask spread on the day when the information event occurred was 0.043, and the overall bid-ask spread in the stock market was relatively small. However, from its standard deviation data statistics, it is found that the standard deviation of the bid-ask spread in the five trading days before the occurrence of the information event is generally higher than the standard deviation of the bid-ask spread in the five trading days after the occurrence of the information event. This shows that the fluctuation range of the bid-ask value before the occurrence of the information event is higher than the fluctuation range of the bid-ask spread after the occurrence of the information event and the fluctuation range of the bid-ask spread decreases after the occurrence of the information event.

In addition to examining the volatility of stocks in terms of trading volume, trading value, and bid-ask spreads before and after the information event. This paper also analyzes the changes in stock market value during the information event window. Table 3 describes the distribution of stock market capitalization during the information event window. Similarly, the stock market value on the day and the second day of the information event was higher than that on the two days before the information event, indicating that the information event had a particular impact on the stock market value. Still, before and after the information event, the overall average market value of the stock did not fluctuate much.

Based on the above analysis, it can be seen that the trading volume and trading value in the five trading days before the occurrence of the carbon information event are smaller than the trading volume and trading value in the five trading days after the occurrence of the information event, and the fluctuation range of the bid-ask spread is reduced after the occurrence of the information event. This shows that carbon information disclosure affects the stock trading volume and transaction amount on the day of information disclosure and the five trading days before and after it, and makes stock prices and stock market values fluctuate in a short period of time, effectively triggering the stock market's response to the information. The overall trend of the stock market's short-term response to carbon information disclosure is that the stock transaction volume and transaction amount have increased on the day of the information event and the five trading days after that, which is conducive to the short-term value creation of enterprises. However, in the short term, carbon information disclosure will indeed cause fluctuations in the performance of the stock market, but the increase in stock market value is not obvious, which makes Hypothesis a proposed in this paper partially supported.

5.2. Investor Income Analysis before and after the Carbon Information Disclosure Event. After examining the short-term impact of carbon information disclosure on stock market performance, this paper further examines the short-

TABLE 2: Affective cognitive rule method.

Tagging	Rules	Explanation
Rule 1	$O = A_1 + A_2 + \dots + A_k$	Rely on basic emotional words
Rule 2	$O = E_1 + E_2 + \dots + E_k$	Rely on emoticons
Rule 3	$O = C_1 + C_2 + \dots + C_k$	Rely on network words
Rule 4	$O = (-1) * k * A$	Negative words appear before emotional words
Rule 5	$O = Q * A$	Adverbs of degree appear in front of emotional words
Rule 6	$O = (-1) * Q * A$	Negative word + degree adverb + emotion

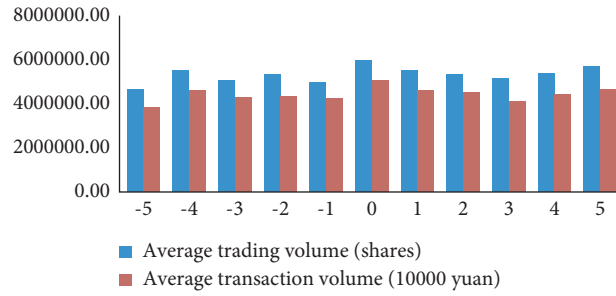


FIGURE 2: Distribution of average trading volume and transaction amount before and after information event.

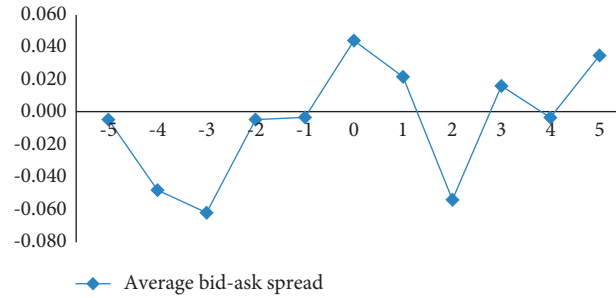


FIGURE 3: Distribution of average bid-ask spread before and after information event.

TABLE 3: Statistics analysis of stock market value before and after information event.

Number of days since the event	Mean	Standard deviation	Minimum value	Maximum value	Skewness	Kurtosis
-5	6.11	1.26	4.34	7.82	0.13	-1.84
-4	6.06	1.26	4.21	8.01	0.18	-1.74
-3	6.02	1.25	4.23	7.72	0.2	-1.83
-2	6.01	1.25	4.32	7.97	0.21	-1.79
-1	6.02	1.26	4.3	7.85	0.2	-1.79
0	6.04	1.28	4.34	7.7	0.2	-1.9
1	6.05	1.29	4.21	7.82	0.18	-1.83
2	6.02	1.26	4.23	7.83	0.23	-1.76
3	6.01	1.17	4.39	7.82	0.25	-1.76
4	6.02	1.16	4.35	7.72	0.22	-1.74
5	6.04	1.15	4.43	7.76	0.25	-1.74

Note. Unit of stock market value: one billion yuan.

term effect of carbon information disclosure on investor returns by comparing the difference between normal and abnormal stock returns before and after the carbon information disclosure event. The test results are shown in Figures 4 and 5. In Figure 4, the vertical axis represents the average yield and the horizontal axis represents the number of days before and after the information event.

At the same time, the stock's return rate was negative within the first 5 trading days of the information event. It showed a gradual upward trend, reaching the maximum value on the day of the information event. The rate of return began to decline on the first trading day after the occurrence of the information event, reached the lowest point on the second trading day, and the normal rate of return gradually

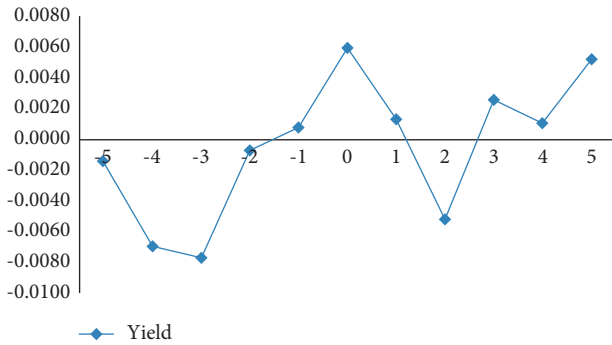


FIGURE 4: Distribution of average yield before and after information event.

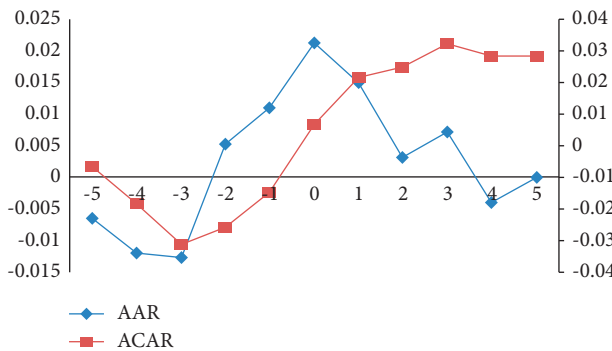


FIGURE 5: Statistics analysis of AAR and ACAR before and after information event.

increased in the following three trading days. In general, the normal rate of return is higher in the five trading days after the information event than in the five trading days before the information event.

Figure 4 depicts the changes in the average abnormal rate of return (AAR) and the average cumulative abnormal rate of return (ACAR) before and after the carbon information disclosure event. In Figure 5, the vertical axis on the left represents the number of AAR, the vertical axis on the right represents the number of ACAR and the horizontal axis represents the number of days before and after the information event. From the analysis results in Figure 5, it can be seen that the average abnormal return begins to show an increasing trend on the third trading day before the occurrence of the information event. The average abnormal rate of return begins to change from negative to positive on the second trading day before the information event occurs. The average abnormal rate of return reaches the maximum value in the current period when the information event occurs. On the first trading day after the information event, the average abnormal return declined, remained positive for the next 3 trading days, and turned negative on the fourth trading day. Overall, the average abnormal return shows a trend of rising first and then falling during the window period of the information event, which shows that the occurrence of the information event has led to the change in the abnormal return of investors. In the first 3 days of the information event, the average return Abnormal returns

begin to rise, and average abnormal returns begin to decline after informational events.

The average cumulative abnormal rate of return is consistent with the trend of the average abnormal rate of return. It began to show an upward trend in the first 3 trading days of the event. However, before the event, the average cumulative abnormal rate of return was still negative. It was positive until the current period of the information event and continued to rise within 3 trading days after the event until the fourth trading day after the event. This shows that the market has reacted in advance to the carbon information disclosed by enterprises. On the whole, in the three trading days before the occurrence of the information event, the average abnormal return rate and the average cumulative abnormal return rate both began to show an increasing trend. After the occurrence of the information event, although the average abnormal rate of return showed a downward trend, the average cumulative abnormal rate of return was still positive. This shows that investors can still obtain additional income within 5 trading days after the event. This conclusion strongly supports Hypothesis *b* proposed in this paper.

6. Conclusions

The disclosure of carbon information has caused the stock market to react, leading to fluctuations in stock trading volume, transaction value, and stock price, which will have an impact on the creation of short-term corporate value, but the short-term increase in stock market value is not apparent. In the empirical analysis, it is found that during the event window period, the fluctuation and change trend of the stock transaction quota is similar to the changing direction of the stock transaction volume, which both show that the transaction volume and transaction volume on the day of the information event have a relatively significant increase and the decline began on the first trading day after the informational event. On the whole, however, the trading volume and transaction value in the 5 trading days before the occurrence of the carbon information event are smaller than that in the 5 trading days after the occurrence of the information event. In terms of price fluctuations, the overall fluctuation range of the bid-ask spread in the five trading days before the occurrence of the carbon information event is higher than that in the five trading days after the occurrence of the information event, which indicates that the fluctuation range of the bid-ask spread decreases after the occurrence of the information event. Also, the stock market value on the day and the second day of the carbon information event is higher than that on the 2 days before the information event. This shows that carbon information disclosure affects the stock trading volume and transaction amount on the day of information disclosure and 5 trading days before and after, making stock prices and stock market values fluctuate in a short period, triggering the stock market's response to the information. The overall trend of the stock market's short-term response to carbon information disclosure is that carbon information disclosure promotes an increase in trading volume and stock market

value on the day of the information event and 5 trading days after that, which is conducive to short-term corporate value creation, but the increase in stock market value Small.

The disclosure of carbon information increases the short-term income of investors, thereby affecting the creation of short-term corporate value. In the empirical analysis, it is found that within the first 5 trading days of the information event, the normal return rate of the stock shows a gradual upward trend, reaching the maximum value on the day the information event occurs, and the return rate on the day after the information event occurs. On the other hand, the normal rate of return 5 trading days after the occurrence of the information is higher than the 5 trading days before the occurrence of the information event. In the first 3 days of the information event, the average abnormal rate of return began to rise. After the information event occurred, the average abnormal rate of return began to decline. It can be seen that the average abnormal rate of return showed a trend of rising first and then falling during the window period of the information event. It shows that the occurrence of information events leads to changes in the abnormal returns of investors. The average cumulative abnormal rate of return is consistent with the trend of the average abnormal rate of return, which shows that carbon information disclosure increases the amount of information for investors, makes investors' decision-making more scientific and reasonable, and is conducive to investors to obtain additional returns in the short term. The empirical analysis of the impact of comprehensive carbon information disclosure on short-term stock market performance and investor returns found that the stock trading volume, trading volume, and stock market value on the day of the information event increased to a certain extent, and the stock price fluctuation range decreased. The five trading days' overall market liquidity and trading activity were higher than those of the previous five, effectively triggering the stock market's market response to carbon information disclosure. At the same time, due to the improvement of market liquidity and activity caused by information events, investors can obtain more abnormal returns among short-term investors. The above research conclusions generally show that carbon information disclosure will positively impact short-term corporate value creation.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Analysis of Safety Behavior of Prefabricated Building Workers' Hoisting Operation Based on Computer Vision

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Safety accidents occur frequently in the construction industry, and unsafe behavior of workers is one of the main reasons for the occurrence of safety accidents. In recent years, the rapid development of emerging technologies has provided effective support for the automatic identification of unsafe behaviors. In particular, computer vision technology does not require equipment to be attached to workers. It has little impact on its operation and can process a large amount of image data in a timely and fast manner. Therefore, it is more suitable for the construction site environment. This study starts from the hoisting operation on the construction site of prefabricated building projects and introduces relevant machine learning methods. Early warning analysis on the safety risk of the tower crane is carried out to complete the hoisting operation of prefabricated components. To suspend dangerous tasks in time according to the warning results, relevant measures are taken and potential risks are eliminated to prevent accidents.

1. Introduction

A prefabricated building is a building assembled on-site with prefabricated parts. Although the promotion of prefabricated buildings has achieved good results, it is moving forward with high progress. However, we have to realize that, at this stage, China's prefabricated buildings are still in the initial stage of development. There is still a big gap compared with developed countries and industrial powers in terms of technical support, market cultivation, supporting construction, and management model transformation [1, 2]. In particular, reflected in the overall level of assembly construction is not high, and there are many hidden dangers in construction safety and so on.

The prefabricated construction operation brings benefits such as cost reduction and efficiency increase, energy conservation, and environmental protection. This low-mature construction method increases the operational safety risks of on-site hoisting and parallel construction of prefabricated buildings [3, 4]. It is more likely to cause safety accidents on the construction site.

The hoisting operation on the prefabricated building construction site consists of two links: hoisting operation and installation operation. In the whole process, tower cranes or forklifts need to be used to change the spatial position of prefabricated components to complete the splicing and assembly of various components [5]. Different from conventional hoisting operations, in the construction process of prefabricated buildings: the hoisting operations of components account for more than half of the on-site engineering volume, with a long duration and high strength; the shape of the lifting object is irregular, and the single-piece mass is large [6, 7]. The assembly requires high operation accuracy, stable suspension, no shaking, and poor visibility. All of these make the on-site hoisting operation of prefabricated buildings become the source of high-frequency safety accidents.

In recent years, the development of new technologies, especially the development of wearable technology and computer vision technology, has made it possible to automatically identify the unsafe behavior of workers. The identification method based on wearable technology mainly

obtains workers' position information or movement information by installing positioning labels, accelerometers, and other devices on workers [8]. After extracting the features, they are analyzed and trained to realize the recognition of workers' unsafe behavior. However, this method requires workers to wear additional equipment, which is cumbersome and inconvenient, has a certain impact on workers' normal operation, and may even cause new potential safety hazards [9].

The recognition method based on computer vision technology does not have the above limitations. It mainly collects workers' behavior images, extracts key features from them, analyzes and trains them, and realizes the recognition of workers' unsafe behaviors. In addition, the monitoring camera is widely used in the construction site, which also provides the basis for the application of computer vision technology. Therefore, the identification method based on computer vision technology is more suitable for the actual construction environment and provides effective support for the automatic identification of workers' unsafe behavior.

2. Relevant Overview and Theoretical Basis

2.1. Prefabricated Building

2.1.1. Definition of Prefabricated Building. Prefabricated building refers to the integration of prefabricated parts for the main parts of the building's structure, outer protection, equipment, and pipelines. Prefabricated buildings are mainly divided into prefabricated concrete buildings, steel structure buildings, wood structure buildings, and their composite structures [10]. Among them, prefabricated concrete buildings are most widely used in China, and they are also the research object of this study. The difference between prefabricated buildings and general cast-in-place buildings is shown in Figure 1.

2.1.2. Prefabricated Building Construction. The difference between prefabricated concrete building and traditional concrete building is that their construction is based on components. Therefore, the prefabricated building construction not only refers to the construction site in the traditional sense but also includes the component production of the factory, the logistics transportation after production, and the component assembly. Therefore, the prefabricated building construction referred to in this study is an extended definition based on the components necessary for its construction.

2.1.3. Prefabricated Hoisting Construction

(1) Composition of Prefabricated Hoisting Construction System. The prefabricated hoisting construction system is a relatively complex dynamic system. It mainly includes four basic elements: prefabricated components, hoisting machinery, hoisting environment, and employees [11]. In the actual hoisting construction process, these four basic factors serve the prefabricated hoisting construction system at the

same time and influence and restrict each other in the service process.

In addition, the continuity of prefabricated hoisting construction operation makes the risk factors contained in each element in the process of continuous dynamic evolution. Therefore, to prevent and control the occurrence of hoisting safety accidents, it is necessary to deeply study and master the specific risk factors and their interaction strengths contained in each production element in the hoisting construction system of prefabricated components. On the contrary, the prefabricated hoisting construction system is safe and reliable only if the harmonious coexistence of various elements within the system is ensured.

(2) Construction Characteristics of Prefabricated Hoisting.

The safety management in the hoisting construction of prefabricated buildings is difficult, which is related to the current situation that the development of prefabricated buildings in China is not quite mature. The relevant technical standards are not complete, and the management concept also stays at the traditional level of safety management [12]. Faced with the frequent safety management bottleneck of hoisting accidents in various industries, the safety management of component hoisting of prefabricated buildings has received much attention.

The hoisting construction of prefabricated buildings has the following characteristics: ① the components themselves have high potential energy and large volume. Once an accident occurs, the consequences will be serious; ② hoisting operation is a combined movement of hoisting machinery, hoisting tools, and prefabricated components. There are many and scattered dangerous points, which makes it difficult to control; ③ the hoisting machinery runs across the operation site with load and is higher than other equipment, facilities, and people; ④ hoisting is a group operation, which requires the cooperation of signal workers, tower crane drivers, installers, and other people, and most of them are exposed to danger, so there is a strong demand for dynamic control; and ⑤ the operation conditions are complex and there are many uncertain factors.

2.2. Definition and Characteristics of Unsafe Behavior of Workers

2.2.1. Definition of Unsafe Behavior. The research object of this study is defined as the unsafe behavior of workers on the construction site. The unsafe behavior of construction workers at the construction site is defined as the behavior of construction workers that violates relevant safety regulations, which directly causes or may directly cause safety accidents.

The research object of this study is behaviors that directly cause or may directly cause safety accidents due to violations of relevant safety regulations, including conscious unsafe behaviors and unconscious unsafe behaviors. Conscious unsafe behavior refers to the influence of construction workers for some motivation, psychological needs, or other factors. He still made the act on the premise that he knew

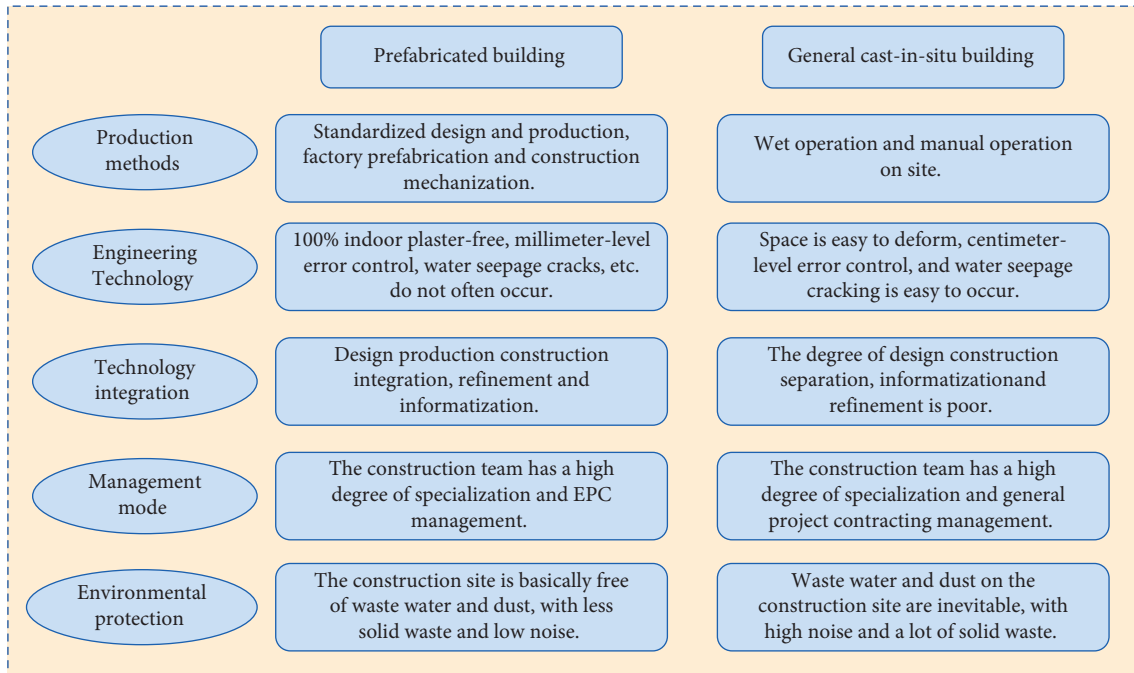


FIGURE 1: Comparison of prefabricated buildings and cast-in-place buildings.

that his behavior violated relevant safety regulations and there were safety risks. Unconscious unsafe behavior refers to the unsafe behavior of construction workers without knowing that their behavior violates relevant safety regulations.

2.2.2. Characteristics of Unsafe Behavior. The construction site operations are carried out in a complex coupled system of man, machine, and environment. Under the operation of this complex coupled system, the unsafe behavior of construction workers is common. The unsafe behavior of construction workers on the construction site has its own uniqueness, which mainly includes the following two aspects.

- (1) The characteristics of construction safety production are different.
 - ① Construction is complex and dynamic. Dangerous sources have great uncertainty in construction site operations. Compared with the traditional manufacturing industry, most of the manufacturing industry produces fixed products in fixed plants, so its production process, influencing factors, and existing hazard sources are relatively stable [13]. Many complex variable factors, such as long construction period, many open-air operations, complex construction processes, and multiple cross operations may have an impact on the working environment of the construction site, resulting in the unsafe behavior of construction workers.
 - ② There are too many safety codes, standards, and operating procedures in the construction field that is complex and scattered. Therefore, construction

workers cannot understand and memorize various terms and relevant safety knowledge, thus inducing unconscious unsafe behavior.

- ③ The level of mechanization of construction and production of construction projects is low, and the construction and production environment is poor. Most of the operations on the construction site can easily lead to fatigue and distraction of construction workers, which can easily lead to unconscious operation errors.
- (2) The main body of unsafe behavior of construction workers is different.
 - ① Construction workers at the construction site have high mobility, low cultural and professional level, and less experience in receiving professional skill training. Unintentional and unsafe behaviors are due to lack of relevant safety regulations and professional skills, such as incorrect operation of construction machinery, equipment, and instruments such as cranes.
 - ② Most construction workers have a low degree of compliance with safety operation procedures, which leads to conscious unsafe behaviors such as taking risks and violating regulations.
 - ③ The habitual unsafe behavior of construction workers is very common. The unsafe behavior of construction workers stems partly from conscious risk-taking and violations and partly from unconscious habitual unsafe behavior [2, 14]. This habitual unsafe behavior is the subconscious result of the long-term habit of construction workers. For example, construction workers often do not wear safety helmets when entering the construction site.

2.2.3. Classification of Unsafe Behaviors. During the construction process, the personnel on the construction site must abide by various standards, specifications, rules, and various safety management regulations. According to the operating procedures, domestic and foreign literature, and the experience of experts on the construction site, the unsafe behaviors of workers are mainly divided into the following three categories:

- (1) Personal protection equipment (PPE) is not used or not used correctly. For example, the on-site high-altitude workers do not wear safety belts as required; workers do not wear safety helmets when entering the construction site; and workers do not use dust masks and noise protective equipment as required [15]. It is worth noting that the use of PPE can protect construction workers from or reduce safety accidents and occupational hazards during operation on the construction site and has a direct protective effect on human body. Common PPE includes ① safety helmet and other head protective articles; ② eye protective equipment such as protective glasses; ③ fall protection devices such as safety belt, safety rope, and safety net; and ④ hand protectors such as protective gloves.
- (2) Close to hazardous areas. Being close to the dangerous area means that the workers on the construction site are within the scope of risks and potential safety hazards. That is, the workers on the construction site stay in unsafe places or carry out construction operations.
- (3) Safety procedures were not followed. Failure to follow safety procedures includes two types of unsafe behaviors: ① workers on the construction site do not operate machinery in accordance with standardized, standard, and correct operation procedures; ② construction workers make unsafe actions unconsciously during construction operations.

Table 1 lists the unsafe behaviors of some workers on the construction site. These unsafe behaviors are chronic diseases that cause safety accidents on the construction site. Some scholars have used computer vision and deep learning methods to automatically recognize that construction workers are not wearing helmets or safety belts during work. These research methods can accurately identify a certain unsafe behavior of workers from a specific construction scene, identify a variety of unsafe behaviors in pictures, and promote the development of automatic and continuous identification of unsafe behavior of construction site workers.

2.3. Behavior-Based Safety Theory. Behavior-based safety (BBS) is a set of theories and methods for accident prevention from the perspective of behavioral science. It was first proposed in 1979 by British scholars Gene Earnest and Jim Palmer under the name of BBS. In the late 1970s, BBS was introduced into China. After more than 40 years of theoretical research and exploration, BBS is considered to be

a very valuable research method to prevent safety accidents, improve safety performance, curb unsafe behavior, and encourage and consolidate safety behavior.

BBS focuses on individual behavior. It is a combination of psychology, sociology, organizational behavior, and ergonomics on the basis of behavior science. By establishing the difference between unsafe behavior and safe behavior, people's unsafe behavior at the production and operation site is identified, monitored, corrected, analyzed, and counted [5, 16]. It is a scientific and progressive management method to continuously solidify habits by adopting the cycle mode to carry out the process of "observation-correction-re-observation-re-correction" and gradually avoid or eliminate people's unsafe behaviors.

BBS research focuses on how to reduce unsafe behaviors of individuals, focusing on people's "unsafe behaviors." Compared with traditional safety management methods, BBS has two main differences: (1) BBS emphasizes observing workers' behavior, while traditional safety management methods examine unpredictable factors, such as workers' safety awareness. (2) BBS advocates encouraging behaviors of normative workers, while traditional safety management methods focus on punishing workers who engage in unsafe behavior.

3. Application and Common Methods of Computer Vision

3.1. Application of Computer Vision in Construction Engineering. In construction engineering, several applications of computer vision are related to the monitoring of construction sites and can be used for productivity and safety management. Image processing algorithms including object detection, object classification, and object tracking are available. Object detection algorithms identify objects of study by detecting their color, shape, or other characteristics. Object classification algorithms classify objects using intelligent classifiers or discriminative functions.

In the existing literature of computer vision in the construction industry, some of them are used to simply detect and track the entities on the scene and recognize the activities and gestures of the entities [17]. With the development of research, more and more scholars apply computer vision to the management activities of construction site.

One of the main applications of computer vision in construction sites is productive detection and recognition. Primarily by detecting and tracking entities on the construction site, it assists managers in calculating productivity, including construction equipment and workers. Luo et al. used computer vision technology to identify the activities of workers installing steel bars on construction sites, which can be used for labor activity assessment. Using photogrammetry and video analysis techniques to create time series of point clouds, Bügler et al. generate statistics of construction activity that estimate productivity on a time scale, assessing productivity levels in underground construction earthwork excavations. Chen et al. proposed a framework for activity and productivity evaluation of multiple excavation

TABLE 1: Unsafe behaviors of workers on construction site.

Unsafe behavior category	Description of unsafe behavior
Improper use of personal safety equipment	Not wearing safety helmet
	Not wearing seat belt as required
	Do not use dust masks and anti-noise protective gear as required
Close to hazardous area	Workers approaching construction machinery within the working radius
	During crane operation, workers stay under the jib
	When the crane is working, the object to be lifted passes directly above the person
Safety procedures not followed	The main and auxiliary hooks of the crane work at the same time
	Crane pulling heavy objects or hoisting buried objects

equipment. Other scholars use computer vision technology to detect and track materials and temporary resources on construction sites.

Another important application of computer vision technology is the detection and tracking of safety in construction sites, which can be divided into unsafe behaviors and unsafe conditions. Worker unsafe behaviors include improperly wearing personal protective equipment (PPE), entering hazardous areas, and failing to follow safety procedures. For PPE-related research, Fang et al. used a deep learning approach to detect workers' PPE. Fang et al. used the same model to detect workers' safety helmets. The difference is that most studies detect safety helmets in a closer distance. This study can detect whether workers wear safety helmets in a further monitoring scene. For the research related to entering dangerous areas, Fang et al. combined computer vision with mask R-CNN. This knowledge is used to identify the unsafe behavior of individuals supported by structures and then determine the relationship between these objects.

Through the above review, it is not difficult to see that computer vision technology has realized the detection and tracking of building entities in construction projects. The computer vision applications used are image classification, target detection, and pose estimation. The above application research will be used as a technical reference for the safety behavior analysis of assembly construction workers in hoisting operation based on computer vision in this study.

3.2. Common Method

3.2.1. Convolutional Neural Network. The combination of the development of deep learning methods and computer vision technology enables computers to better understand what they see, thus promoting the development of the field of computer vision. Compared with traditional machine learning methods, the biggest feature of deep learning is that it can automatically learn the features suitable for the task and has stronger ability of feature learning and feature expression. Among them, the most widely used deep learning method is a convolutional neural network (CNN).

The deep learning method based on CNN has been widely used in the field of computer vision since it was proposed, for example, image classification, object detection, image semantic segmentation, pose estimation, and face recognition, and it achieved good results. Common deep convolution neural network models include AlexNet,

VGGNet, GoogleNet, and ResNet. The application and development of CNN provide theoretical and technical support for the identification of workers' unsafe behavior in construction site [18].

3.2.2. Recurrent Neural Network. A recurrent neural network (RNN) is a neural network with short-term memory ability. It can not only process the current input information but also store the output information of the previous layers, forming a network structure with loop. RNN has been widely used in the field of natural language processing and has made great breakthroughs in machine translation, machine reading, text classification, and other tasks.

RNN can be regarded as the expansion of neural network in time series. Theoretically, it can deal with sequences of any length. RNN is very intuitive in design, and the shared parameters in each time step make it not easy to fall into overfitting, so it is very suitable for sequence modeling. In response to the long-term dependence problem of RNN, the Sepp long-term short-term memory (LSTM) introduces input gate, output gate, and forgetting gate on the basis of RNN to selectively forget or remember the information in neurons, so that RNN can model longer time series. Chung et al. proposed gated recurrent unit, which combines the forgetting gate of LSTM with the input gate and greatly improves the operation speed without losing the accuracy of the model.

3.2.3. Support Vector Machines. A support vector machine (SVM) can identify arbitrary samples by reconciling the learning accuracy of the model and the ability of error-free according to the limited sample data information. That is to find the optimal compromise between model complexity and learning ability and then obtain the best generalization ability, which is widely used in function fitting, regression analysis, and so on. Because it can quickly solve the disadvantages of small samples, high-dimensional nonlinearity, and local minima, it has become a new research hotspot after neural networks.

SVM is a novel small sample learning method with solid theoretical foundation. Different from the existing statistical methods, SVM does not involve probability measure and the law of large numbers. In terms of computational complexity, because the final decision function only depends on the support vector, not all samples, there is no need to worry about the "dimension disaster" to a certain extent, and it is

easy to grasp the key samples and has good robustness. However, the selection of kernel function and the determination of function parameters have an impact on the output results, which need to be improved in combination with practical application such as least-squares vector machine and correlation vector machine, and using particle swarm optimization or grid search method to determine function parameters.

4. Safety Behavior Analysis and Measures of Prefabricated Building Hoisting

4.1. Safety Behavior Analysis of Prefabricated Building Hoisting

4.1.1. Hoisting Operation Procedure and Safety Measures. The hoisting operation at the construction site of prefabricated buildings consists of two parts: hoisting operation and installation operation. The whole process requires tower crane or forklift to change the spatial position of prefabricated components, so as to complete the splicing and assembly of various components [19]. After the hoisting operation is completed accurately and qualified according to the technical scheme of construction organization design, the next step of component node connection can be carried out. The basic operation procedures, key points, and measures of safe construction are described as follows:

- (1) Basic Procedures of Hoisting Operation: during the basic process of hoisting prefabricated components, the connection between the component and the tower crane cannot be separated until the temporary support of the component hoisted in place is fixed well.

Among them, “component lifting and installation” and “component adjustment, correction, and temporary fixation” are often the unstable links that are most likely to cause accidents and last for a long time in the construction process. Due to the quality, shape, size, and other factors of the hanging object, there are a lot of uncertain factors in many processes in the two links, such as poor visual range, high shaking frequency, long duration, and large strength strain of the connection point. To fully and accurately identify the risk factors existing in the hoisting operation as much as possible, it is necessary to understand each process of these two links.

- (2) Safety Measures for Hoisting Operation.

Regarding the safety measures for the construction of prefabricated buildings, the safety measures for related hoisting operations are shown in Table 2.

Based on the summary of the operation characteristics of tower crane and the analysis of the hoisting operation procedures and key points and measures of safe construction on the construction site of prefabricated building, compared with the traditional cast-in-place process construction, the characteristics of prefabricated concrete construction

engineering in construction safety protection are as follows: ① frequent lifting operation; ② the lifting capacity is greatly increased; ③ a large number of formwork erection operations become temporary support; and ④ reduced work on external scaffolds. Therefore, when identifying the hazard sources of hoisting operation, it is necessary to analyze and establish the identification list of hazard sources of prefabricated building hoisting operation and determine the safety influencing factors in combination with the above four characteristics.

4.1.2. Problems in Safety Management of Hoisting Operation. Due to the limited supply and uneven quality of prefabricated components at this stage, the low technical level of workers on the construction site, and the lack of tools, instruments, and equipment matching with the construction process of prefabricated buildings, the risk level of prefabricated construction system is high, and the potential safety hazards cannot be ignored [20]. The problems existing in the safety management of hoisting operation in prefabricated building construction mainly include the following aspects:

- (1) The safety production management system of all parties involved in construction safety management is not perfect.
 - ① It is difficult to control the procurement, ordering, supply, and quality of components, limited control of on-site progress, quality and safety production, and limited investment in safety measures.
 - ② The management capabilities of technology and general subcontracting mode need to be improved, and the responsibilities and capabilities of the existing security officers need to be changed accordingly.
 - ③ The ability of in-depth design of prefabricated components is lacking, the proportion of consideration of construction safety in the design process has changed, and the design mode and drawing process are not suitable for the characteristics of prefabricated construction.
 - ④ The supervision content, method, and control means are different from those of the traditional cast-in-place process.
- (2) The safety production management guarantee system is absent.
 - ① The safety production management of prefabricated buildings cannot directly copy the current safety technical standards and specifications based on traditional construction and production operations.
 - ② The financial security measures are backward, and the safety and civilized construction fee items in the existing measure fees cannot meet the actual requirements of mechanization and modularization required for the construction of prefabricated buildings.

TABLE 2: Safety measures for hoisting operation.

Measure content	Factors involved
The hoisting personnel of prefabricated components shall wear safety shoes, safety helmets, and safety belts, and the safety hook shall be fixed in the designated safety area	Personnel and materials
During the hoisting process, hook removal and other climbing operations should use qualified ladders, tools, and accessories. Anti-slip measures should be taken, and it is strictly forbidden to throw up and down	Personnel and materials
During the hoisting process, the suspended workplace shall be provided with protective railings or other temporary and reliable protective measures	Materials and management system
Before the commencement of hoisting operation, the operation area shall be enclosed, a warning line shall be set and special personnel shall be assigned to take care of it. Safety signs shall be arranged to prevent personnel irrelevant to installation from entering	Personnel and management system
During hoisting, it is strictly forbidden for personnel to stay below the operating radius. Relevant operators can only approach when the component is lowered to within 1m from the ground	Technology and management system
When hoisting edge components, operators should wear lifelines, and temporary protection should be done during edge operation	Personnel, materials, and management system
The operation should be stopped when there are safety hazards or unqualified safety inspection items during the hoisting process	Management system

- ③ The current safety supervision model cannot be fully controlled. The operation of prefabricated construction projects includes the production, transportation, and hoisting of components. The space is parallel and multidimensional. The entire production system is cross-regional and cross-industry, and it is easy to find regulatory loopholes.
- ④ There is a lack of mature and professional prefabricated construction project management team and construction operation team, and the supporting management system, education and training, assessment standards, and other systems are not perfect.

(3) The standard system is not perfect.

Safety management standards applicable to prefabricated building construction operations have not been formed, and the management systems, operating procedures and standards of all parties, and the scope of responsibilities and rights of management departments are unclear. The current safety construction standards and regulations in the industry are difficult to directly guide the safe and civilized operation of the assembly site, and there is no ready reference for the settings of safety enclosures, three treasures and four ports, and scaffolding.

The above three aspects lead to a large number of factors affecting the safety of operators, materials, equipment, and mechanical appliances in the hoisting operation of prefabricated building construction. It should be considered in the early warning analysis of prefabricated building hoisting operation, and combined with the actual demand, the influence degree and control mode of each point are analyzed, to achieve the accurate, scientific, and objective early warning goals.

4.1.3. Hazard Identification of Hoisting Operation. At present, the total amount of hoisting and assembly work is regarded as the most dangerous factor in the whole construction process. It is also regarded as the weakest point of

safety control in the whole construction process. At the same time, there are also safety risks in the links such as on-site layout and component stacking and transportation, which precede the hoisting operation, resulting in the frequent occurrence of hoisting accidents. Therefore, when identifying the hazard sources of hoisting operation, these pre-sequence links should be considered and determined in combination with the actual needs.

Combined with the theory of the causes of safety accidents and the characteristics of prefabricated building construction, reference is made to relevant building construction safety technical standards, research literature, and accident case analysis reports [21]. According to the safety table inspection method, all the risk factors that may lead to safety accidents in the four aspects of on-site stacking, lifting, installation, and high-altitude work are collected and summarized, and a list is listed. Combined with the hazard source control objectives, the hazard sources are identified in each link that may cause hoisting accidents.

Compared with the safety risks faced by the tower crane lifting operation in the traditional cast-in-situ process, the key construction processes, key points and measures of safe construction, and the current situation of safety management of hoisting operation of prefabricated buildings are analyzed, to complete the hazard identification of hoisting operation of prefabricated buildings. Based on this, a comprehensive list of hazard sources for prefabricated building hoisting operation is obtained, from which the safety early warning index system of prefabricated building hoisting operation can be analyzed and determined.

4.2. Suggestions for Safety of Hoisting Operation. According to the safety early warning analysis of the hoisting operation process of the above prefabricated building project engineering cases, combined with the safety management characteristics of prefabricated building construction, the following countermeasures and suggestions are put forward to help improve the safety level of hoisting operations.

- (1) During the hoisting operation, the tower crane driver needs to pay attention for a long time, and measures shall be taken to ensure the operation state of the driver. For example, a high frequency of communication and dialogue is kept, to avoid fatigue, sleepiness, inattention, and other situations of the driver. At the same time, the impact of high-temperature operation in summer on the tower crane driver should be considered, the operation time should be adjusted, the drinking water supply should be increased, and the cooling and heatstroke relief supplies and drugs should be distributed to reduce the probability of heatstroke and heat radiation disease.
- (2) The prefabricated components have heavy weight and long suspension duration, which is easy to cause the performance fatigue of tower crane long arm trolley, steel wire rope, sling hook, and other metal parts. Then, cracks, shrinkage, and deformation occur, resulting in instability of tower crane structure and falling of lifting objects, resulting in safety accidents. Therefore, redundant connections should be arranged between the tower crane and the spreader and between the spreader and the lifting object to ensure the safety in case of cable breakage.
- (3) The finished products of components shall be protected before delivery, especially the positions of embedded parts, bolt sockets, etc. The auxiliary operation time in the process of component installation is reduced and the continuity of operation lapping is improved. In addition, it is also necessary to increase the investment in technology and scientific research to realize the dynamic simulation of operation links such as component hoisting, wet operation at nodes, and erection of temporary support system as soon as possible. Potential safety hazards in advance are discovered and eliminated.
- (4) As a key operation link, the presence and role of relevant personnel shall be ensured during hoisting operation, and the absence of supervision by the supervision unit in construction and production shall not occur frequently. The comprehensive co-operation of safety self-management and multiparty supervision is ensured, the unsafe behavior of people and the unsafe state of objects are discovered timely, and it is dealt and solved as soon as possible according to the special scheme and emergency plan for hoisting operation. At the same time, it is also necessary to prepare emergency plans in advance for various emergencies according to the actual situation and do a good job in relevant safety education and training, as well as the preview of the plan.
- (5) The property rights and other information of all parties involved in the project are collected and sorted, for example, adjacent buildings, subways, basements, hydropower and natural gas pipelines, and the probability of eliminating adverse factors caused by temporary local load changes caused by the stacking of prefabricated

components. The requirements of high-intensity load of air conditioner and high-temperature exposure operation on power and heat dissipation system shall also be considered, and the power safety and tower crane body maintenance shall be strengthened.

5. Conclusion

The method for identifying unsafe behavior of workers constructed in this study has both theoretical and practical values. First, the identification method constructed in this study is top-down, systematic, and universal. The fragmented scenarios are aggregated for overall consideration, not limited to specific unsafe behaviors or application scenarios. Second, the behavioral data obtained in this study can support long-term digital security management. The unsafe behaviors and dangerous areas that need to be managed at a certain stage are identified, and corresponding resources are allocated to improve the level of safety management. Furthermore, this research provides the possibility for the utilization of a large amount of video data on-site and improves the level of informatization on the construction site. Finally, the method is applied in the actual construction site. That is, the identification of unsafe behaviors of workers can effectively support construction site early warning and reduce the occurrence of safety accidents.

Data Availability

The dataset can be accessed upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

University Teaching Management and Education Reform Based on Multisource Data and Edge Architecture of IoT

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With the rapid development of wireless sensor and network technology, learners can learn anytime and anywhere through various intelligent terminals. For this reason, this paper is research on education and teaching reform in universities that use cloud computing and big data. Teaching practice has proved that the teaching reform based on popular technology not only combines theory with practice, can improve students' interest, and achieve good teaching effect but also is a beneficial exploration for students' comprehensive training. Aiming at the existing problems of distributed teaching system, this paper proposes to teach the theoretical knowledge points of distributed system under the framework of cloud computing and at the same time cooperate with related teaching reform of comprehensive design.

1. Introduction

Cloud computing has the characteristics of safety, reliability, scalability, and low cost. Moreover, cloud computing is built on the basis of the original technology, which reduces the cost and enhances the flexibility and speed of the service. Cloud computing has innovated concepts and applications based on the original method. However, from another point of view, cloud computing is completely new, because it develops some application software and the development and operation of infrastructure and improves the application quality of basic equipment.

For example, the study of [1] designed a mobile cloud computing workflow task dynamic scheduling model, using multiscale and multiscale feature analysis methods to aggregate and cluster the preference information of mobile cloud computing workflow tasks; this paper proposes a localized scheduling algorithm for mobile cloud computing based on Hadoop and provides an improvement plan for the hot data problems that may occur in practical application scenarios [2]; the study of [3] analyzes the research progress and security of elastic mobile cloud computing [4].

A learner-centered interactive teaching must be based on the cloud computing environment to ensure that interactive learning can be conducted at any time, in any way, with anyone, anywhere. Even if the learning environment is different, the form of the open course is the same. In recent years, my country's information technology has been developing continuously, and credits are gradually accepted in open courses. Open courses will be transformed from informal learning methods to formal learning methods, thereby expanding the scope of the audience [5, 6], to provide more learners with learning opportunities, so that more people can receive higher education, so as to improve their comprehensive quality. Since there are still some problems in open courses, in this research, it mainly designs the aspects of user service management, existing open courses, real-time interaction, and learning effects.

2. Problems in Teaching

2.1. Distributed Systems Are Highly Theoretical. When studying this course, students not only need a certain knowledge of hardware but also need the concept of system

architecture, which requires students to have a sufficient understanding of the previous pilot courses, such as computer network, operating system, object-oriented programming, and other courses. Based on these courses, students can better understand distributed systems, which is making it more difficult for students to learn distributed systems. At the same time, each chapter has a lot of fragmented knowledge points. Only distributed algorithms involve environmental consistency and parallelism, which increases the difficulty of students' learning. Students feel that a large number of concepts and theories in the course are abstract and difficult to understand, so they lack interest in the course, can only remember a few scattered knowledge points, and cannot understand the relationship between distributed system architecture and knowledge point modules from a higher level relationship between the studies of [7, 8].

2.2. Teaching Methods Are Not Flexible Enough. The traditional teaching mainly adopts the classroom teaching method, and the teachers teach the knowledge points in the classroom. The focus of this teaching method is that the teacher explains one knowledge point after another, while the students are relatively passive, just bury their heads in recording the knowledge points taught by the teacher, and think less. Due to more theoretical knowledge, teachers rarely use diverse teaching methods, and there is a lack of interaction between students and teachers in the classroom. Teachers cannot understand students' mastery of courses in the classroom, and there is less interaction between students and teachers after class. The quality of teaching is shown in the studies of [9, 10].

3. Cloud Computing Architecture

From the problems in teaching, it can be seen that the knowledge points of distributed system courses are complicated. How to guide students to master this course in limited classroom time and actually apply it to life is the goal of our teaching reform. The traditional teaching method is not well integrated with real life but only explains the knowledge points in the textbook, which leads to students' lack of interest in distributed systems, and their understanding of distributed systems only stays on abstract concepts. We believe that the teaching of distributed systems should be based on the popular technology (cloud computing) as an entry point, which can not only stick to the content of classroom teaching but also arouse students' interest in distributed systems.

3.1. The Relationship between Cloud Computing and Distributed Systems. As we all know, cloud computing belongs to distributed system, which is a combination of data sharing and service sharing computing mode, and the distributed system is the architecture of cloud computing in the era of big data. The architecture of cloud computing is shown in Figure 1 [11].

- (1) A cloud computer cluster is formed by multiple computers. Because the cloud computing architecture is based on a distributed system, the degree of coupling and interaction between the computers in the cluster is higher than that of ordinary computers on the Internet, which makes the computing efficiency of cloud computing very high [12].
- (2) Because the distributed system is the underlying system of cloud computing, based on the characteristics of the distributed system, cloud computing can provide powerful data storage and computing capabilities.
- (3) Cloud computing can provide high reliability with the support of distributed systems. This comes from the basic idea of distributed systems (consistency, fault tolerance, and security), the failure of any node will not terminate the application service.
- (4) Because of the excellent fault tolerance, strong fault recovery ability, and security considerations of distributed systems, cloud computing can provide services at a low cost and has a high cost performance.
- (5) Distributed systems can provide frameworks and simple models to implement cloud computing applications. Developers do not need to consider issues such as fault tolerance, which is convenient for developers to quickly and effectively develop software.

4. Realization of Cloud Computing-Based Teaching Resource Platform Architecture

The teaching resource platform has three layers, the bottom layer is the mobile cloud computing platform layer, the middle layer is the teaching resource service layer, and the upper layer is the mobile application layer, as shown in Figure 2.

4.1. Cloud Computing Platform Layer. The mobile cloud computing platform layer is the foundation and core of the teaching resource platform. It builds a cloud environment through software technology and hardware resources and provides data services, computing services, storage services, and security services for the middle layer of the teaching resource layer. These services are implemented through virtualization technology VMware Workstation, distributed storage Hadoop distributed file system, and parallel computing technology MapReduce programming framework. The platform adopts a distributed storage system, which can meet the needs of storing different types of teaching data. Fault-tolerant processing, data parallel processing, load balancing, etc., are all implemented by the MapReduce programming. The Hadoop distributed file system separates the ownership and control of data on the network. To share data between different devices, some important private data will be at risk. Therefore, the mobile cloud computing platform must first ensure data security. The solution of the

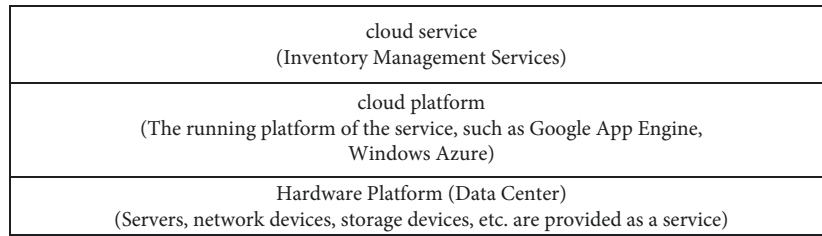


FIGURE 1: The three-tier structure of cloud computing.

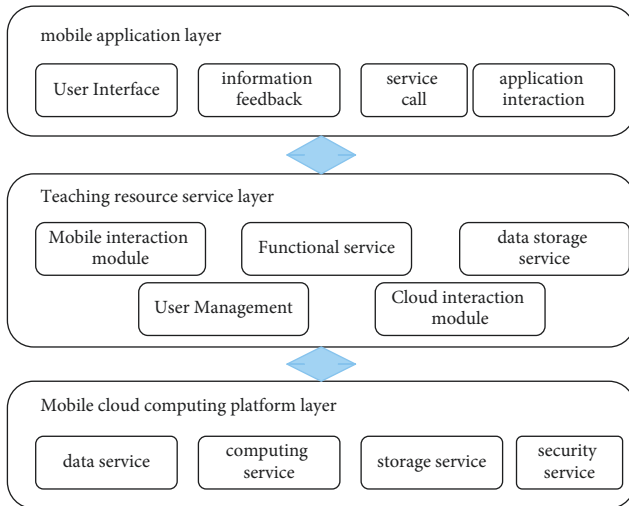


FIGURE 2: Teaching resource platform.

security service is to encrypt the data stored on the cloud server in advance. When accessing the data on the cloud server, decrypt it as needed [13, 14].

4.2. Teaching Resource Service Layer. As the middle layer, the teaching resource service layer is a bridge between users and the platform, providing users with services related to teaching resources. This layer provides an interactive interface for the mobile cloud computing platform layer through the cloud interaction module. This interface requires high adaptability and can be transplanted to different cloud computing platforms. The mobile interaction module in the teaching resource layer is used to provide interactive services for the mobile application layer and the teaching resource service layer, and customer requests and operations on the mobile application layer are processed and fed back by the mobile interaction module. The data in the teaching resource platform have the characteristics of rich types and a large amount of data, especially when the concurrency is large, the relational database cannot meet the needs of the platform. Therefore, the data storage adopts a distributed structure, and other transactions such as distribution and expansion are completed by the cloud [15, 16].

The design purpose of the teaching information management platform of cloud computing technology is to use cloud computing virtualization technology to establish a virtual resource pool for unified scheduling and management of teaching information. In this way, the software and

hardware resources of the teaching information platform can be managed in a unified manner, the teaching information can be integrated efficiently, and the integrated application system can truly share the data of the teaching information resources. Combined with the advantages of cloud computing technology analyzed above and the characteristics of the school's educational information management platform construction business, this paper designs an educational information management platform based on cloud computing technology, as shown in Figure 3.

4.3. Mobile Application Layer. The mobile application layer is directly oriented to customers and can be said to be the window provided by the platform to users, including four modules: user interface, information feedback, service invocation, and application interaction. The mobile application layer generates data interaction between the application interaction module, wireless network technology, and the teaching resource service layer and does not perform actual calculation processing. It is mainly used for information communication with the teaching resource service layer. More consideration should be given to the design. User-friendly interface for providing services and presenting data. The main functions of the mobile application layer are as follows: first, to provide users with a friendly operation interface; second, to provide the required static files or resources for the application; third, to provide a communication interface for the mobile application layer and the teaching resource service layer; fourth, to customize the relevant information to be displayed to the user by calling the interface of the mobile terminal; fifth, to call other application services through the mobile platform interface [17].

4.4. Cloud Computing Design. The educational information management platform in this paper is implemented based on cloud computing technology. The Hadoop cloud framework is selected in this paper, and MapReduce and HDFS technologies are responsible for the efficient processing of massive data information. In the operation using the MapReduce programming model, new intermediate values can be generated without changing the original information data, so the Map operation has strong parallel computing capabilities. HDFS is a key cloud computing technology used in the design of this paper. As a distributed file system, it forms a typical master-slave structure, including the NameNode master node and multiple DataNode slave

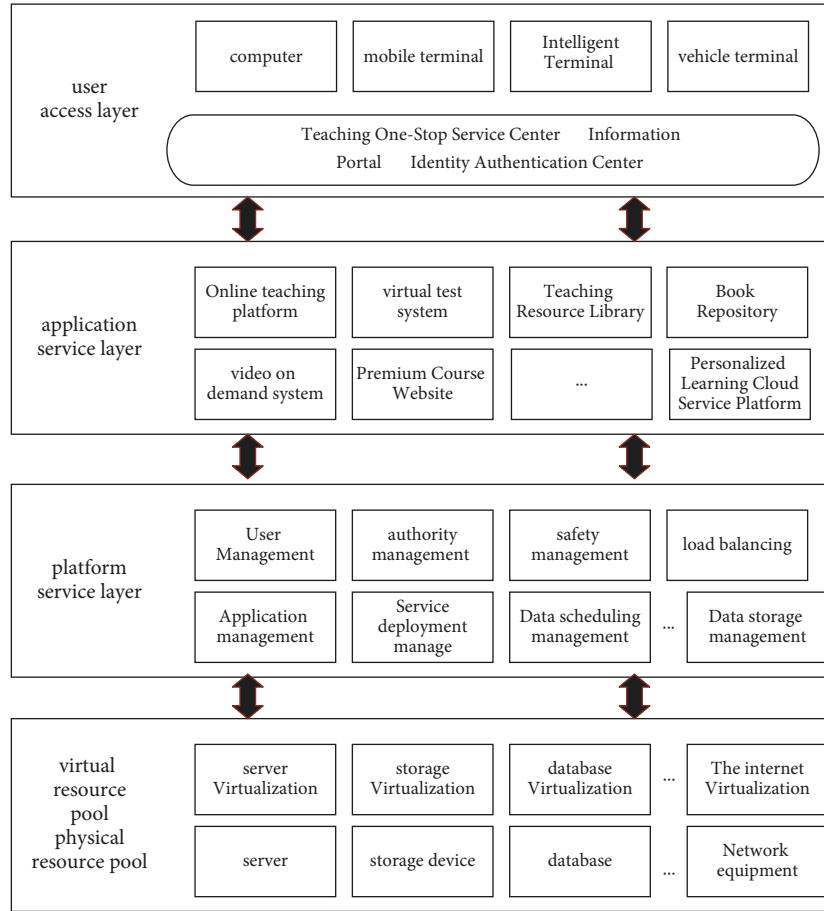


FIGURE 3: Educational information management platform.

nodes. In general, HDFS can name information files, and then cloud users can save relevant information to HDFS files in the name space or divide the information data into multiple content blocks and save them in different DataNode nodes [18, 19]. Figure 4 is an architecture diagram of HDFS, and Figure 5 is an architecture diagram of education information cloud computing based on HDFS technology.

The education information management platform is mainly for the collection, management, retrieval, and application of education information. The functional modules are designed as follows.

In this platform application, administrators can set system titles, columns, layouts, and specific pages, as well as custom management metadata and class library management.

In the design of this function, it is necessary to manage basic information such as user name, password, and department, divide the different application user roles of the platform, and design the corresponding user platform management authority level, including uploading, downloading, commenting, status display, and Information review.

The modular design is implemented in the platform of this paper, and cloud users can customize the display design of all levels of the platform. When designing teaching courses, you can refer to the subject classification method. First-level disciplines correspond to multiple second-level

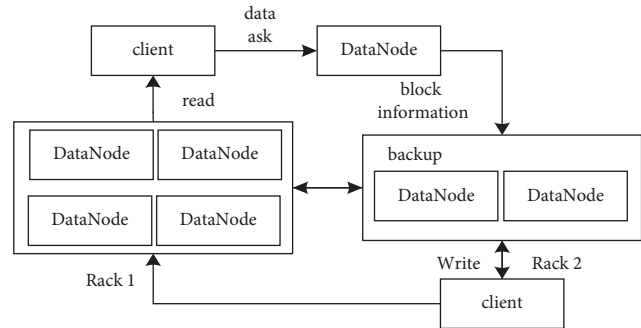


FIGURE 4: HDFS architecture diagram.

disciplines, and each second-level discipline can add corresponding course resources according to different professional courses of users [20].

Responsible for creating, modifying, and deleting categories, including videos, e-books, e-learning plans, high-quality courses, and other resources in the information category management, can upload, modify, delete, review, and publish related resources, as well as add and publish specific course information title, introduction, attachments, pictures, etc. and display them dynamically.

The education information management platform can not only realize the construction and management of

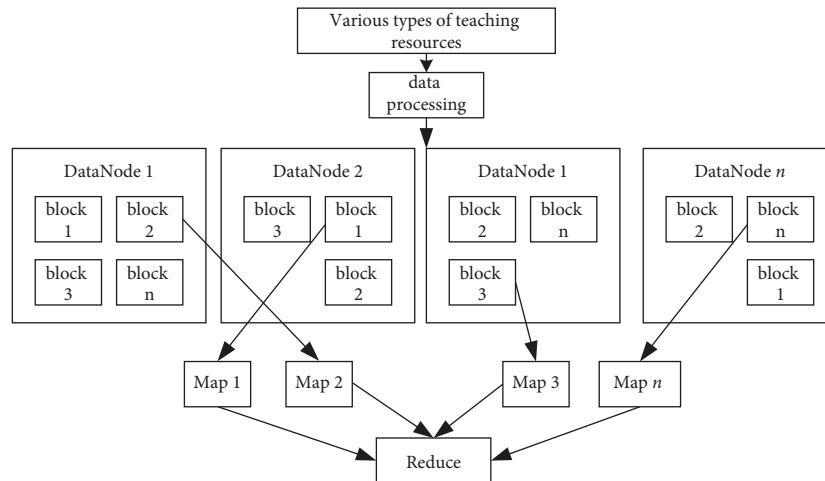


FIGURE 5: Educational information cloud computing architecture based on HDFS.

teaching resources for cloud users but also realize the connection of resources between platforms at different levels of schools, provinces, and countries, so as to satisfy users' resource sharing in platform applications and realize the sharing of teaching resources: public cloud and private cloud.

5. Database Design

The educational information management system platform in this paper is based on the B/S platform architecture to meet the operational needs of teachers, students, and platform administrators. The system is based on the Linux operation server, uses the Web server to establish the SQL Server database, and is designed in combination with the functional modules of the platform. The database relationship table to be created includes users, departments, teachers, courses, and teaching resources.

In the design of the educational information management platform, JDBC provides a set of Java APIs for database operations. All database classes and interfaces are implemented by the Java programming language to achieve the characteristics of cross-platform technology.

When designing the cloud computing education information management platform, it is necessary to comprehensively consider the roles of cloud users, the level of authority, and the operation and management of information resources. Three types of users are divided, including administrators, auditors, and users. The administrator is mainly responsible for the professional management of the educational information of the whole school and has the right to authorize the auditor of a certain department to manage and maintain the educational information resources as a whole; the auditor is responsible for the template management of educational information, the establishment of a professional resource database, and the approval of data resource information, including the functions of uploading, modifying, and deleting information; users can build an educational information management website and establish a personalized personal operation service center to extract

data to meet cloud user applications. Figure 6 shows the business process of the educational information platform [21].

6. Case Studies

The user service management module includes managers, paid users, visitors, and registered users. Managers can view the progress of learning, use the learning community, etc. The user's identity to open the designated resources according to the type of the user. As shown in Figure 7, the optimization effect of teaching cloud resources by different methods [22].

The academic team evaluates the open courses according to specific regulations, processes the open courses according to the actual needs of the learners, and then publishes them on the real-time interactive platform, giving the corresponding retrieval function. Share and publish it on your personal real-time interactive platform. In addition, you can also select excellent open course resources from the public course resources and put them into your own real-time interactive platform to conduct more effective learning. For some open course resources, teacher evaluation or an evaluation system can be set up to improve the teaching quality of open courses and attract more learners' attention. As shown in Figure 8, the acceptance of teaching by different learners, teachers can use corresponding tools to record the teaching process in the process of teaching the course and make it into the courseware of the open course for learners to learn and use. Teachers can also add content where they need to be added, thereby improving learners' comprehension. In general, when producing a new open course, there is no need for the help of professionals and production companies, thus reducing the workload of the staff [23, 24].

During the learning process of open courses, many learners will choose the same courseware to study at the same time, resulting in a relatively high number of on-demand courses. As shown in Figure 9, different learners have different clouds. Calculate the learning tracking of teaching, and provide timely feedback on the teaching situation of

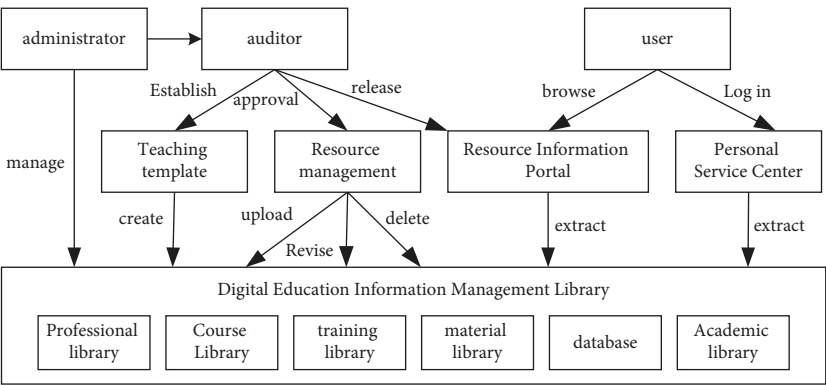


FIGURE 6: Business process of education information platform.

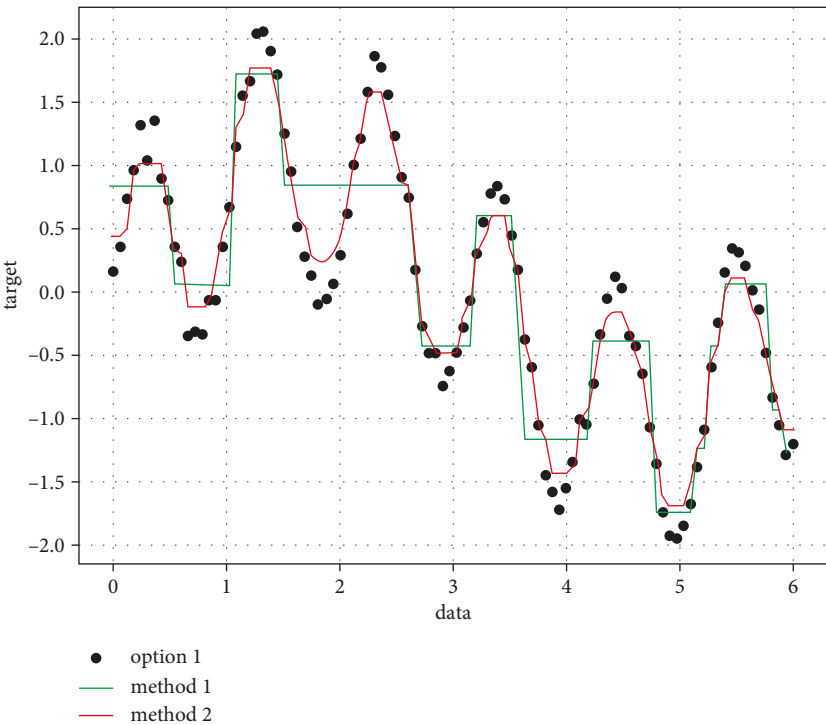


FIGURE 7: Cloud computing optimization with different methods.



FIGURE 8: Acceptance of different learners.

teachers, so as to obtain a better teaching effect. In addition, the platform can also analyze the learners' listening status and attention level through corresponding technology, thereby improving the application of the open course real-time video interactive platform.

The application of network signal in the place where the learners are located, no matter whether accessing the open courses. The most important thing is that the version of mobile phones and computers is taken into account when making open courses so that various interfaces are produced to meet the needs of various versions, making it very convenient to enter the course for learning. In addition, if the learner wants to log out after logging in, he can keep the current state, and the next time he logs in, he can directly continue the learning in the last place, which saves many

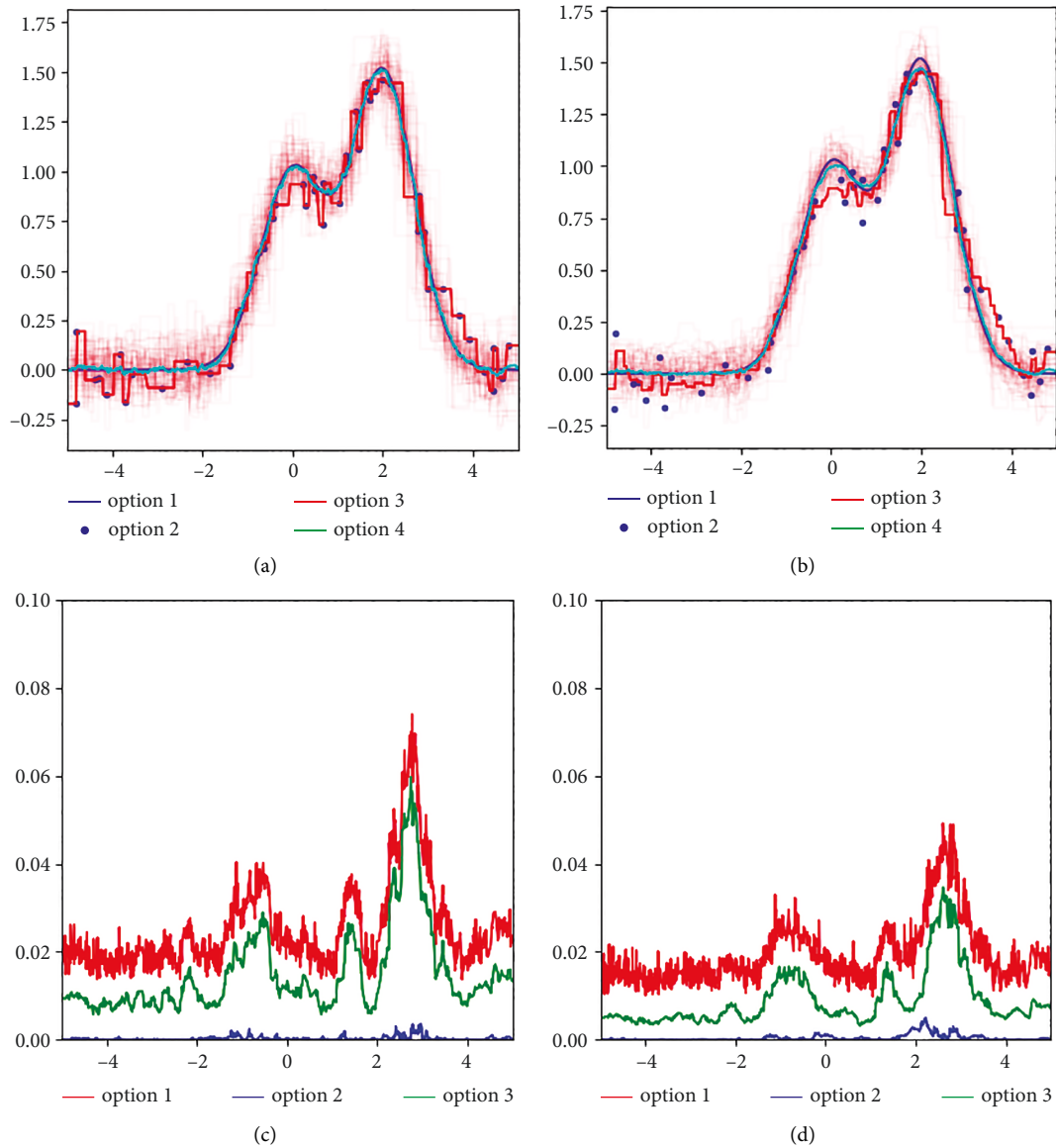


FIGURE 9: Learning tracking of different learners and different cloud computing teaching.

unnecessary steps, and the interface and the entrance are also designed in a very human way. In this very convenient situation, the enthusiasm and initiative of the learners to visit the open courses are improved, and the effective promotion of the open courses is realized.

7. Conclusion

The cloud computing environment checks whether the avatar is a logged-in registrant. During the learning process, the system will take the learner's avatar and log in. The avatars of the registrants are compared and accurate information is sent to the teacher. The learner's attention can be monitored in terms of how long the learner is away from the screen and the number of times other procedures are taken to cover the learning page. If the learner's concentration level is below the specified level, the system will

automatically determine that the learner did not concentrate all the way as a basis for evaluating the learner's learning effect. In order to improve the model performance, we plan to optimize different parameters, design more advanced models, etc. and have expanded the application scenarios of this method.

Data Availability

The experimental 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 to report regarding the present study.

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Research Article

Target Filter Tracking Algorithm Based on IABBSCA-IMM

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Aiming at the problem that the probability transition matrix is set by prior information and the filtering parameters are fixed in the traditional interactive multimodel (IMM) algorithm, which leads to the model probability lag in the switching process and the low filtering and tracking accuracy, an interactive multimodel filter tracking (IABBSCA-IMM) algorithm with improved parameter adaptive and bare bone sine cosine optimization is proposed. First, the Markov probability transition matrix is dynamically adjusted and limited conditions are added through the parameter adaptation method; then, the filtering parameters Q and R are optimized by the bare bones sine cosine algorithm (BBSCA); finally, three motion models of CV (uniform velocity motion), CA (uniform acceleration motion), and CT (uniform velocity turning motion) are used to conduct filtering and tracking experiments on the target. The simulation results show that, compared with the IMM algorithm, the AMP-IMM algorithm, the IASCA-IMM algorithm, and the IABBSCA-IMM algorithm proposed in this study have the smallest position and velocity root mean square error (RMSE) in the X and Y directions, and the accuracy is better.

1. Introduction

In recent years, with the vigorous development of electronic information technology and modern control technology [1], target filtering and tracking technology has been widely used in automatic driving [2], smart security [3], traffic planning [4], navigation, and positioning [5] and has played a vital role. Its essence is to use the state information of the target at the current moment and the measurement information obtained by the sensor to realize the method of estimating the state information at the next moment [6]. The interacting multiple model algorithm (IMM) [7] is a very effective target filtering and tracking algorithm. It adopts multiple fixed parallel models to describe the motion pattern of the target and introduces the Markov probability transition matrix to associate the input state of each motion model with a dynamic model to interact with each other. The commonly used motion models include the constant velocity model (CV), the constant velocity turning model (CT), the constant acceleration model (CA), and the Singer model [8]. The optimal state estimation is obtained by calculating the filtering results of each filter using weighted fusion. Although

the IMM algorithm overcomes the problem of fixed single model, there are also problems such as the presetting of Markov probability transition matrix elements and the fixed filtering parameters Q and R , which have a great impact on the filtering and tracking accuracy.

The prior setting of the probability transition matrix leads to the probability lag problem of the switching process model. Rongchun Z et al. proposed the AMP-IFIMM algorithm, defined the concept of error compression ratio, and adaptively adjusted the Markov probability transition matrix through the ratio of the error compression ratio to increase the probability of matching models and reduce the probability of mismatching models. However, this method is only suitable for two-model systems and cannot be generalized to multiple models [9]; Puwen et al. proposed a Markov matrix modified IMM filter tracking algorithm (AMP-IMM), which extended the method of literature [9] to three or more models, but some necessary conditions still need to be met during adaptive adjustment, and there are also certain restrictions on the use of the model [10]; Biao et al. proposed to use the current measurement information to adaptively update the model probability of the target and use the

updated model probability to make a hybrid prediction of the target state, which improved the filtering performance of the algorithm to a certain extent [11]; YE et al. defined a new correction factor and used the posterior information to correct the probability transition matrix in real time, which improved the probability of matching the model and improved the filtering and tracking accuracy to a certain extent [12]. The above algorithms modify the probability transition matrix and improve the probability lag problem of the switching process model but do not solve the problem of filtering parameters Q and R fixed.

Aiming at the problem of low filtering and tracking accuracy caused by fixed filtering parameters, Lijun Y et al. used adaptive innovation Kalman filter to estimate the process noise covariance matrix Q and the measurement noise covariance matrix R , which improved the prediction accuracy, but it has not been extended to multimodel [13]; Ullah I et al. adjusted the covariance matrix of noise through artificial neural network, which improved the filtering performance of the algorithm to a certain extent, but the calculation amount was large and the model design was complicated [14]; Zhao C et al. used fuzzy control method to adjust the weight of the matching model and automatically adjusted the process noise level through the fuzzy inference mechanism, which enhanced the adaptiveness of the algorithm [15]; Liu H et al. adaptively adjusted the error covariance matrix of the dynamic model through a synchronous optimization feedback learning algorithm for maneuvering target tracking based on Elman neural network (ENN), optimized the final state estimation, and improved the estimation accuracy of the algorithm [16]. The above algorithms adjust the filtering parameters Q and R and improve the filtering accuracy to a certain extent. However, the problem of the probability lag of the switching process model caused by the prior setting of the probability transition matrix is not studied.

Based on the IMM algorithm, this study uses the parameter adaptation method to dynamically adjust the Markov probability transition matrix after each model probability update, which increases the switching probability to the matching model. The BBSCA is used to optimize the filter parameters Q and R , which improves the filter tracking accuracy. Then, the IABBSA-IMM algorithm is proposed, and the effectiveness of the proposed algorithm is verified by simulation experiments.

2. Principle of Interactive Multimodel (IMM) Algorithm

When filtering and tracking a target, since it may contain a variety of motion states, if a single model is used for filtering and tracking, then it may cause large errors or even loss of the target. The IMM algorithm first sets the model set $M = \{m_1, m_2, \dots, m_r\}$, which contains multiple possible motion models; then, the different models in M are filtered in parallel by the filter to match the model with the motion state; then, the optimal estimated value of the previous moment is mixed to obtain the initial condition of the filter

matching the specific model and filtered; finally, the maximum likelihood function is used to update the model probability, and the optimal state estimate is obtained through weighted calculation.

If the target has r motion states, corresponding to r models and state transition equations, then the target state equation represented by the j th model is as follows:

$$X_j(k+1) = \Phi_j(k+1)X_j(k) + G_j(k)W_j(k). \quad (1)$$

The measurement equation is as follows:

$$Z_j(k+1) = H(k+1)X_j(k+1) + V_j(k), \quad (2)$$

where $X_j(k)$ is the state vector of model j at time k , $Z_j(k)$ is the measurement vector of model j at time k , $\Phi_j(k+1)$ are the state transition matrix and noise coefficient matrix of model j at time k , respectively, and $H(k+1)$ is the measurement matrix. Both the process noise $W_j(k)$ and the measurement noise $V(k)$ of model j have zero mean, and the covariance matrices are Gaussian white noise of Q_j and R_j , respectively. The switching between models is determined by the Markov probability transition matrix, P_{ij} represents the probability that the i th motion model is transferred to the j th motion model, and the probability transition matrix is as follows:

$$P = \begin{bmatrix} p_{11} & \cdots & p_{1r} \\ \vdots & \ddots & \vdots \\ p_{r1} & \cdots & p_{rr} \end{bmatrix}. \quad (3)$$

The IMM algorithm is mainly divided into four steps: input interaction, parallel filtering, probability update, and output interaction. The specific analysis is as follows:

Step 1. Enter the interaction.

The mixed estimate $\hat{X}_{0j}(k-1|k-1)$ and covariance $P_{0j}(k-1|k-1)$ are calculated from the state estimate $\hat{X}_i(k-1|k-1)$ at the previous moment and the probability $\mu_i(k-1)$ of each model, and the mixed estimate is used as the initial state of the step cycle. After normalization, the predicted probability of model j is as follows:

$$\bar{c}_j = \sum_{i=1}^r p_{ij}\mu_i(k-1). \quad (4)$$

The mixture probability of model i to model j is as follows:

$$\mu_{ij}(k-1|k-1) = \sum_{i=1}^r p_{ij}\mu_i\left(\frac{(k-1)}{\bar{c}_j}\right). \quad (5)$$

Mixed state estimation for model j is as follows:

$$\hat{X}_{0j}(k-1|k-1) = \sum_{i=1}^r \hat{X}_i(k-1|k-1)\mu_{ij}(k-1|k-1). \quad (6)$$

The mixed covariance of model j is estimated as follows:

$$P_{0j}(k-1|k-1) = \sum_{i=1}^r \mu_{ij}(k-1|k-1) \left\{ P_i(k-1|k-1) + \left[\hat{X}_i(k-1|k-1) - \hat{X}_{0j}(k-1|k-1) \right] \left[\hat{X}_i(k-1|k-1) - \hat{X}_{0j}(k-1|k-1) \right]^T \right\}. \quad (7)$$

where P_{ij} is the transition probability from model i to j , and $u_j(k-1)$ is the probability of model j at time $k-1$.

Step 2. Carry out the filtering process.

Kalman filtering is performed with $\hat{X}_{0j}(k-1|k-1)$, $P_{0j}(k-1|k-1)$, and $Z_j(k)$ as input, and the prediction state $\hat{X}_j(k|k)$ and filter covariance $P_j(k|k)$ are updated.

Predicted state is as follows:

$$\hat{X}_j(k|k-1) = \Phi_j(k-1) \hat{X}_{0j}(k-1|k-1). \quad (8)$$

Prediction error covariance is as follows:

$$P_j(k|k-1) = \Phi_j P_{0j}(k-1|k-1) \Phi_j^T + G_j Q_j G_j^T. \quad (9)$$

The gain is as follows:

$$X_j(k) = P_j(k|k-1) H^T [H P_j(k|k-1) H^T + R]^{-1}. \quad (10)$$

result of filtering is as follows:

$$\begin{aligned} \hat{X}_j(k|k) &= \hat{X}_j(k|k-1) \\ &+ K_j(k) [Z_j(k) - H(k) \hat{X}_j(k|k-1)]. \end{aligned} \quad (11)$$

Filter covariance is as follows:

$$P_j(k|k) = [I - K_j(k) H(k)] P_j(k|k-1). \quad (12)$$

Step 3. Update the model probability.

The model probability is updated using the likelihood function, and the likelihood function of model j is as follows:

$$\Lambda_j(k) = \frac{1}{(2\pi)^{n/2} |S_j(k)|^{1/2}} \exp \left\{ -\frac{1}{2} v_j^T S_j^{-1}(k) v_j \right\}. \quad (13)$$

In the above equation,

$$v_j(k) = Z(k) - H(k) \hat{X}_j(k|k-1), \quad (14)$$

$$S_j(k) = H(k) P_j(k|k-1) H^T(k) + R(k). \quad (15)$$

Then, the model probability is as follows:

$$\mu_j(k) = \Lambda_j(k) \frac{\bar{c}_j}{c}, \quad (16)$$

where $c = \sum_{j=1}^r \Lambda_j(k) \bar{c}_j$ is the normalization constant.

Step 4. Obtain the output.

According to the model probability calculated in the previous step, the results of each filter are weighted and fused to calculate the total state estimate $\hat{X}(k|k)$ and the total covariance estimate $P(k|k)$. The total state estimate is as follows:

$$\hat{X}(k|k) = \sum_{j=1}^r \hat{X}_j(k|k) \mu_j(k). \quad (17)$$

Total covariance estimate is as follows:

$$P(k|k) = \sum_{j=1}^r \mu_j(k) \left\{ P_j(k|k) + \left[\hat{X}_j(k|k) - \hat{X}(k|k) \right] \left[\hat{X}_j(k|k) - \hat{X}(k|k) \right]^T \right\}. \quad (18)$$

3. IABBSA-IMM Algorithm

In this study, an IABBSA-IMM target filter tracking algorithm is proposed. First, the Markov transition matrix is dynamically adjusted and limited conditions are added to increase the switching probability to the matching model; then, the bare bones sine cosine algorithm (BBSA) improved on the basis of the SCA is used to optimize the filtering parameters Q and R to improve the filtering and tracking accuracy; finally, the detailed flow of the IABBSA-IMM algorithm is given and verified by simulation.

3.1. Dynamic Adjustment of Markov Transition Probability. Analyzing the error compression rates proposed in literature [9] and [10], it can be seen that the denominator parts are all C_j defined by equation (4), while the compression ratio defined by the AMP-IMM algorithm proposed by the latter has fewer numerator terms. According to literature [17], it can be seen that for the system including multimotion models, the expression of the molecular part is no longer the same, so the error compression ratio of each model is also different, and the ratio of the error compression ratio needs to be redefined:

$$d_{ij} = \frac{p_{ji}}{p_{ij}} \times \frac{\bar{C}_j}{\bar{C}_i}, \quad (19)$$

where $\bar{C}_j = p_{1j}\mu_1(k) + p_{2j}\mu_2(k) + \dots + p_{Nj}\mu_N(k)$, d_{ij} represents the ratio of the error compression ratio for switching from model i to model j , and the adjusted Markov transition matrix is as follows:

$$P_{ij}^* = \begin{bmatrix} p_{11}^* & p_{12}^* & \dots & p_{1N}^* \\ p_{21}^* & p_{22}^* & \dots & p_{2N}^* \\ \dots & \dots & \ddots & \dots \\ p_{N1}^* & p_{N2}^* & \dots & p_{NN}^* \end{bmatrix}, \quad (20)$$

where the diagonal element is $p_{ii}^* = 1 - d_{i1}^l p_{i1} - \dots - d_{iN}^l p_{iN}$, $i \neq j$ and the off-diagonal element is $p_{ij}^* = d_{ij}^l p_{ij}$, $i \neq j$. This study takes three models as an example, and the ratio of the error compression ratio is as follows:

$$d_{12} = \frac{p_{21}}{p_{12}} \times \frac{p_{12}\mu_1(k) + p_{22}\mu_2(k) + p_{32}\mu_3(k)}{p_{11}\mu_1(k) + p_{22}\mu_2(k) + p_{33}\mu_3(k)}. \quad (21)$$

Comparing the model error compression rate defined in literature [9], it can be found that equation (21) is a generalization in three or more models, and the Markov transition matrix elements in the multimodel system no longer have the characteristic of $p_{11} = 1 - p_{12}$. The necessary conditions for adaptive adjustment at this time are as follows:

$$\frac{\bar{C}_i}{\bar{C}_j} > \frac{p_{ji}}{p_{ij}}, \mu_i(k) > \mu_j(k). \quad (22)$$

For a system that satisfies the above equation, the Markov transfer matrix can be adaptively adjusted by equation (19), and the condition $0 < p_{ij} < 1$, $\sum_{j=1}^N p_{ij} = 1$ is satisfied, but after multiple adaptive adjustments, the main diagonal elements of the Markov transfer matrix may not always be the same. Occupying a large proportion, the transition probability $p_{ii} < 0.5$ corresponding to the model with smaller μ_i will appear, which is contrary to the physical meaning of the Markov transition matrix. p_{ii} indicates that the target maintains the current motion mode. If its value is less than 0.5, then it means that the state is an instantaneous switching state rather than a stable motion mode, and it may also cause the covariance matrix to be nonpositive definite. Therefore, this study adds a limit to this situation and adds a judgment link in the process of algorithm iteration. If the value of the main diagonal element of the Markov transition matrix is greater than 0.6, then the matrix element is updated; otherwise, it is not updated.

To sum up, the specific steps of dynamic adjustment of Markov transition probability are as follows:

Step 1. Complete interactive input, filtering process, and model probability update according to equations (4)–(16).

Step 2. Determine whether the model switching probability satisfies equation (22), and if so, adjust each

element in the probability transition matrix according to equation (19).

Step 3. Determine according to the elements in the adjusted Markov transition matrix. If the main diagonal elements are all greater than 0.6, then update the probability transition matrix; otherwise, do not update.

Step 4. According to equations (17) and (18), calculate the results of each filter and weight them for fusion, and calculate the total state estimation value and covariance matrix.

3.2. BBSCA Optimizes Filter Parameters Q and R . Through the dynamic adjustment of Markov transition probability, the problems of fixed probability transition matrix and slow adjustment of model probability are solved. However, the IMM algorithm still has the disadvantage of fixed model noise. The stronger the degree, the larger the covariance, and vice versa. In this study, the BBSCA proposed on the basis of the SCA is used to optimize the filtering parameters Q and R , and the optimized parameters are used as a new round of filtering input to optimize the filtering process and improve the target filtering tracking accuracy.

3.2.1. Basic Sine Cosine Algorithm (SCA). The SCA is a new swarm intelligence optimization algorithm [18], which has the characteristics of high flexibility and fast convergence. The optimization process can be divided into two phases: search and development. The first stage quickly finds feasible regions in the search space by combining a random solution among all the random solutions. In the second stage, the random solution changes gradually, and the change is lower than that in the first stage. The algorithm starts from a series of random solutions, optimizes by combining sine and cosine functions and random factors, and continuously approaches the global optimal solution. The update equation is as follows:

$$X_i^{t+1} = \begin{cases} X_i^t + r_1 \times \sin(r_2) \times |r_3 p_i^t - X_i^t|, & r_4 < 0.5, \\ X_i^t + r_1 \times \cos(r_2) \times |r_3 p_i^t - X_i^t|, & r_4 \geq 0.5, \end{cases} \quad (23)$$

where X_i^t is the position in the i th dimensional search space in the t th iteration of the current particle; r_1 is a linearly decreasing function, and its expression is as follows:

$$r_1 = a - t \frac{a}{T}, \quad (24)$$

where a is a constant 2 and T is the maximum number of iterations; r_2 is a random number in $[0, 2\pi]$; r_3 is a random number in $[0, 2]$; r_4 is a random number in $[0, 1]$; p_i^t represents the position of the i th dimension of the optimal individual position variable in the t th iteration. Parameter r_1 determines the location area (or moving direction) of the next solution, and it controls the algorithm for global search or local development. The parameter r_2 determines the current solution direction or the distance away from the target solution. Parameter r_3 is a weight given by the target solution, and the purpose is to randomly enhance ($r_3 > 1$) or

weaken ($r_3 < 1$) the influence of the target solution in defining the distance of the candidate solution. The function of parameter r_4 is to switch the components of sine and cosine with equal probability.

3.2.2. Bare Bones Sine Cosine Algorithm (BBSCA). In SCA, the direction of particle movement is only determined by the parameter r_1 , which causes the algorithm to converge prematurely and fall into a local optimum. The BBSCA improves the problems of the SCA from three aspects [19]. First, the directional control parameters are reasonably selected, and a nonlinear decreasing control strategy based on an exponential function is adopted. The newly proposed update mechanism is shown in the following equation:

$$r_1 = a \times \exp\left(\frac{t}{T_{\max}}\right). \quad (25)$$

The parameter a is a constant, t is the current iteration, and T_{\max} represents the maximum number of iterations. As r_1 changes, the value of X_i^t will also change when the position is updated. The expression is similar to equation (23) in the SCA, and the formula is expressed as follows:

$$X_i^t = \begin{cases} X_i^{t-1} + r_1 \times \sin(r_2) \times |r_3 p_i^{t-1} - X_i^{t-1}|, & r_4 < 0.5, \\ X_i^{t-1} + r_1 \times \cos(r_2) \times |r_3 p_i^{t-1} - X_i^{t-1}|, & r_4 \geq 0.5, \end{cases} \quad (26)$$

where r_2 , r_3 , and r_4 are consistent with the standard SCA and r_1 is the newly proposed parameter in equation (25). The BBSCA uses the Gaussian skeleton search equation to revise the updated position equation and uses the useful information of the global optimal solution to improve the SCA convergence speed. The formula is expressed as follows:

$$dY_i^t = N\left(\frac{X_{g_{\text{best}_j}(t)} + X_i^t}{2}, |X_{g_{\text{best}_j}(t)} - X_i^t|\right), \quad (27)$$

where $X_{g_{\text{best}_j}(t)}$ is the j th component of the optimal solution at the t th iteration, $j \in \{1, 2, \dots, D\}$ is a randomly selected indicator, X_i^t is a randomly selected global optimal solution, and the reason for using random selection is that it is fast, easy to calculate, and maintains diversity. Finally, in order to improve the local search ability, the greedy selection strategy and the frame optimization algorithm are integrated into the optimal solution search equation to maintain the optimal fitness value of the individual in the next generation. The formula is expressed as follows:

$$X_i^{t+1} = \begin{cases} Y_i^t \text{fit}(Y_i^t \leq \text{fit}(X_i^t)), \\ X_i^t \text{fit}(Y_i^t > \text{fit}(X_i^t)), \end{cases} \quad (28)$$

where fit is the fitness function and the “ \leq ” sign reduces the possibility of search stagnation. The search equation introduced according to the previous introduction is as follows:

$$Y_i^t = \begin{cases} \text{Eq. (27)}, & r_5 < 0.5, \\ \text{Eq. (26)}, & r_5 \geq 0.5, \end{cases} \quad (29)$$

where r_5 is a random number between 0 and 1.

To sum up, the BBSCA maintains the advantages of simple principle and convenient use of SCA. It obtains useful information contained in the optimal solution through the Gaussian search equation and uses the exponential decrease and greedy selection strategy based on fitness value to guide the search to a better direction.

3.2.3. Filter Parameter Optimization. In this study, the BBSCA is used to optimize the parameters Q and R , and the actual mean square error of the innovation is used as the objective function, as shown in the following equation:

$$f_i = \frac{\sum_{j=1}^N \epsilon_j^i(k)^2}{N}. \quad (30)$$

In the above equation, $\epsilon_j^i(k)$ is the innovation sequence, defined as $\epsilon_j(k) = Z(k) - H(k)X_j(k|k-1)$, f_i represents the fitness value of the i th particle, and j represents the filter corresponding to the j th model. Since three motion models are selected, $N = 3$.

First, the innovation sequence of each filter is calculated to obtain the actual mean square error of the state information, and then the BBSCA is added to optimize the filter parameters online. The parameter Q is a diagonal matrix, and R is a constant matrix [20]. The specific optimization process is as follows:

Step 1. Initialize each filter and corresponding parameters after adjustment of Markov transition probability parameters, and establish a filter model.

Step 2. Set basic parameters. Since there are a total of 6 parameters in 3 models to be optimized, the problem dimension D is selected as 6, the number of individuals N is set as 10, the maximum optimization algebra itmax is 100 generations, the BBSCA control parameters r_1 – r_5 and the related control equations are initialized, and the parameters Q and R contained in the three filters are optimized respectively for each group.

Step 3. According to the parameter optimization range, randomly initialize the position information of the particle swarm in the search area, and limit the boundary.

Step 4. Set the fitness function as the actual mean square error of the state information, substitute the parameters of each particle into the algorithm to establish a filter model, and obtain the fitness value of each particle through calculation.

Step 5. Compare the fitness values of 10 particles in the first population and find the particle with the smallest value, take its value $\text{my_bb1}(j)$ as the optimal Q_1 value of the j th generation result, and record its location as $\text{my_bbg1}(j)$ as the optimal position of the j th generation group. If the result is the first generation optimization result, then $\text{bbg1}(j)$ is used as the optimal

position (i.e., the optimal parameter) of the current population, and the same is true for other groups.

Step 6. Compare the minimum fitness value $my_bbil(j)$ obtained by the j th generation of particles in the population with the minimum fitness value obtained after the optimization of the previous generations of particles, if the minimum fitness value of the j th generation particle is smaller, then replace the values loaded by $my_bbil(j-1)$ and $my_bbg1(j-1)$ with the minimum fitness value and optimal position of the j th generation, otherwise unchanged, and the same is true for other groups. After the j th generation optimization in this way, the optimal group parameter with the smallest fitness value is the optimal position of the current group.

Step 7. Adjust the particle control parameter r_1 according to equation (25), and regenerate new random numbers r_2 – r_5 according to the range.

Step 8. Determine whether the end condition is reached, if not, go to step 5; otherwise, output the optimal value, and the optimization ends.

The end condition of the optimization process is that the number of iterations reaches a predetermined value or the fitness function is zero. After the end, the obtained individual optimal positions (Q_1, R_1, Q_2, R_2, Q_3 , and R_3) are passed to the IMM filter tracking algorithm dynamically adjusted by Markov transition probability, and apply the new optimized Q and R to the next state estimation model.

3.3. IABBSCA-IMM Algorithm Flow. As shown in Figure 1, it is a schematic flow chart of the IABBSCA-IMM algorithm. First, set the initial Q and R values, initialize the filter model, establish a state estimation model, and perform input interaction, time update, and measurement update; secondly, complete the state update and covariance update according to the new measurement value, calculate the model probability, dynamically adjust the transition probability matrix, and complete the weighted fusion output of the filtering results; then, calculate the fitness function, use the BBSCA to optimize the filtering parameters, and obtain the next round of new filtering parameters \hat{Q} and \hat{R} ; finally, filter and track the next moment according to the new filtering parameters and transition probability matrix, and loop until the end of the algorithm.

4. Experimental Simulation and Process Analysis

Experiments were performed using MATLAB R2018b on Intel(R) Core(TM) i5-1135G7 CPU @2.40 GHz, 16.00 GB RAM, and Windows 10 system. Let the target be maneuvered in a two-dimensional plane, and the state variables $x_k = [x_k \ v_x \ y_k \ v_y \ a_x \ a_y]^T$ represent the position, velocity, and acceleration components of the target in the x and y directions. The initial state of the target is

$x_0 = [5 \ 0 \ 100 \ -5 \ 0 \ 0]^T$. The observations are the position and velocity information of the target. The sampling interval $T=0.1$ s and the simulation time $t=43$ s. Suppose the target does uniform linear motion between 0 and 10 seconds with $v_x = 0$ m/s and $v_y = -5$ m/s, does uniformly accelerated turning motion between 10 and 14 seconds with constant acceleration $a_x = 0.25$ m/s² and $a_y = 1$ m/s², ending with $v_x = 1$ m/s and $v_y = -1$ m/s, does uniform turning motion at the end of the phase above 14–34 seconds with v_x and v_y , and does uniform turning motion between 34 and 38 seconds and does uniform acceleration motion between 34 and 38 seconds, and constant acceleration is applied in the x and y directions, the end of $v_x = 0$, $v_y = 8$ m/s; and does uniform linear motion in the rest of time. The system noise and observation noise are independent of each other. The CV process noise covariance matrix is $Q_{cv} = \text{diag}(0^2 \ 0^2)$. The CA process noise covariance matrix is $Q_{ca} = \text{diag}(0.1^2 \ 0.1^2)$. The CT process noise covariance matrix is $Q_{ct} = \text{diag}(0.12^2 \ 0.12^2)$. The measurement noise covariance matrix of each model is $R_{cv} = I_3 \text{ m}^3/\text{s}^6$, $R_{ca} = 0.8I_3 \text{ m}^3/\text{s}^6$, and $R_{ct} = 1.2I_3 \text{ m}^3/\text{s}^6$. The obstacle filter tracking algorithm uses three models CV (uniform motion), CA (uniform acceleration motion), and CT (uniform turning motion) for tracking. The initial probability of each model is $\mu_0 = [0.8 \ 0.1 \ 0.1]$. The initial value of the Markov probability transfer matrix is as follows:

$$P_0 = \begin{bmatrix} 0.8 & 0.1 & 0.1 \\ 0.1 & 0.8 & 0.1 \\ 0.1 & 0.1 & 0.8 \end{bmatrix}. \quad (31)$$

First, the error compression rate is introduced and the Markov probability transfer probability is dynamically adjusted. Then, the filter parameters Q and R are optimized. For optimization, the problem dimension D is selected as 6, the number of individuals N is 10, and the maximum optimization generation $itmax$ is 100 generations. The SCA and BBSCA are used for parameter optimization. In this experiment, the filter tracking of state information is performed from the 2nd second (i.e., the 20th sampling point). Since parameter optimization is performed for each filtering, the convergence curve of the fitness function can be obtained as shown in Figures 2(a) and 2(b) for the first filtering, where the horizontal axis is the number of iterations and the vertical axis is the fitness value, that is, the actual mean square error of the innovation.

Respectively optimized by the standard sine cosine optimization algorithm (SCA) and bare bone sine cosine optimization algorithm (BBSCA), the respective new filter parameters Q and R can be obtained for each corresponding CV, CA, and CT motion models. Using them for the next moment of filter tracking can further improve the filtering accuracy. The time consumed by the above two algorithms and the parameters of each motion model after optimization are listed in Table 1.

As shown in Figure 3, the optimization results and time consumption of the two algorithms are compared. It can be seen that the time consumed by the two algorithms is

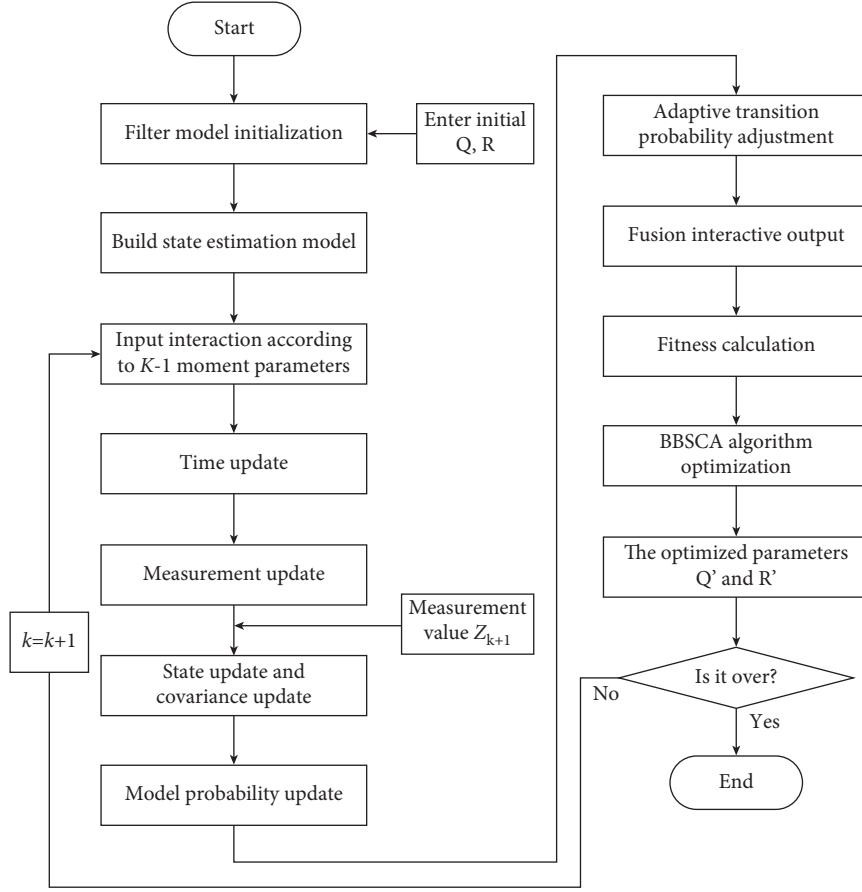


FIGURE 1: Schematic diagram of the IABBSCA-IMM algorithm flow chart.

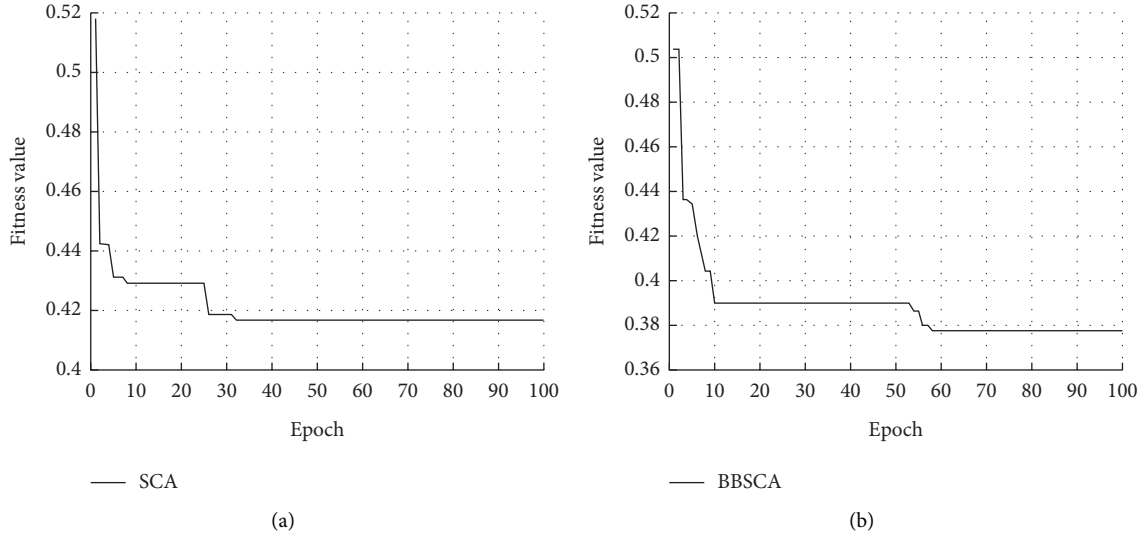


FIGURE 2: Convergence curve of the fitness function. (a) SCA. (b) BBSCA.

basically the same, the mean square error of the test results of the BBSCA is smaller, its optimization results for the filtering parameters are significantly better than those of the standard SCA, and the optimization accuracy is higher. Therefore, it is effective and feasible to combine the bare bone sine cosine algorithm with the Markov transfer probability parameter

dynamic adjustment method to form the IABBSCA-IMM algorithm for building the filter tracking model. Its convergence is better, the optimization accuracy is higher, and the stability and robustness are stronger.

After parameter adjustment, 50 Monte Carlo simulations are performed respectively for the IABBSCA-IMM

TABLE 1: Parameters of each model after optimization.

Algorithm	Time (s)	Sports model	Parameter Q	Parameter R
SCA	0.085	CV	0.1332	7.3358
		CA	0.5561	8.6030
		CT	0.4467	9.7868
BBSCA	0.092	CV	0.2891	1.1364
		CA	0.5159	1.5427
		CT	0.9741	1.1555

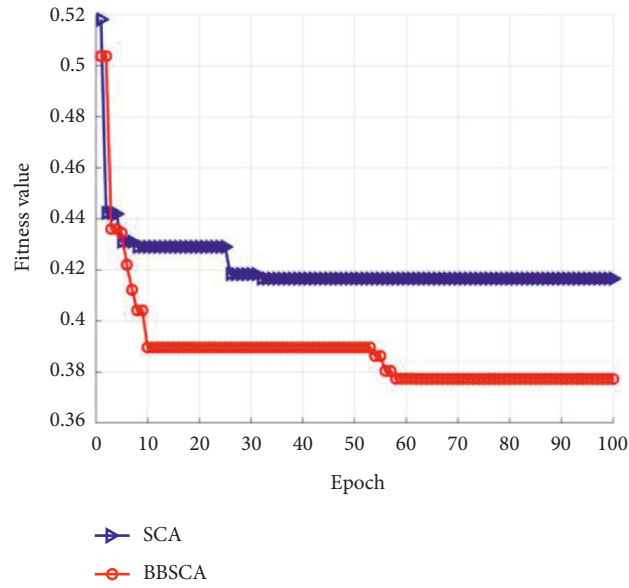


FIGURE 3: Optimization search results of two algorithms.

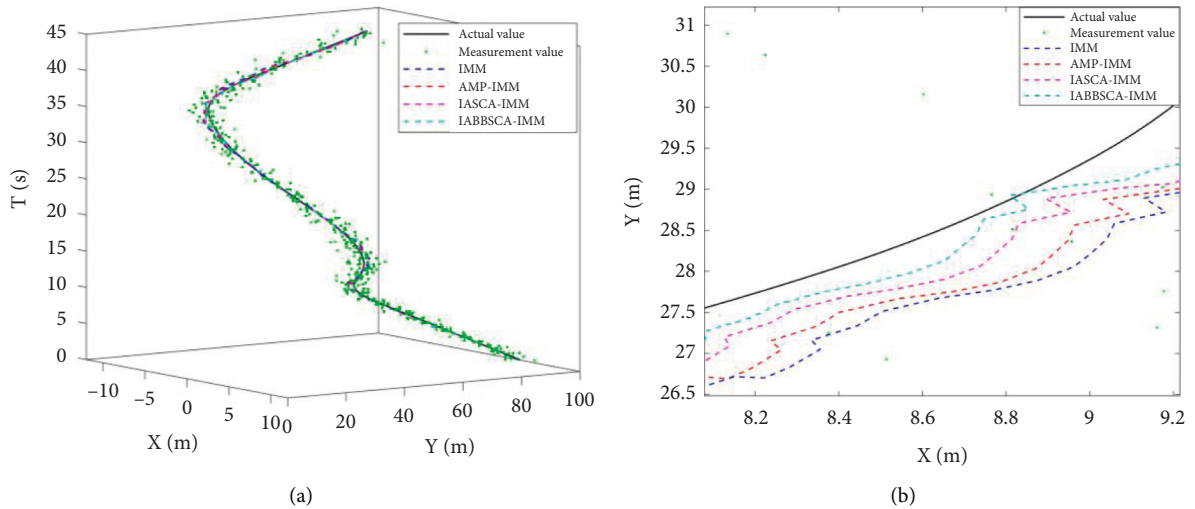


FIGURE 4: Filter tracking process of several algorithms. (a) Filter tracking trajectory. (b) Local enlargement.

algorithm and IMM algorithm, AMP-IMM algorithm, and IASCA-IMM algorithm. The AMP-IFIMM algorithm of literature [9] is not considered since it is only applicable to two-model systems. The root mean square error (RMSE) was used to evaluate the algorithm performance. The results of filter tracking of the target motion trajectory are shown in

Figure 4(a), where the X axis is the lateral displacement, the Y axis is the longitudinal displacement, and the vertical axis t denotes time, and Figure 4(b) shows a local zoom in.

It can be seen from Figure 4 that in the process of filtering and tracking the target state information, the trajectory of the IABBSCA-IMM algorithm is closer to the true

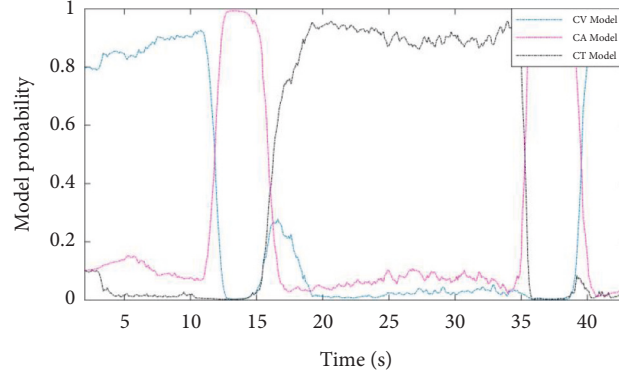


FIGURE 5: Model probability change curve.

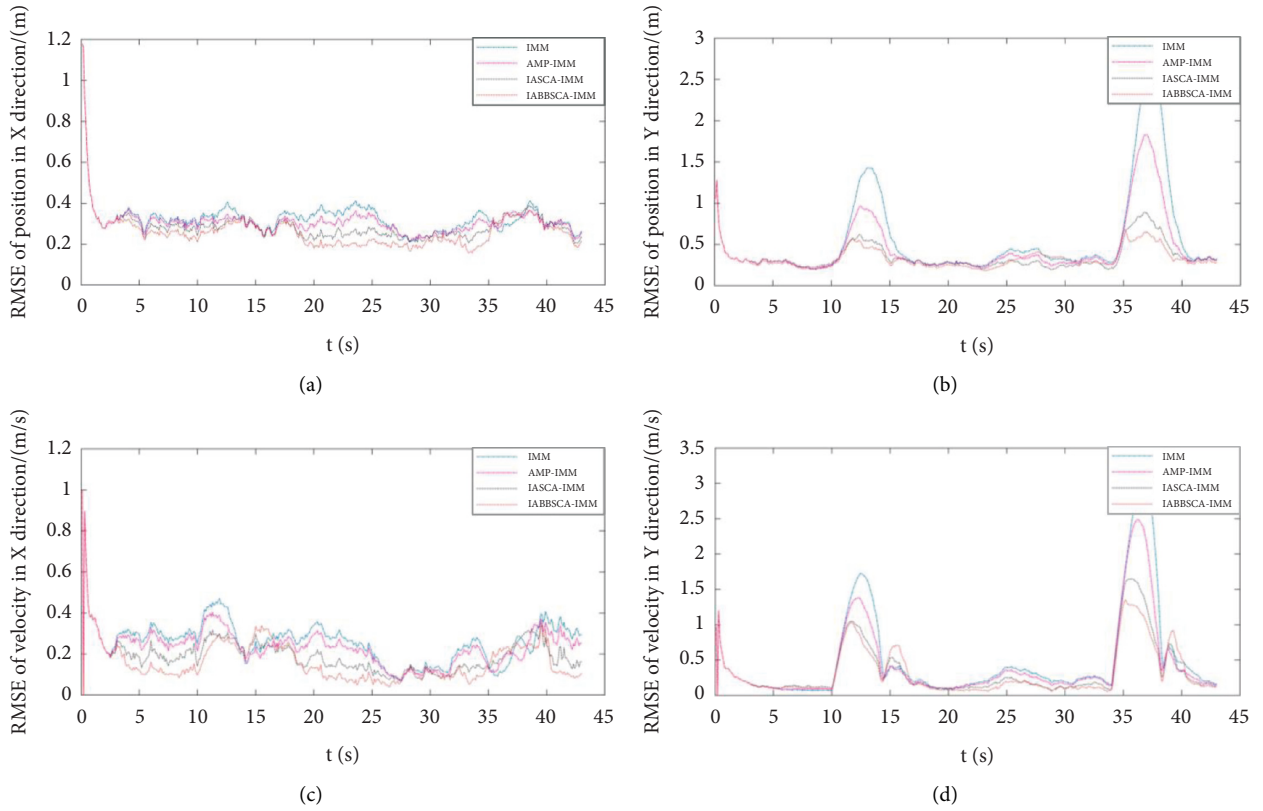


FIGURE 6: RMSE curves for different positions and velocities. (a) Position RMSE in X direction. (b) Position RMSE in Y direction. (c) Velocity RMSE in X direction. (d) Velocity RMSE in Y direction.

TABLE 2: Mean value of RMSE for each algorithm.

Algorithm	Position RMSE (m)		Velocity RMSE (m/s)	
	X direction	Y direction	X direction	Y direction
IMM	0.3466	0.5531	0.2785	0.4951
APM-IMM	0.3237	0.4457	0.2521	0.4248
IASCA-IMM	0.3006	0.3685	0.2202	0.3416
IABBSCA-IMM	0.2795	0.3451	0.1935	0.3169

value. The IASCA-IMM algorithm, the AMP-IMM algorithm, and the traditional IMM algorithm are less effective.

In the process of filter tracking by the IABBSCA-IMM algorithm, the three motion models of CV, CA, and CT are switched automatically. Under the conditions set in this experiment, the model probability change curves are shown in Figure 5.

The probability of the CV model prevails between 0 and 10 seconds, which corresponds to the target's uniform linear motion. The probability of the CA model prevails between 10 and 14 seconds, which corresponds to the target's uniform accelerated turning motion. The probability of the CT model prevails between 14 and 34 seconds, which corresponds to the target's uniform turning motion. The probability of the

CA model prevails between 34 and 38 seconds, which corresponds to the target's uniform accelerated motion. The probability of CV model prevails in the rest of time, corresponding to the target's uniform linear motion. The process is consistent with the experimental setting, which indicates that the probability model curve is correctly switched, and the probability of the corresponding model in the specific motion mode is superior and switched rapidly.

The variation curves of position and velocity RMSE with time for each algorithm in X and Y directions during filter tracking are shown in Figure 6.

The mean values of the specific RMSE values for each algorithm in the process of target filtering tracking are listed in Table 2.

It can be seen that compared with the traditional IMM algorithm, the IABBSCA-IMM algorithm proposed in this study reduces the RMSE by 19.36% for the position in the X direction and 30.52% for the velocity and reduces the RMSE by 37.61% for the position in the Y direction and 35.99% for the velocity. Compared with the APM-IMM algorithm and the IASCA-IMM algorithm, the RMSE of this method is smaller and the accuracy is better.

5. Conclusion

After dynamic adjustment of Markov transition probability and optimization of filtering parameters, the IABBSCA-IMM algorithm proposed in this study speeds up the switching probability to the matching model and improves the filtering and tracking accuracy. It can be applied to automatic driving, collision avoidance warning, traffic monitoring, and other fields. The main conclusions are as follows:

- (1) By dynamically adjusting the Markov probability transition matrix and adding constraints, the switching probability to the matching model is increased, the influence of the nonmatching model is reduced, the speed of model probability switching is accelerated, and the fast and accurate switching of the system motion model is realized.
- (2) The improved bare bones sine cosine algorithm (BBSCA) is used to optimize the filtering parameters Q and R , and they are used as new inputs to optimize the next round of filtering process, which improves the filtering and tracking accuracy of the target.
- (3) Compared with the IMM algorithm, the AMP-IMM algorithm and the IASCA-IMM algorithm, the position and velocity RMSE of the IABBSCA-IMM proposed in this study are reduced by 19.36%–30.52% in the X direction, the position and velocity RMSE in the Y direction are reduced by 35.99%–37.61%, and the accuracy is better.

In addition, with the continuous maturity and improvement of intelligent algorithms such as vulture search algorithm, artificial neural network algorithm, and ant colony flower algorithm, it is expected to be combined with

interactive multimodel algorithm to improve the tracking accuracy of the algorithm.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis on the Way and Potential of Economic Low-Carbon Development of China Based on Genetic Algorithm

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How a developing China can meet the challenges of the post-Kyoto era in the process of rapid industrialization is a hot issue in current academic research. Facing the pressure of the international community to reduce emissions and the energy and resource constraints under the development trend of the heavy chemical industry, China can only turn the pressure into a driving force and seek a low-carbon development path. This paper proposes a prediction model for China's low-carbon economic development based on the combined model of genetic algorithm (GA) and long short-term memory neural network (LSTM). The data are encoded with one-hot, embedding is used to reduce the dimension, and the genetic algorithm is used to obtain the optimal hyperparameters of the LSTM model to improve the accuracy of the model. The results show that the model accuracy remains above 90%.

1. Introduction

Under the influence of the global warming environment and the market environment impacted by the financial crisis, all countries in the world are developing at a high speed in order to achieve a more ideal economic level as soon as possible, and in most cases, a low-carbon economy is based on the actual situation. Development strategy emerges based on economic growth. In the process of developing a low-carbon economy, my country has adopted many effective technologies and formulated many innovative mechanisms to better promote the development of my country's low-carbon economy and effectively realize the traditional economic model. Turning to a low-carbon economic model, after fully combining my country's current economic development, a low-carbon economic model is created that can meet my country's characteristics [1–5].

Affected by the pattern of economic globalization, the emission reduction behavior of some developed countries will have a certain economic impact on most developing countries. Countries with advanced technology consume a

lot of energy and emit a lot of energy. In order to reduce the amount of greenhouse gas emissions, industries with high emissions such as electricity, industry, and building materials industry will start to explore their own energy-saving potential and carry out effective technology. At the same time, it will also carry out overseas market development work, with the help of foreign direct investment to improve corporate profits, and then make up for the losses caused by domestic compliance [6–8]. Affected by global economization, most developing countries, including China, have transformed into world industrial bases after implementing the agreement, and China has thus obtained much-needed development funds and high-tech. Economic growth has developed rapidly since 2005, but the economic price paid at that time cannot be ignored. Our country is still in the stage of economic development. Once we need to deal with greenhouse gas emission reduction or fulfill the obligation to limit emissions, it is likely to be trapped by investment again.

As far as the characteristics of the technology economy are concerned, the development of a low-carbon economic model that is coordinated with the climate and environment

can help our country realize the transformation of the economic growth model and, at the same time, can effectively protect the domestic environment. On the whole, the essence of a low-carbon economy is high energy efficiency. As well as the structural problems of clean energy, the core content is the innovation of energy technology and the innovation of the system. Analyzing this characteristic, it is basically consistent with the measures of energy conservation currently carried out in our country. Therefore, it can be considered that the development and application of low-carbon economic energy and new technologies in the international arena will greatly improve my country's traditional development model of high energy consumption, high-carbon emissions, and low economic benefits. The goal of effectively promoting the construction of a well-off society can be achieved. Especially in the low-carbon economy, the content of technological innovation for the utilization of traditional energy has far-reaching value for my country [9–13]. From two perspectives, first, in order to achieve the ideal emission reduction target, most developed countries will promote energy technology cooperation; that is, government departments and enterprises will increase investment in research and development and increase the speed of technology development; thereby, promoting technological innovation is considered from a technical point of view, and the measures taken by developed countries have a relatively positive impact on developing countries. Second, in order to reduce costs, developed countries will transfer emission reduction projects to developing countries. The cost of emission reduction in developed countries is relatively high, so they will reduce costs by transferring them to developing countries. Developed countries provide certain financial assistance and technical support and assist developing countries to reduce emissions, so that developing countries can also achieve good sustainable development. For China, at the current stage and in the future development, it is necessary to adopt some active and effective policies, grasp the favorable opportunities it already has, and use the cooperation with developed countries to reduce greenhouse gas emission technologies and strong financial support.

This paper proposes a prediction model for China's low-carbon economic development based on a combination of a genetic algorithm (GA) and long short-term memory (LSTM) model [14–17]. The weather, temperature, week, and holiday features are added to the original data of time and low-carbon economy to assist in prediction, which improves the prediction accuracy. The accuracy rate of the model remains above 90%, and the accuracy is also higher than the one used in the current scheduling system. Exponential smoothing model only needs to be trained once, and then, the model data can be directly loaded for prediction without retraining, which has a good prospect of practical application.

2. Theoretical Background

2.1. Long Short-Term Memory. LSTM is improved by the recurrent neural network (RNN). RNN will be affected by short-term memory. If a sequence is long enough, it is difficult to transmit information from earlier time steps to

later time steps, so RNN is not suitable for long-term memory. LSTM solves the problem of RNN short-term memory very well. LSTMs have internal mechanisms called gates, and the gate structure learns what information to save or forget during training. Subsequently, it can pass relevant information along long-chain sequences for prediction. The structure of each cell unit of LSTM is shown in Figure 1.

A cell unit of LSTM contains three gate structures: forget gate, input gate, and output gate. At the same time, it contains two states, the cell state vector and the hidden layer state. The hidden layer state is the output of the final network, and the cell state will participate in the calculation of the hidden layer state. The expression of the LSTM layer is

$$\begin{cases} i_t = \sigma(W_{ii}x_t + b_{ii} + W_{hi}h_{t-1} + b_{hi}), \\ f_t = \sigma(W_{if}x_t + b_{if} + W_{hf}h_{t-1} + b_{hf}), \\ g_t = \tanh(W_{ig}x_t + b_{ig} + W_{hg}h_{t-1} + b_{hg}), \\ o_t = \sigma(W_{io}x_t + b_{io} + W_{ho}h_{t-1} + b_{ho}), \\ c_t = f_t \odot c_{t-1} + i_t \odot g_t, \\ h_t = o_t \odot c_t. \end{cases} \quad (1)$$

In (1), the symbol \odot represents the Hadamard product. N is the size of a batch of training data. L_{in} is the length of the time series in the time dimension. H_{in} is the feature number included by the time series. i_t , f_t , g_t , and o_t are called input gates, forget gates, cell gates, and output gates at time t , respectively. c_t and h_t are called cell states and hidden states at time t .

2.2. Genetic Algorithm. Genetic algorithm originated from the computer simulation research of biological systems, and it is an efficient, parallel, global search method to seek the optimal solution of the problem by imitating the evolution mechanism of the biological world. The genetic algorithm includes coding, initializing population, evaluating fitness, judging termination, condition, selection, crossover, mutation, and decoding steps, and its process is shown in Figure 2.

Due to the strong scalability of the genetic algorithm, the number of cells in each layer of LSTM, the fully connected layer, the L2 regularization weight parameter, the dropout parameter, the number of iterations, and the batch_size can be used as the parameter set, and the RMSE can be used as the fitness function. Using the genetic algorithm iterations, the optimal hyperparameters of the LSTM model were found. The L2 regularization parameter is a penalty item in the model learning process, and the purpose is to prevent the model from overfitting. Dropout means that during the training process of a deep learning network, the neural network unit is temporarily dropped from the network according to a certain probability. The dropout parameter is the probability of dropping. batch_size is the number of samples selected for one iteration of training. RMSE is the square root of the ratio of the square of the deviation

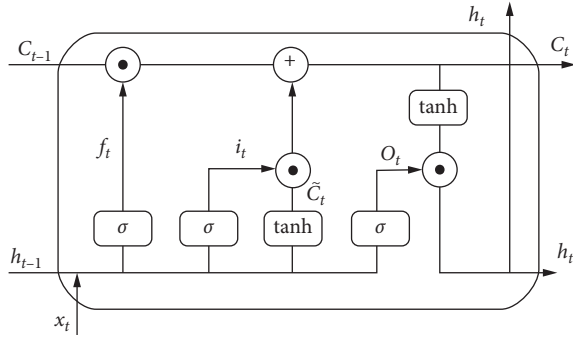


FIGURE 1: The structure of each cell unit of LSTM.

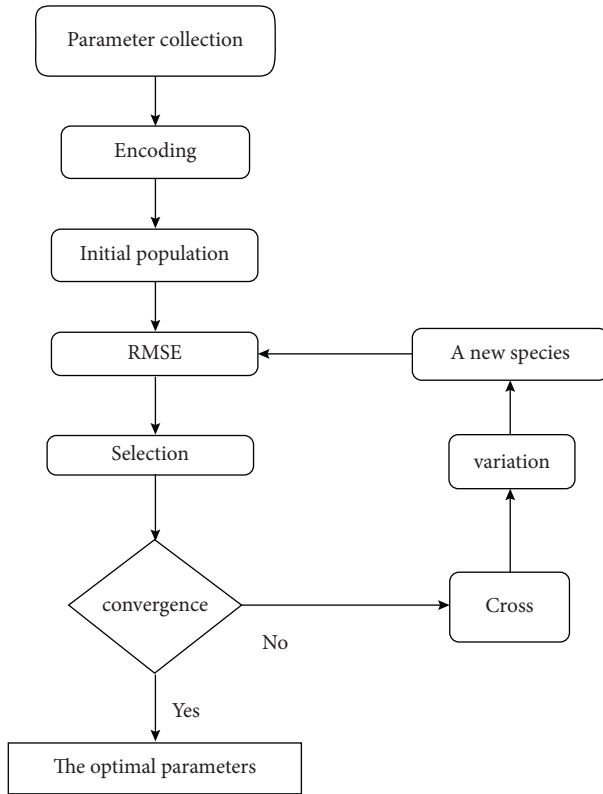


FIGURE 2: The process of genetic algorithm.

between the predicted value and the true value to the number of observations n , and it is one of the indicators to evaluate the accuracy of the model.

2.3. One-Hot Encoding. The main purpose of embedding is to reduce the dimension of sparse feature vectors and reduce the dimension by calculating the weight matrix of the embedding layer. In addition, the embedding matrix assigns a fixed-length vector representation to each categorical variable, and this length can be set by yourself.

Let the maximum length of the text be n , and there are m different kinds of texts. Each text is represented by a vector T_i ($i = 1, 2, \dots, m$) after one-hot encoding. Then, the dimensions of T_i are all $1 * n$. The resulting text vector is

$$\begin{bmatrix} T_{11} & T_{12} & \dots & T_{1n} \\ T_{21} & T_{12} & \dots & T_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ T_{m1} & T_{m2} & \dots & T_{mn} \end{bmatrix}. \quad (2)$$

3. The Proposed Model

3.1. Feature Screening. Feature importance evaluation is performed using a random forest; that is, the feature importance score of each tree in the random forest is calculated and averaged. Usually, the Gini index can be used as an evaluation index to measure. The feature importance score is represented by VIM, and the Gini index score $VIM_j(\text{Gini})$ of each feature X_j , which is the average of the node splits of the j th feature in all decision trees in the random forest. The calculation formula of the Gini index GI_m of this variable in node m is

$$GI_m = \sum_{k=1}^K \sum_{k' \neq k} P_{mk} P_{mk'}. \quad (3)$$

Among them, K indicates that the random forest has K categories, p_{mk} indicates the proportion of category k in node m , and p_{mk} indicates the proportion of category k in node m . Feature importance scores are obtained by random forest for temperature, week, weather, and holidays. As shown in Figure 3, it can be seen that the importance scores of weather and temperature features are both low, but considering that severe weather has a greater impact on the low-carbon economy, only the temperature feature is deleted. From an objective point of view, the reason why temperature has little effect on sales volume is actually a geographical factor; that is, the low-carbon economic development predicted by this project is located in Kunming, and the temperature change is relatively small.

3.2. Model Establishment. The original data of this project are the time series data of time and sales, and the modeling process is shown in Figure 4. (a) Feature extraction: add temperature, weather, holidays, and week features. (b) Feature screening: the feature importance score is performed on the expanded features through the random forest, and the temperature feature is deleted. (c) Text encoding: one-hot encoding is performed on the two text-like features of weather and week. Then, use the embedding method for dimensionality reduction, reduce the dimensionality of the week from the 17-dimensional vector to 11, and reduce the weather from the 18-dimensional vector to 13. (d) LSTM model prediction: put the processed data into the LSTM model for prediction. (e) Genetic algorithm parameter adjustment: input the hyperparameters of the LSTM model as the parameter set into the genetic algorithm, use the RMSE as the objective function, and obtain the maximum value through the genetic algorithm. (f) Excellent

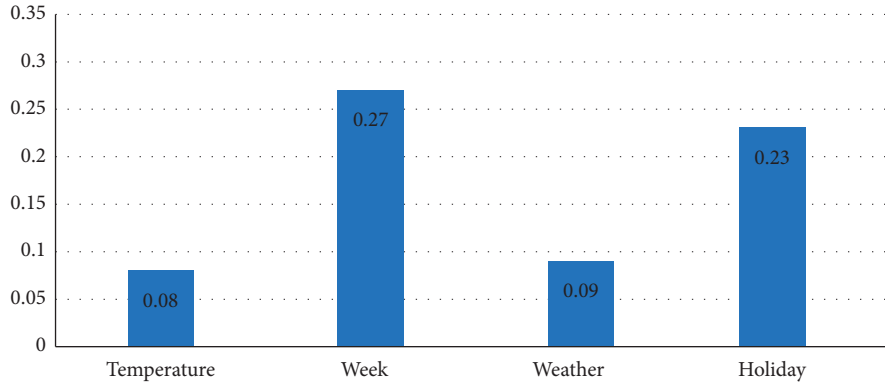


FIGURE 3: The importance scores of features.

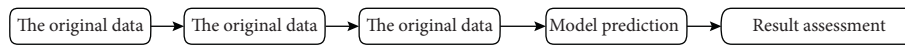


FIGURE 4: The original data of this project are the time series data of time and sales, and the modeling process.

hyperparameters: result evaluation: verify the accuracy of the model.

3.3. Analysis of Results. GA-LSTM and one-time exponential smoothing were used for prediction, respectively. The results obtained are shown in Table 1. It can be seen that the one-time exponential smoothing model has the problem of prediction lag, especially in the time period before and after the Spring Festival. The carbon economy fluctuates violently, the prediction lag of the first-order exponential smoothing model is obvious, and the prediction of the first-order exponential smoothing in the second half of the test set is basically a straight line. The prediction of GA-LSTM can better predict the peaks and troughs, and it can also have a good prediction effect on data with obvious nonlinear characteristics such as low-carbon economy.

At the same time, due to the large number of LSTM hyperparameters, the genetic algorithm is used to adjust the hyperparameters of LSTM. Compared with the empirically set LSTM model, the GA-LSTM model improves the accuracy by 3%, and the RMSE decreases by 40 L/d, which makes the LSTM model prediction more accurate. From the data analysis, the RMSE of GA-LSTM is much smaller than that of one-time exponential smoothing, and the accuracy is improved by 9%. At the same time, due to the addition of holiday features, GA-LSTM is also more sensitive to the severe fluctuation of a low-carbon economy before and after holidays which is able to make effective predictions.

4. Analysis of China's Development Paths to Realize Low-Carbon Economy

4.1. Adhere to the Overall Interests of the Country, and Make a Correct Assessment of the Obligations and Responsibilities of Greenhouse Gas Emission Reduction within My Country. In the process of evaluating my country's carbon emissions, it is necessary to fully combine the various influencing factors that my country will involve in the process of

TABLE 1: Comparison of results from different models.

Models	GA-LSTM		One exponential smoothing	
	Training set	Test set	Training set	Test set
RMSE/Ld ⁻¹	564	570	—	812
Accuracy (%)	91	90	—	82

development. At the same time, effective and accurate assessment and analysis are carried out according to the actual development of modernized trade activities and the situation of investment introduction and transfer. In particular, it must be combined with the carbon emissions that may arise in the process of exporting high-carbon products. Combining with the specific developmental stage of our country, formulate a reasonable plan, put survival and development on the level that must be considered, compare carbon emissions with some western countries to find the unique characteristics of carbon emissions, and strictly control the export process. During the export process, it is necessary to strictly abide by the carbon emission regulations of the demand side for products, and at the same time improve the situation of paying the bill for emissions. In this way, it can significantly reduce the emission pressure of various greenhouse gases that my country needs to face, refuse to pay for emissions at will, and strictly prohibit developed countries from setting traps for my country's economic development. In addition, each country is carrying out win-win cooperation for low-carbon economic development. In the process of cooperation, my country needs to adhere to its own development path and, on this basis, carry out detailed inspections in combination with various technologies and products, and at the same time, the product cost is repeatedly checked, so that the emission trading can maintain the ideal degree of fairness and openness and effectively avoid the developing countries becoming a platform for developed countries to carry out carbon emissions in the process of economic exchanges.

4.2. Improve the Concept Content and Development Form of Backward Economic Development. If our country wants to realize the effective development of low-carbon economy to the greatest extent, what we need to do is to actively enter into the action of emission reduction, have an in-depth understanding and analysis of the low-carbon economy, and effectively take appropriate measures and means to carry out comprehensive abatement treatment interventions. First of all, as a government department, we must first formulate a relatively complete basic model that can promote the all-round development of a low-carbon economy and give macroscopic adjustment and control in combination with the environment of economic development. At the same time, it is also necessary to build a comprehensive legal foundation and implement an effective policy support system to carry out the low-carbon transformation in stages. It cannot be rushed for a while, and stable development should be combined. Combined with the efforts and characteristics of multiple parties, there may be problems in the process of transformation. The problems that occur should be properly resolved and dealt with so that the mode of economic development can be properly transformed. Secondly, strengthen the emphasis on people to ensure that people can achieve solidarity and cooperation in the process of economic development transformation on the basis of efficient cooperation. In the work, the actual effect of low-carbon emission reduction is effectively guaranteed.

4.3. Create Pilot Areas and Find Specific Ways to Develop a Low-Carbon Economy. Pilot areas can be selected based on the characteristics of different regions and different departments. For example, a low-carbon economy pilot area can be set up in the eastern and western parts of my country, and appropriate policy support can be used to attract high-end manufacturing industries and R&D industries to invest in them and timely transform or appropriately eliminate some high energy consumption. High-polluting industries enable the pilot area to gradually become a low-carbon economy demonstration area.

5. The Potential of Low-Carbon Economic Development in China

5.1. The Development of Science and Technology. Technology is one of the important factors for realizing low-carbon economic development. From a microlevel, the importance attached to science and technology by various enterprises in our country has increased significantly. These enterprises have improved their environmental protection technology level through investment in environmental protection technology and the addition of human resources. This change has laid a good material foundation for the realization of the low-carbon economic development goals of enterprises. From a macro perspective, the proportion of scientific and technological development in national policies has also increased accordingly. Taking the national science and technology plan as an example, new energy and high technology have become the main target of introduction in

the plan. In addition, ecological environmental protection work and new energy application work also belong to the key content of the national science and technology plan. The national science and technology plan's emphasis on new energy companies provides a strong guarantee for the improvement of new energy companies' market competitiveness. In this context, various strategic measures of new energy enterprises can be well realized.

5.2. Management and Control System. In this regard, the potential of low-carbon economic development in my country mainly includes the following: first is the potential of laws and regulations. Laws and regulations have an important binding and normative role. Judging from the current laws and regulations formulation work in my country, the formulation of laws and regulations based on energy conservation and emission reduction indirectly promotes the realization of economic development goals. Second is the potential of the management system. My country's major enterprises began to form a correct concept of energy conservation and emission reduction. Some enterprises have begun to apply the whole-process energy conservation and emission reduction management to their actual operations. Compared with other management modes, the application advantage of the whole-process management mode of energy saving and emission reduction is that its application in all links such as production and sales can effectively avoid the occurrence of resource waste. In addition, some enterprises have also formulated a sound assessment system and responsibility system for energy conservation and emission reduction. As far as the employees of these enterprises are concerned, they can obtain certain material and spiritual rewards through the reasonable development of energy conservation and emission reduction work, so the enthusiasm of these employees to participate in energy conservation and emission reduction work will increase accordingly. From another point of view, the differentiation of responsibilities and the application of punishment measures reduce the probability of employees wasting resources. Therefore, the establishment of an energy-saving and emission-reduction management system has effectively improved the sustainable development capacity of enterprises, and this change will have a positive effect on the realization of economic low-carbon development goals.

5.3. Potential for the Transformation of the Global Low-Carbon Economy. As far as the current situation is concerned, the low-carbon economy has become the mainstream development trend of the global economy. In this context, the potential for low-carbon development of my country's economy is mainly manifested in the following aspects: first is to enhance international competitiveness. Developing international transactions and enhancing international competitiveness are one of the important contents of my country's development strategy. From my country's past development experience, it can be seen that in order to achieve this purpose, China has made efforts from multiple

export channels. In this case, when the world is transforming into a low-carbon economy, my country's economy will naturally take it as a development goal. The second is to enhance the international status. Compared with my country's traditional extensive economic model, the advantage of a low-carbon economy is that it can obtain higher production quality through lower energy consumption, and the emissions in this process are relatively small. From an essential point of view, a low-carbon economy can be regarded as a high-quality activity that obtains the greatest return at the least cost. This advantage and the development goal of enhancing international status have induced the formation of my country's economic low-carbon development potential.

5.4. Growth Potential of National Economy. The growth potential of the national economy to achieve the goal of low-carbon economic development is mainly reflected in the following aspects: first is the consumption of household appliances. The consumption process of this kind of consumer goods is based on the continuous consumption of energy, and in addition, it itself belongs to heavy chemical materials. Therefore, the consumption of household appliances can be used to reflect the low-carbon development potential of my country's economy. As the main tool for people to meet people's living needs, the consumption of household electrical appliances in urban residents in my country in recent years is mainly reflected in the categories of advanced and technological electrical appliances. The popularity of basic household appliances among rural residents is relatively low, so there is a certain potential for the realization of low-carbon economic development goals. Second is the car consumption. Judging from the current situation, there are relatively many cities in my country that have reached the threshold of 30 cars per thousand people. First-tier cities such as Beijing and Shenzhen exceeded this threshold by 10 times as early as 2001. These data also reflect the potential of my country's low-carbon economic development.

6. Conclusion

A gas station sales prediction model based on the GA-LSTM combination model is proposed, and the weather, temperature, oil price, week, and holiday features are added to the original data of time plus sales to assist the prediction, and the prediction accuracy is improved. The accuracy rate of the model remains at 90% above, the accuracy is also higher than the one-time exponential smoothing model used in the current refined oil scheduling system, and the model only needs to be trained once, and then, the model data can be directly loaded for prediction without retraining, which has a good prospect of practical application. The prediction flexibility of the model is strong, and the data of the first m days can be used to predict the data of the next n days to meet the needs of different predictions. The model is not only suitable for gas stations and sales forecasts but also for other sales and forecasts that are affected by a variety of

factors. Further exploration is to add attention mechanisms and mine features that potentially affect sales. The model is configured in the refined oil scheduling system of the enterprise, so that the prediction model can be applied in the enterprise system.

On the whole, facing the impact of the external environment and the negative impact of the financial crisis all over the world, my country's economy will inevitably embark on the development path of the low-carbon economy. However, in order to effectively and comprehensively develop and implement my country's low-carbon economic development model, it is necessary to base itself on my country's overall national interests and conduct a comprehensive analysis of the form of economic development under the traditional model on the development path of a low-carbon economy. In the process of developing a low-carbon economy, China has the advantages of Chinese characteristics, but it is necessary to actively adopt some scientific and effective means to effectively improve the level of low-carbon economic development.

Data Availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

Acknowledgments

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Research Article

Identification of Molecular Mechanism of OSA with Hypertension Based on Multiple Microarray Analysis

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Purpose. OSA is closely associated with hypertension, and both epidemiological and experimental studies have confirmed that OSA is one of the most important independent risk factors for hypertension. The pathological mechanisms by which OSA causes hypertension are not well understood, and in this paper, we explored the molecular mechanisms by which OSA may mediate hypertension at the bioinformatics level. **Materials and Methods.** We downloaded disease-related datasets from the GEO public database, calculated the differential genes between the two groups of patients by the limma package, and then further constructed the WGCNA network based on the clinical characteristics of patients to explore the important regulatory genes in the disease. Subsequently, ssGSEA was used to explore the potential molecular mechanisms of disease progression and GSVA was applied to analyze the specific signaling pathways. Finally, we performed real-time quantitative PCR (qRT-PCR) to validate these pivotal genes. **Results.** Three genes were selected as target genes, namely, GPR179, RNF150, and JPH4. The results showed they were strongly correlated with immune cell content that high expression of the three core genes was associated with myogenesis, angiogenesis, oxidation, metabolism, and PI3K/AKT/mTOR pathways. qRT-PCR validated that all three genes have statistically significant differences between the OSA group and OSA combined with hypertension group. **Conclusion.** Our study provides new evidence for the potential molecular mechanisms of OSA combined with hypertensive disease as well as diagnosis and treatment.

1. Introduction

OSA (obstructive sleep apnea) is a common sleep disorder characterized by chronic intermittent nocturnal hypoxia. Patients can have recurrent complete and/or incomplete upper airway obstruction during sleep, resulting in apnea or hypoventilation with intermittent nocturnal hypoxia or sleep fragmentation, which is the main pathophysiological heterogeneity of the disease. OSA is now widely recognized as an independent risk factor for hypertension [1, 2], and is associated with the development of multiple systemic diseases, including cardiovascular diseases [3], metabolic syndrome [4], and cognitive dysfunction [5].

Epidemiology shows a prevalence of arterial hypertension between 35% and 80% in patients with OSA, and the degree of elevated blood pressure is positively correlated

with its severity [6]. When focusing on hypertensive patients, the prevalence of OSA patients is approximately 40%, rising to nearly 90% in patients with intractable hypertension [7]. OSA is closely related to hypertension through a variety of pathophysiological factors, and the current possible causative factors, including activation of neural sympathetic nerves, oxidative stress, endothelial dysfunction, insulin resistance, and inflammatory response [8, 9]. In addition, hypertension itself may promote vascular remodeling and endothelial dysfunction, forming a vicious circle [10].

However, hypertension is a complex disease and mechanisms may be affected by genetic factors, dietary factors, and ethnic differences. Disease may be involved in the development of immune activation, inflammation, and alterations in the levels of various cytokines. It is necessary to

explore the pathogenesis of OSA at the molecular level, developing new biomarkers, and exploring potential targets to prevent and treat hypertension.

In recent years, bioinformatics analysis has been widely used to analyze microarray data to identify differentially expressed genes (DEGs) and perform various analyses. In our study, we found the genomes of OSA patients and normal subjects from the GEO database and investigated the pathway enrichment of possible differentially expressed genes by gene ontology (GO) annotation, Kyoto Encyclopedia of genes and genomes (KEGG), then we looked up the gene sets of hypertensive patients from the GEO database, which were analyzed by the WGCNA coexpression network to find their core genes. Ultimately, a total of three core genes were screened for possible prospective diagnostic biomarkers and therapeutic targets for OSA combined with hypertensive disease.

2. Materials and Methods

2.1. Data Download. Microarray data were downloaded from GEO (<https://www.ncbi.nlm.nih.gov/geo/>), a public genomic database containing sufficient high-throughput gene expression data [11]. We downloaded Series Matrix File data files for GSE75097 (<https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE75097>), as well as annotation platform GPL10904, with 28 transcriptome data sets, including the package OSA group ($n=19$), OSA combined hypertension group ($n=9$); we download Series Matrix File data files for GSE74144 (<https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE74144>), as well as annotation platform GPL13497, a total of 22 transcriptomic data sets, including the normal group ($n=8$) and the disease group ($n=14$).

2.2. GO and KEGG Functional Annotation. To obtain biological functions and signaling pathways involved with disease development, gene ontology (GO) analysis, and Kyoto Encyclopedia of genes and genomes (KEGG) pathway analysis were performed for specific genes using the Metascape database (<https://www.metascape.org/>) for annotation and visualization [12]. Min overlap ≥ 3 and $p \leq 0.01$ was considered statistically significant.

2.3. WGCNA Analysis. The weighted gene coexpression network was constructed to find coexpressed gene modules and to explore the association between gene networks and phenotypes, as well as the core genes in the network. The coexpression network of all genes in the dataset was constructed separately using the WGCNA-R package [13], and the genes with the top 5000 variance were screened for further analysis using this algorithm, where the soft threshold was set to 8. The weighted adjacency matrix was transformed into a topological overlap matrix (TOM) to estimate the network connectivity, and the hierarchical clustering method was applied to construct the clustering tree structure of the TOM matrix. Different branches of the clustering tree represent different gene modules, and

different colors represent different modules. Based on the weighted correlation coefficients of genes, which are classified according to expression patterns, and genes with similar patterns are grouped into one module, and tens of thousands of genes are divided into multiple modules by expression patterns [14].

2.4. Immunogenetic Correlation. To evaluate the effect of genes on immune infiltration, ssGSEA was used to quantify the level of immune cell infiltration in each sample, and Spearman correlation analysis was performed for gene expression as well as immune cell content [15].

2.5. GSVA (Gene Set Variation Analysis). Gene set variation analysis (GSVA) is a nonparametric unsupervised method to assess the enrichment of transcriptomic gene sets. GSVA converts gene level changes into pathway level changes by composite scoring of gene sets of interest, and then determines the biological function of the samples. In this study, gene sets will be downloaded from the molecular signatures database (v7.0), and the GSVA algorithm [16] will be used to score each gene set comprehensively to assess the potential biological functional changes of different samples.

2.6. GeneMANIA Analysis. GeneMANIA (<https://www.genemania.org>) is a flexible and a user-friendly PPI network building database for visualizing functional networks between genes and analyzing gene functions as well as interaction relationships. The site allows setting up data sources for gene nodes with various bioinformatics analysis methods, such as physical interaction, gene coexpression, gene colocalization, gene enrichment analysis, and site prediction [17]. In this study, the core gene network was generated by GeneMANIA to explore its possible mechanisms of action in patients.

2.7. Reverse Transcription and Quantitative Real-Time PCR (qRT-PCR). Total RNA was isolated from PMBC of normal human models ($n=10$), OSA patients ($n=10$), and OSA combined hypertensive patients ($n=10$), respectively, using RNAiso Plus (Takara, Japan). The quality and quantity of RNA were measured by using the spectrophotometer according to the manufacturer's instructions. The RNA was then reverse transcribed into cDNA using the PrimeScript™ RT kit (No. RR047 A, Takara, Japan) and qRT-PCR was performed on a LightCycler 480 (Roche). qRT-PCR was performed using the TB Green Premix Ex Taq™ kit (No. RR820, Takara, Japan) to analyze gene expression levels, and the relative expression of genes was calculated by the $2^{(-\Delta\Delta Ct)}$ method with HS-GAPDH as the internal reference. The thermal cycling program was set to predenaturation: 95°C, 30 s, 1 cycle; quantitative analysis: 95°C, 5 s, 60°C, 30 s, 40 cycles; melting: 95°C, 5 s, 60°C, 1 min, 1 cycle; cooling: 50°C, 30 s, 1 cycle. Three biological replicates were performed for our experiments, and all primer sequences are shown in Table 1.

TABLE 1: Primer sequences for qRT-PCR.

No.	Gene	Primers sequences (5' to 3')
1	GPR179 forward	CTTCCCTAAATCCCACAGCCTCAAG
2	GPR179 reverse	GACTCTCCTCCACACTCTCCTTCTC
3	JPH4 forward	AACTAGCTGGCTATGAGGCTGAGG
4	JPH4 reverse	TCCTCCTCTCGAAGACTTCCTGAAC
5	RNF150 forward	ACTTCGGTTGTGTTTGTCTCCATCTC
6	RNF150 reverse	GCTGGTTCCTATCCCTGGCATTG

2.8. *Statistical Analysis.* Statistical analysis was performed using the R language (version 3.6). All statistical tests were two-sided, and $p < 0.05$ was statistically significant.

3. Results

- (1) We downloaded the GSE75097 disease-related dataset from the NCBI GEO public database, and included expression profile data from 28 groups of patients, including the OSA group ($n = 19$) and OSA combined with the hypertension group ($n = 9$). We further used the limma package [18] to calculate differential genes between the two groups of patients with differential gene screening conditions of $p < 0.05$ and $|\text{Log}_2 \text{FC}| > 1$. A total of 808 differential genes were screened, including 344 upregulated genes and 464 downregulated genes (Figure 1). We further performed pathway analysis of differential genes, and the results showed that differential genes were mainly enriched in cell-cell adhesion via plasma-membrane adhesion molecules, neuromuscular synaptic transmission, reversible differentiation, sensory perception of taste, amoebiasis, and other pathways (Figure 2(a)). The interaction diagram between the genes is shown in the figure, with upregulated genes in red and downregulated genes in green (Figure 2(b)).
- (2) We downloaded GSE74144 from the NCBI GEO public database for a total of 22 groups of patients, containing healthy controls ($n = 8$) and disease groups ($n = 14$). The WGCNA network was further constructed based on the clinical traits of patients to explore the important regulatory genes in the disease. The soft threshold β was determined by the “sft\$powerEstimate” function, and the soft threshold was set to 8. Then, based on the tom matrix, 15 gene modules were detected in this analysis, namely black (221), blue (524), brown (372), cyan (363), greenyellow (342), grey (16), grey60 (162), lightgreen (148), lightyellow (97), magenta (439), midnightblue (642), pink (195), tan (177), turquoise (977), and yellow (325) modules. We further analyzed between modules and traits and found that the tan module had the highest correlation with disease phenotype ($\text{cor} = -0.49$, $p = 0.02$), therefore, the tan module will be selected for subsequent validation (Figure 3).

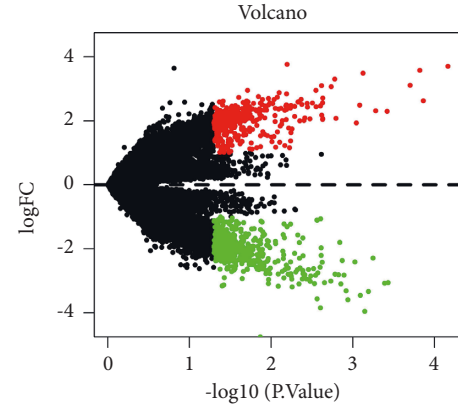
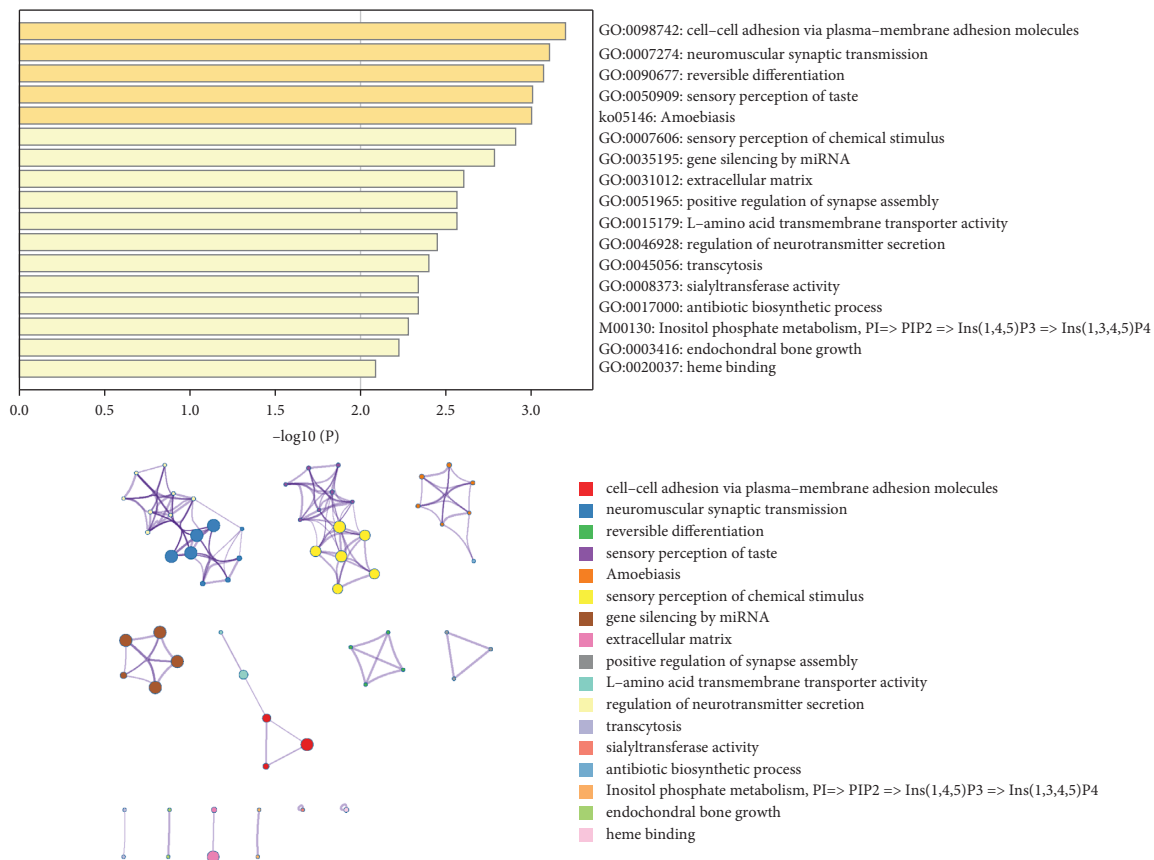


FIGURE 1: The limma package was used to calculate the differential genes between the two groups of patients. $p < 0.05$ and $|\text{Log}_2 \text{FC}| > 1$ were used for differential gene screening, and a total of 808 differential genes were screened, including 344 upregulated genes and 464 downregulated genes.

- (3) The two datasets were selected for further intersection by difference analysis as well as WGCNA analysis to derive the module with the highest correlation, resulting in three core genes: GPR179, RNF150, and JPH4 (Figure 4).
- (4) Disease may be involved in the development of immune activation, inflammation, and alterations in the levels of various cytokines. It is necessary to explore the pathogenesis of OSA at the molecular level, developing new biomarkers, and exploring potential targets to prevent and treat hypertension. By analyzing the relationship between core genes and immune infiltration in the disease dataset, the potential molecular mechanisms of core genes affecting disease progression were further explored. The results of the study showed that all three genes were strongly correlated with immune cell content (Figure 5), and the results were as expected.
- (5) Next, the specific signaling pathways involved in the three core genes were investigated to explore the potential molecular mechanisms by which the core genes affect disease progression. GSEA results showed that high expression of the GPR179 gene was associated with MYOGENESIS, ANGIOGENESIS, OXIDATIVE_PHOSPHORYLATION, XENOBIOTIC_METABOLISM, and other pathways; high expression of JPH4 was associated with ANDROGEN_RESPONSE, ESTROGEN_RESPONSE_EARLY, PI3K_AKT_MTOR_SIGNALING, and other pathways; while high expression of RNF150 was associated with the MYC_TARGETS signaling pathway (Figure 6). The protein interaction networks involved in the three core genes are shown in the figure (Figure 7).
- (6) We validated these three genes by qRT-PCR. The expression of GPR179 in OSA with the hypertension group was lower than that in the OSA group, and both were higher than the normal group; the expression of JPH4 and RNF150 in OSA with the



(a)

FIGURE 2: Continued.

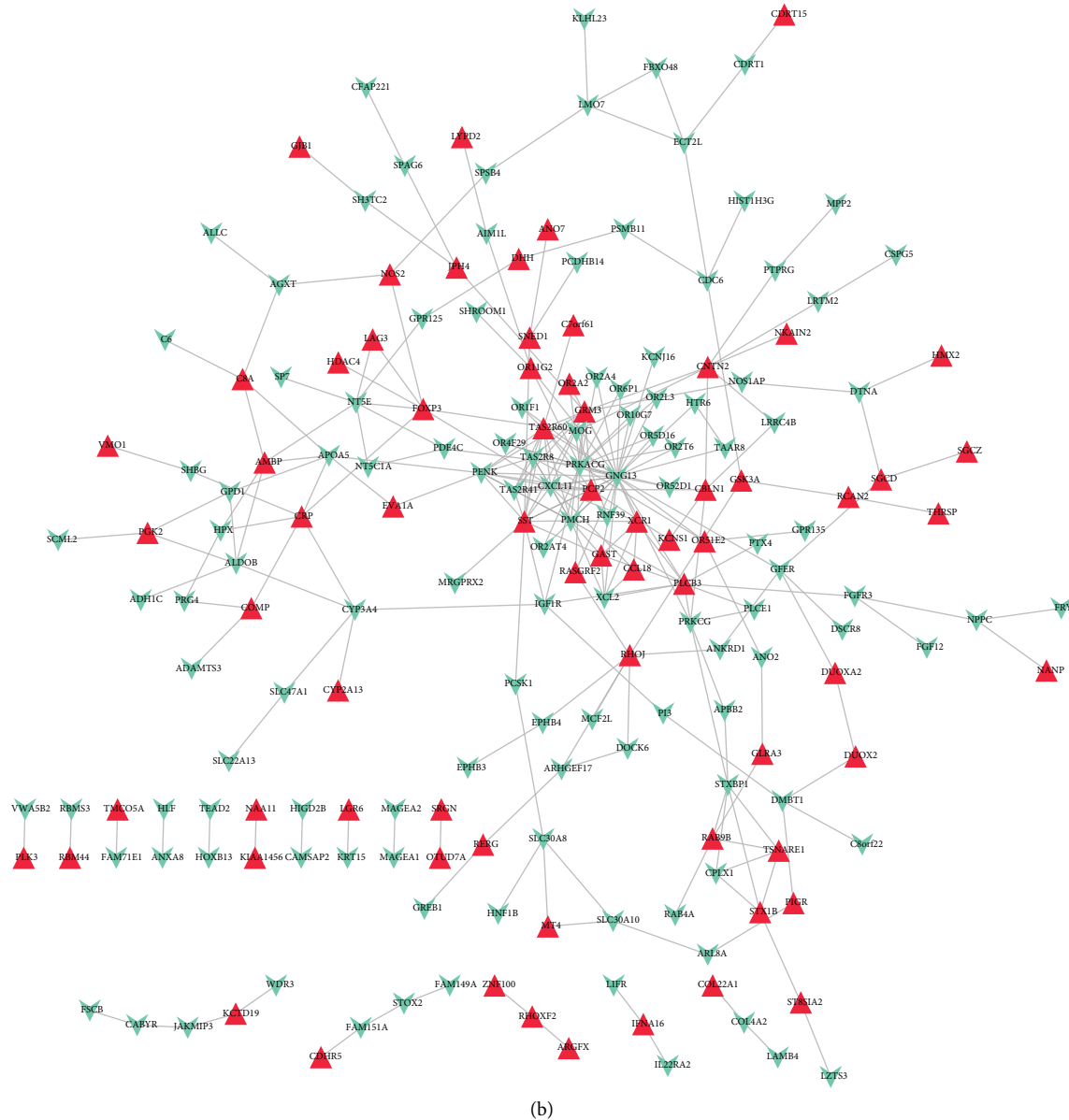


FIGURE 2: Gene expression, correlation, and enrichment analysis, showing the significant function related to DEGs. (a) The results showed that the differential genes were mainly enriched in cell-cell adhesion via plasma-membrane adhesion molecules, neuromuscular synaptic transmission, reversible differentiation, sensory perception of taste, amoebiasis, and other pathways. (b) The interaction between the genes is shown in the diagram, with upregulated genes in red and downregulated genes in green.

hypertension group was higher than the OSA group, while the expression of RNF150 in the OSA group was higher than the normal group (Figure 8).

4. Discussion

GPR179 is short for G protein-coupled receptor 179, which encodes a member of the glutamate receptor subfamily of G protein-coupled receptors. The encoded protein has an EGF-like calcium-binding structural domain and a 7-transmembrane structural domain in the N-terminal region of protein [19]. GPR179 was recently found to be required for depolarizing bipolar cell function and is mutated in

autosomal recessive complete congenital resting night blindness [20]. JPH4 is a member of the junctophilin family, a family of transmembrane proteins involved in the formation of the connecting membrane complex between the plasma membrane and the endoplasmic reticulum in excitable cells that regulate Ca^{2+} signaling and impair the nuclear factor (NFAT) and extracellular signal-associated kinase (ERK) signaling pathways in T cells [21]. An important homolog of the RNF150 gene is ZNRF3, and the human genome encodes approximately 300 RNF proteins, most of which are thought to be E3 ubiquitin ligases, many of which are soluble proteins that play roles in tumorigenesis, development, signal transduction, cell cycle and

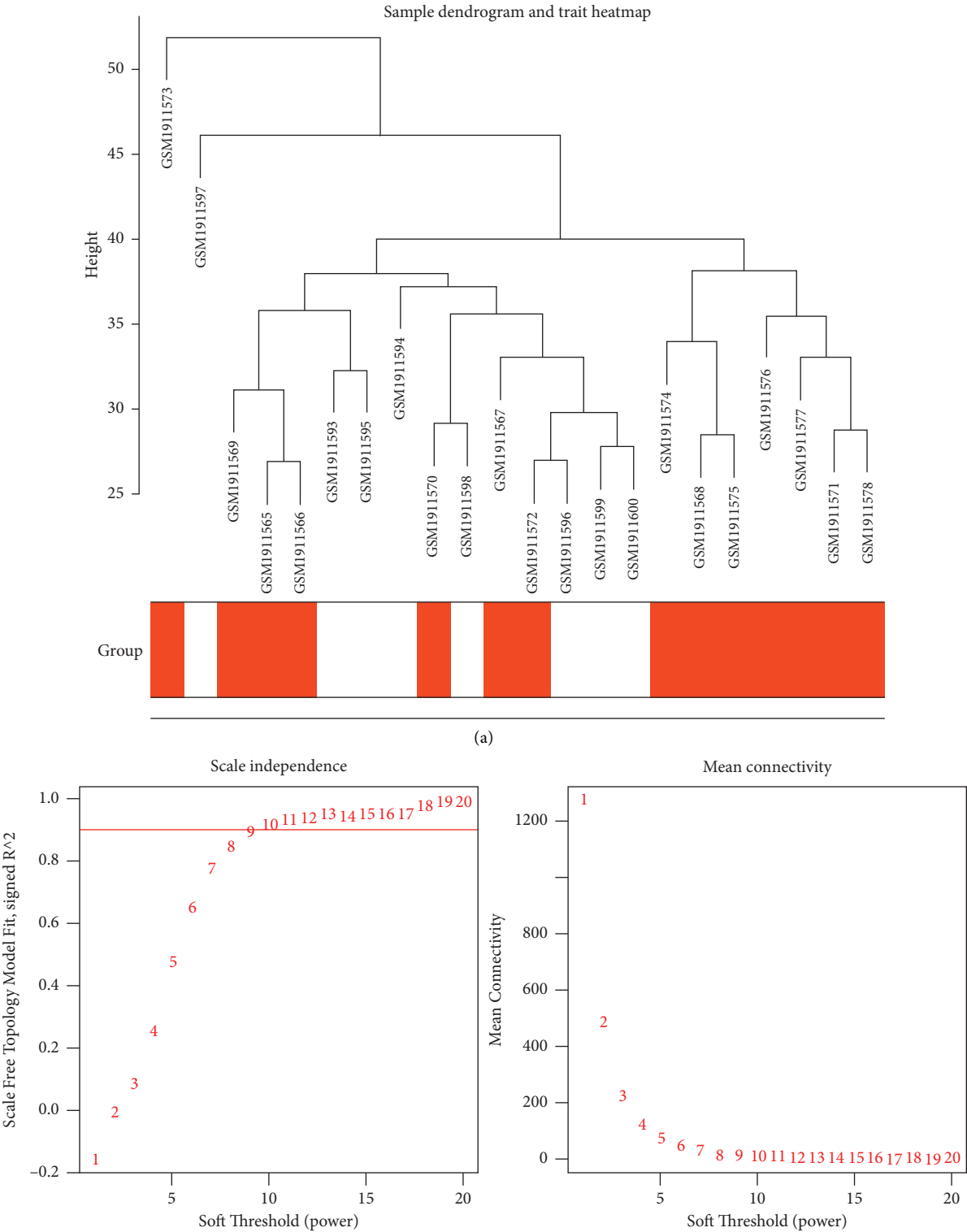


FIGURE 3: Continued.

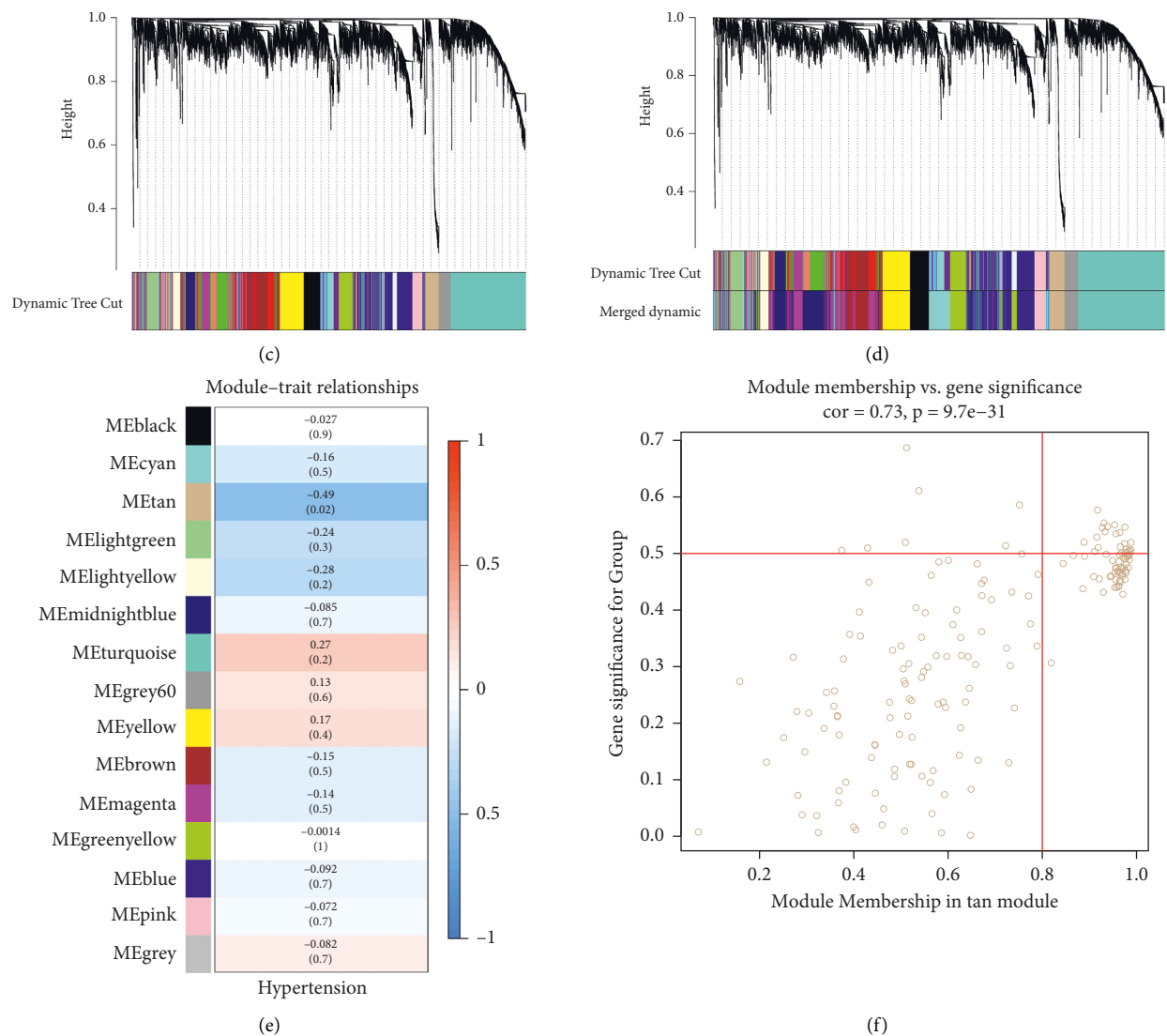


FIGURE 3: The WGCNA network was further constructed based on the clinical traits of patients to explore the important regulatory genes in the disease. (a) Heat map of clustering for all samples. (b) A scale-free index and average connectivity for each soft threshold. (c, d) A tree diagram of gene clustering, different colors represent different modules. (e) Heat map of correlation between module feature genes and hypertension, blue indicates negative correlation, red indicates positive correlation, and the tan module with the highest correlation is selected for subsequent analysis. (f) A scatter plot of tan module feature genes.

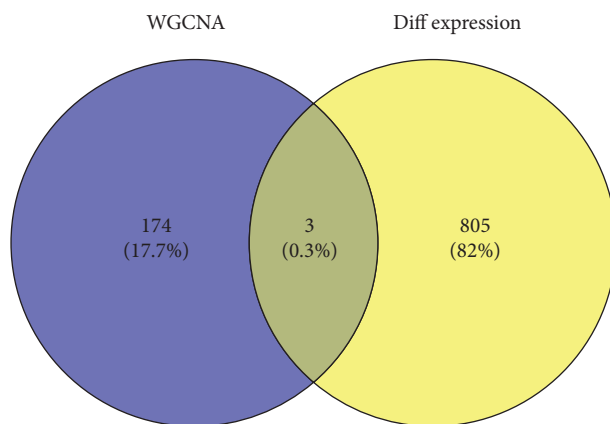


FIGURE 4: The results of DEGs were further intersected with modules with the highest correlation from WGCNA analysis, resulting in three core genes: GPR179, RNF150, and JPH4.

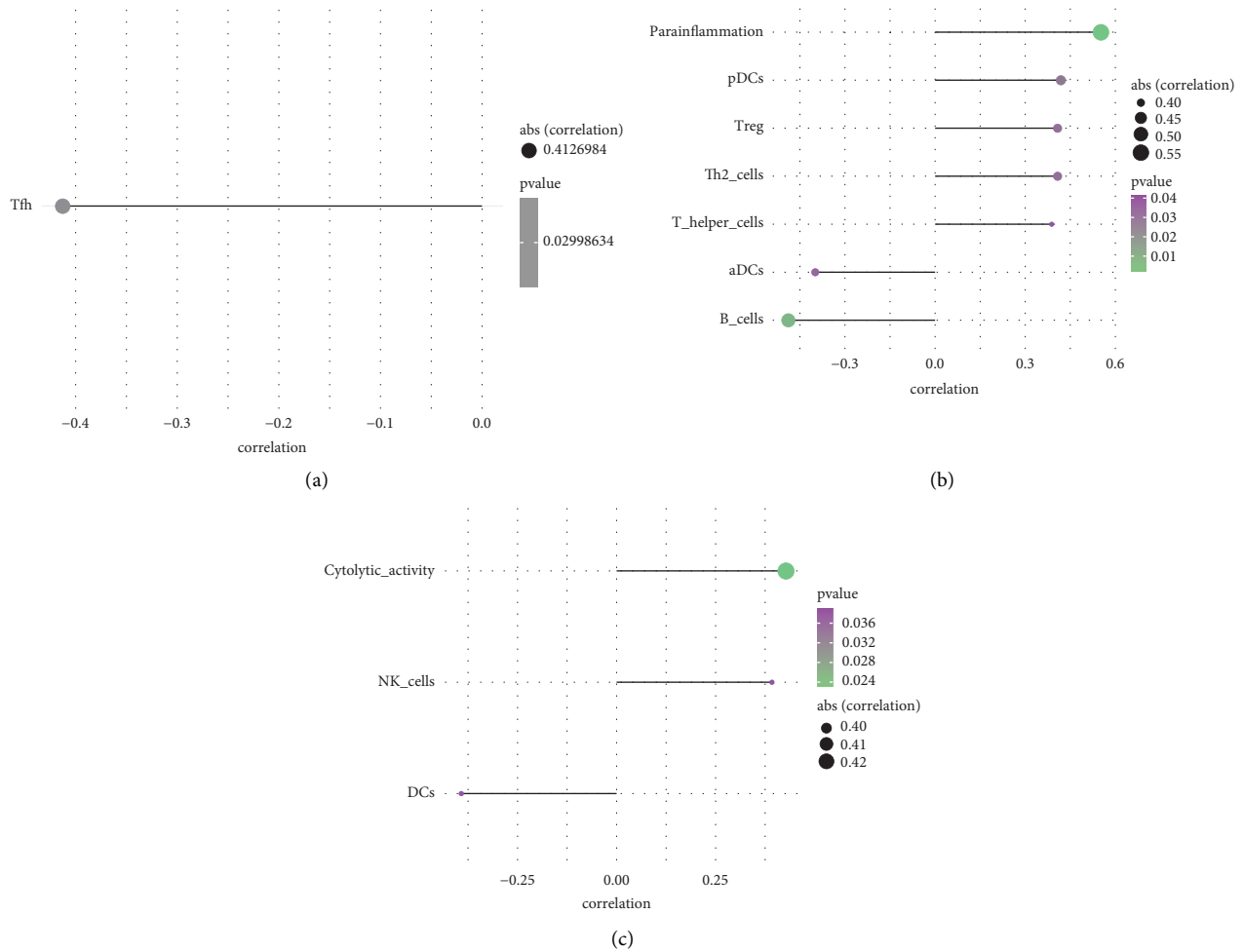


FIGURE 5: All three genes showed a strong correlation with immune cell content. (a) Correlation between CIBERSORT and expression of GPR179. (b) Correlation between CIBERSORT and expression of JPH4. (c) Correlation between CIBERSORT and expression of RNF150.

apoptosis, protein quality control, protein transport, cell proliferation and differentiation, apoptosis, immune regulation, signaling, and mitochondrial dynamics [22, 23]. There are few literature reports on RNF150, but it has been mentioned that single nucleotide polymorphisms in RNF150 may be significantly associated with the risk of COPD (chronic obstructive pulmonary disease, COPD) development in Hainan population, and polymorphisms in RNF150 may be a novel pathogenesis of COPD [24].

Hypertension is a disease with a complex pathogenesis. In addition to disorders of the sympathetic and parasympathetic nervous systems, the renin angiotensin aldosterone system and the endothelin system, genetic predisposition, and the environment, low-grade inflammation is an important factor in causing and maintaining elevated blood pressure. Studies have found that natural immune cells (monocytes/macrophages) and adaptive immune cells (T lymphocytes) are increased in number in hypertension. Natural and adaptive immune responses may be involved in the pathology of high blood pressure and target organ damage [25, 26]. Chronic immune activation of the vascular wall damages endothelial cells and inhibits nitric oxide production and release, leading to structural changes in

blood vessels and diastolic dysfunction; also, immune cells can damage the kidneys, leading to more water and sodium retention, further contributing to elevated blood pressure. In addition, activation of chronic inflammation can cause end-organ damage and dysfunction, ultimately leading to hypertension related complications including coronary artery disease, heart failure, stroke, and chronic kidney disease [27].

Sleep deprivation is the typical pathophysiological feature of OSA, which have been shown to affect the immune system by reducing neutrophil phagocytosis and NADPH oxidase activity, altering the balance of the associated chemokine Th1 and decreasing the levels of CD4+ T Lymphocytes thus affecting vascular endothelial function and the level of inflammation-associated lymphocytes, leaving the whole body in a state of hypo-inflammation, which may be an important factor in the development and progression of hypertension [28]. The three genes we screened have a strong correlation with immune cell content and may also be involved in the pathological course of chronic inflammation.

It is also important to understand the molecular mechanisms of gene pathogenesis by exploring signaling pathways analyzing of the potential mechanisms by GSVA

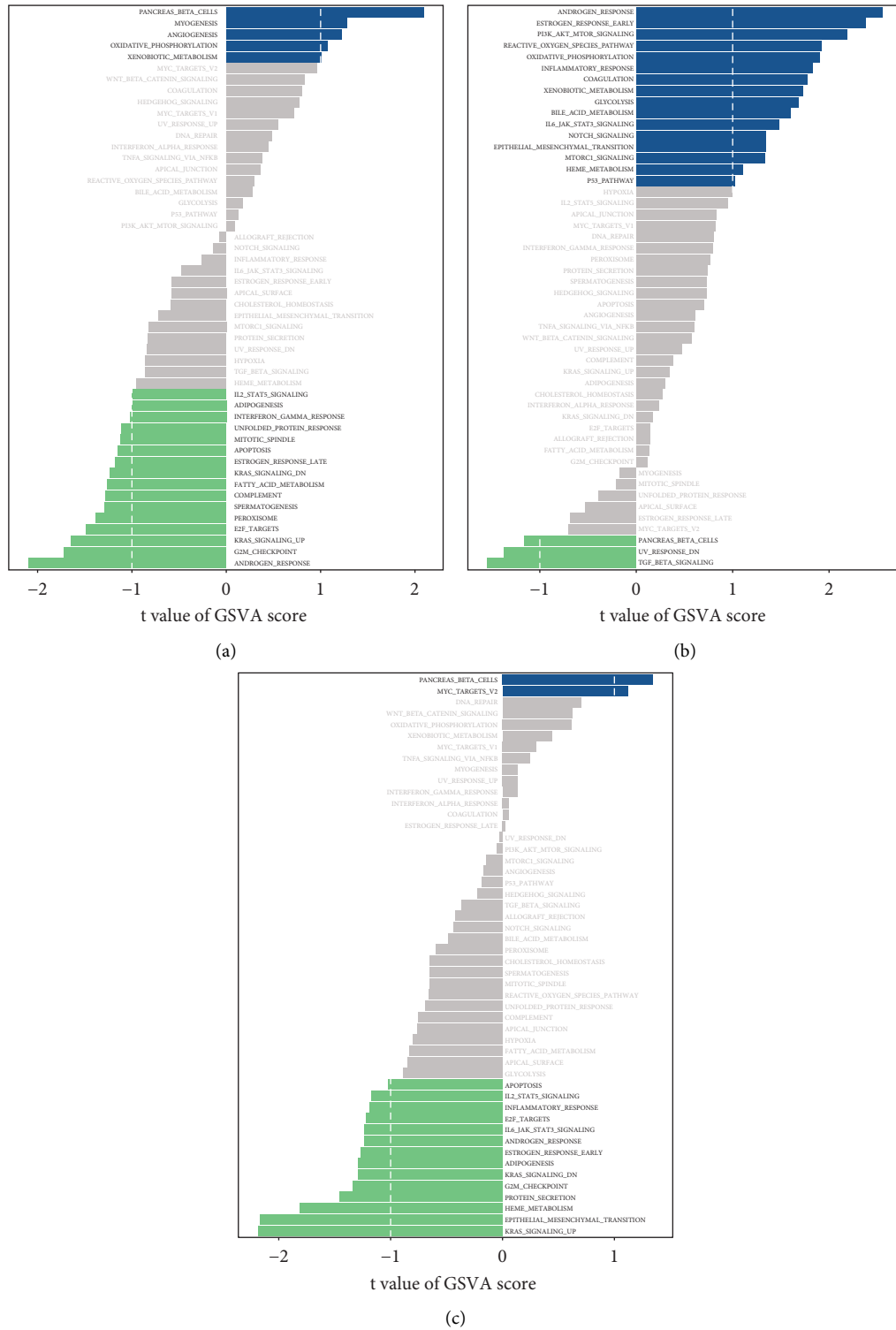


FIGURE 6: Using GSEA to investigate the specific signaling pathways involved in the three core genes and to explore the potential molecular mechanisms by which the core genes affect disease progression. (a) High expression of GPR179 gene was associated with MYOGENESIS, ANGIOGENESIS, OXIDATIVE_PHOSPHORYLATION, and XENOBIOTIC_METABOLISM pathways. (b) High expression of JPH4 is associated with ANDROGEN_RESPONSE, ESTROGEN_RESPONSE_EARLY, and PI3K_AKT_MTOR_SIGNALING pathways. (c) High expression of RNF150 is associated with the MYC_TARGETS signaling pathway.

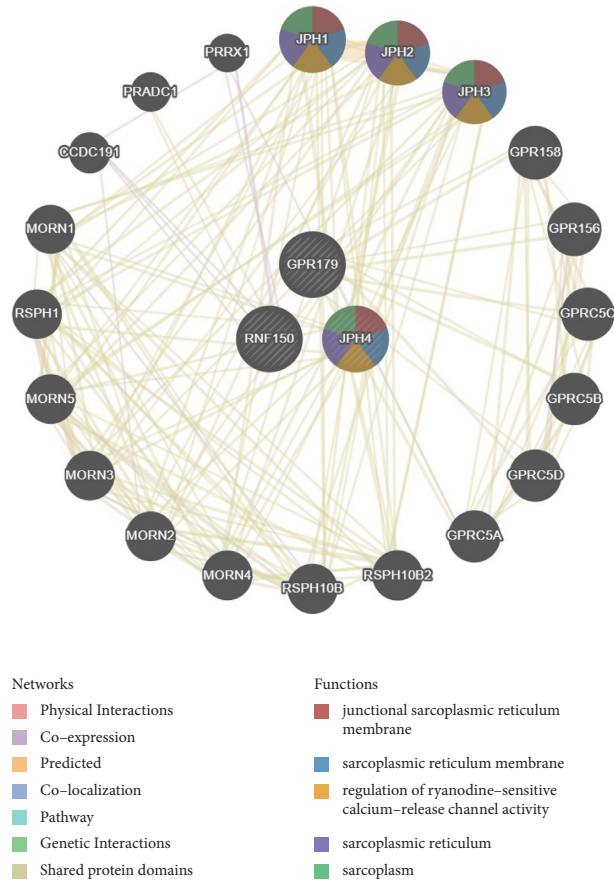


FIGURE 7: Exploring the protein interaction network involved in three core genes through geneMANIA.

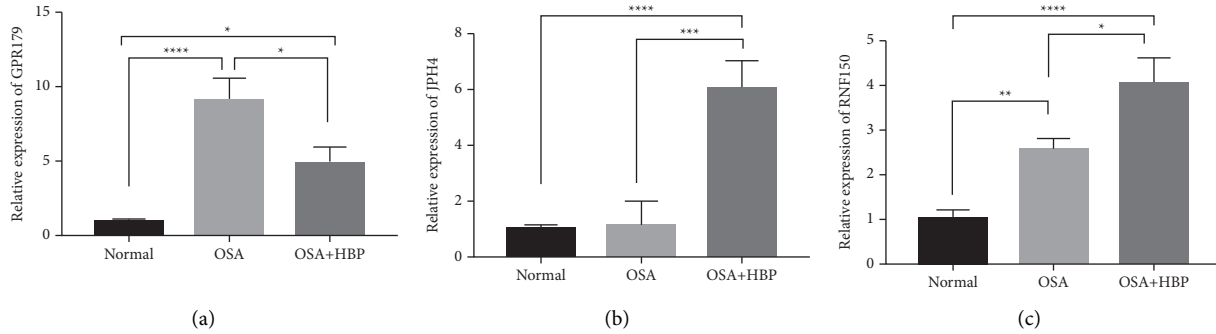


FIGURE 8: The expression of GPR179, JPH4, and RNF150 determined by qRT-PCR; OSA, obstructive sleep apnea; HBP, hypertension. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, **** $P < 0.0001$.

of three core genes affecting disease progression revealed that high expression of the GPR179 gene is associated with myogenic, angiogenic, oxidative stress, and metabolic pathways. In primary hypertension, small arterial smooth muscle cells reorganize around smaller lumens, and in some secondary hypertension, hypertrophic remodeling can be detected. Regardless of the mechanism that initiates blood pressure elevation, systemic vascular structural changes are the end result of hypertension [29]. Studies have shown that increased oxidative stress is an important mediator of endothelial injury in hypertension,

which is associated with the production of prooxidants, such as superoxide peroxide, decreased synthesis of nitric oxide, and reduced bioavailability of antioxidants. Oxidative stress is associated with endothelial dysfunction, inflammation, hypertrophy, apoptosis, cell migration, fibrosis, and angiogenesis which may change vascular remodeling in hypertension [30]. High expression of JPH4 is associated with signaling pathway PI3K/AKT/mTOR. The phosphatidylinositol 3-kinases (PI3K)/serine/threonine kinase (AKT) signaling pathway is a classical transduction pathway involved in cellular activities, such as cell

activation, growth, differentiation, survival, malignancy, and apoptosis, and regulates important biological processes, such as protein synthesis, energy metabolism, and angiogenesis [31]. Studies have shown that nesfatin-1 mediates the PI3K/Akt/mTOR signaling pathway, affecting phenotypic transformation and proliferation of VSMC (vascular smooth muscle cells, VSMC), and controls blood pressure changes [32]. High expression of RNF150 is associated with the MYC signaling pathway, a classical cancer cell pathway that regulates the development of cancer cells [33]. It has now been found that enhanced expression of c-Myc may be associated with the proliferation of smooth muscle cells in small arteries of spontaneous rats [34].

5. Conclusion

Based on a comprehensive bioinformatics analysis, the biological functional differences between OSA combined with hypertension and OSA alone were determined. The combined role of GPR179, RNF150, and JPH4 in the progression was explored. The results showed that all three core genes are associated with immune function and may be involved in the progression of the disease through signaling channels, such as myogenesis, angiogenesis, oxidative stress, PI3K/Akt/mTOR, and MYC, providing a new basis for the potential molecular mechanisms of OSA combined hypertensive as well as diagnosis and treatment.

Abbreviations

DEG: Differentially expression gene
 GEO: Gene expression omnibus
 GO: Gene ontology
 KEGG: Kyoto Encyclopedia of genes and genomes
 PPI: Protein-protein interaction
 WGCNA: Weighted correlation network analysis
 GSEA: Gene set variation analysis
 NADPH: Nicotinamide adenine dinucleotide phosphate.

Data Availability

The codes analyzed during the current study are available in the github repository: <https://github.com/maodunzhazheng/article.git>. The datasets were derived from the following public domain resources: <https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE75097> and <https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE74144>.

Ethical Approval

The clinical experiments involved in this paper were approved by the Ethics Committee of the Second Hospital of Shanxi Medical University (Approval number (2021) YX(230)).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Urban Planning and Design Layout Generation Based on Artificial Intelligence

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Today's cities are becoming more and more complex, the spatial layout is gradually becoming more and more complex, and all aspects of urban construction that need to be considered are increasing. The traditional urban planning and design methods have encountered new challenges. Based on the unique perspective of urban “mesoscale,” this study attempts to apply artificial intelligence technology in the early stage of urban planning and design, predict the positioning of design land based on the surrounding environment, so as to break the limitations of manual decision-making, explore the spatial layout problem from the perspective of machine, find the correlation between land data, and generate results with certain reference value to assist decision-making. By delimiting the research area and collecting and processing data, we trained and generated the artificial neural network model and selected three different areas for model test. The test results verify the feasibility and effectiveness of the method process.

1. Introduction

Human beings have created cities for survival and development. The most important and primary role of cities is to serve as gathering places for people living in them. Human activities connect people with urban space [1–4]. After the rapid development of urban construction, many urban plots have changed towards simplification and homogenization, the urban vitality has been weakened, and various problems have emerged in urban development. In fact, reasonable “mixing” is the form in which the city should exist and the ideal state for the sustainable development of the city. Even if the initial planning is relatively simple, the city still evolves in the direction of mixing in people's actual use until it reaches a more balanced state [5, 6].

In recent years, with the increase of population and the enrichment of human activities, people also put forward new demands for urban construction [7]. The mixed development of cities is not only the current situation, but also a sustainable trend. In this context, the factors to be

considered in urban construction will be more complex, comprehensive, and diversified [8–12]. The traditional experience-based urban planning and design methods have certain limitations, and the scheme ideas put forward by designers based on practical experience are sometimes not comprehensive and in-depth [13]. Today, in a digital era, computer technology is widely used in various fields [14–19], including architecture and urban areas. Concepts are parametric architectural design [20, 21], computational urban design [22, 23], urban big data analysis [24, 25], and smart city emerge [26] one after another.

Although the design field is more subjective than other science and engineering disciplines, it is not without rules to follow. When designers refer to and study excellent cases and apply them to their own schemes, they actually summarize the common laws and patterns of “good design.” Designers can find the law from the scheme. Similarly, if the data is input into the computer, the computer can also mine the law between the data. This kind of computer technology is called machine learning [27, 28], which is a subset of artificial intelligence technology. It aims to “learn” the correlation

between the characteristics of input data and label data through a large amount of data driving, so as to make a more accurate prediction. In urban research, machine learning technology can mine the potential laws between urban spatial layout data and try to generate urban spatial layout scheme from the perspective of computer to assist the existing manual planning and design.

Data input is an important part of machine learning model. The first law of geography reveals the close relationship between adjacent things. The surrounding environment is obviously one of the key factors to be considered in the design of urban spatial layout. The isolated scheme design separated from the environment will be very abrupt. Therefore, if the surrounding environment data of the design land is used as the input, the machine learning model can learn the relationship between the design land and the surrounding environment. The input data will cover multiple dimensions related to urban spatial layout, so as to give full play to the advantages of computer, put the city in a more complete quantitative environment for analysis, and comprehensively consider multiple attribute data of the plot to generate results. To sum up, in urban planning and design, how to use artificial intelligence technology to realize the generation of hybrid urban space layout scheme and create richer urban space to better meet the needs of residents is of great significance for the exploration of new urban research roads in the digital background.

2. Urban Planning and Design Layout Generation

With the help of artificial intelligence technology, we describe the construction process of the urban spatial layout generation method explicitly. The necessary steps of method construction are presented universally to form a standardized process [3, 5]. The premise of method construction is to clarify the basic research unit form of urban spatial layout. This study selected the artificial neural network as the main model algorithm. The relevant data of urban spatial structure is input into the model in a numerical matrix. This study will deal with these data in a grid and take the data grid obtained by dividing the research area into the most basic research unit.

2.1. Overall Framework. This study explores how to construct a method for generating urban spatial layout based on artificial intelligence technology. The method in this study is as follows: the build will consist of specific data preparation and algorithm development. In practical application, the design land may occupy multiple divided grid units. The algorithm development will be subdivided into two parts: single-grid algorithm development and multigrid algorithm development. In the case of an unknown grid, the multigrid algorithm expands the scope of application. The method construction is generally divided into three parts: data preparation, single-grid essential algorithm development, and multigrid expansion algorithm development.

The data preparation part aims to provide data input for the algorithm development part. After data acquisition, data preprocessing, and dataset generation, three-dimensional data is generated for each grid. In addition, when there is a severe imbalance in the number of classes in the dataset, additional processing methods are required to reconstruct the dataset to make the class relatively balanced.

The essential algorithm development part aims to realize the spatial layout generation of a single research grid, including the steps of artificial neural network construction, model training optimization, and result generation and display. The expansion algorithm development part starts from two ideas to realize the generation of multigrid results: They are the solution space optimization search idea based on Monte-Carlo Tree Search (MCTS) [29, 30] and the iterative elimination idea based on adjacent grid filling. The MCTS algorithm uses the complete single-grid model of the neighborhood grid generated by the basic algorithm. The adjacent grid filling algorithm also needs to train several single-grid models with incomplete neighborhood grids. These incomplete models require sample augmentation to the original dataset to ensure sufficient data volume.

The above three parts of the work constitute the entire method content, and the framework flow is shown in Figure 1.

2.2. Data Preparation

2.2.1. Data Collection. This research aims to use machine learning technology to provide a reference for the generation of urban spatial layout. After selecting a target city, to avoid the tendency of result generation to be too evident and single, it will try to delineate the cities with more mature development and more mixed conditions. Areas are used as the research scope, and data acquisition work is carried out so that the data can cover more complex situations and enhance the generality of the method. For a target city, after the training is completed, the model can learn the layout logic of the city; that is, when it is practically applied, the generated reference layout scheme will present a “style” or “feature” similar to the city.

After determining the research scope, to describe the concept of urban spatial layout more comprehensively, this research screened out three elements that are closely related to spatial layout and have a substantial impact: land use function, urban morphology, and traffic connections, and collect the required data from these three aspects as the input to the machine learning algorithm.

(1) Functional Elements of Land Use. The function is one of the most intuitive elements to describe the content of urban land, guiding different human activities. The nature of land use generally refers to the functional use of a piece of land at the planning level, which can be directly obtained from planning data or indirectly obtained through the classification of planned or completed building functions on the plot.

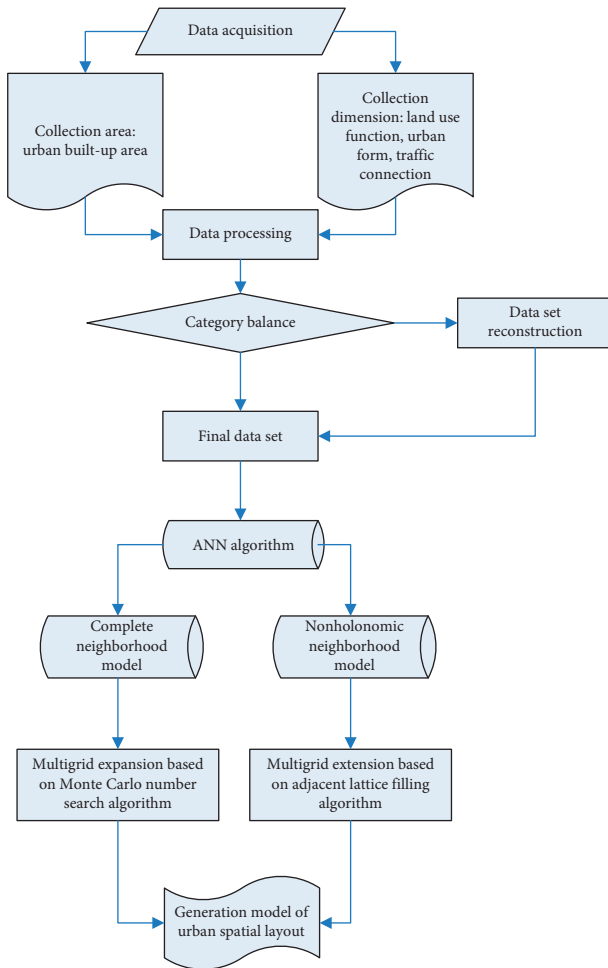


FIGURE 1: Overall framework.

The land use properties in the traditional sense are obtained through the urban land use status map. Still, the drawing of these maps has a significant delay and does not fully conform to the status, and the classification is not precise enough to show the mixed state of the region. In contrast, Point of Interest (POI) is another way of describing land use functions. Each point contains information such as name, latitude and longitude coordinates, and functional classification; the classification is detailed and updated quickly. However, POI also has a big problem: For functions with a single nature but a large area, such as schools and the industrial regions, one point obviously cannot cover the actual range, and the error is significant. The study integrates land use status and various real-time POI data crawled to generate more accurate data on land use properties. Land use status data and POI data are obtained using open map APIs like Baidu Maps and Tencent Maps.

(2) *Functional Elements of Urban Morphology.* Urban morphology is another key element in describing urban space. Applying machine learning requires using a quantitative, discretized representation of urban form so that this element can be smoothly fed into the model in numerical form. At the macroscale, common quantitative expression

methods of the urban form include space syntax, Forntax, Morpho, LCZ theory, etc. Among them, LCZ theory covers more comprehensive quantitative indicators of urban conditions than other methods. While establishing qualitative and quantitative description indicators, it also provides a more applicable method for urban form's quantitative description and research.

The LCZ theory divides urban forms into 17 classes; the built environment includes 10 classes: high-density high-rise, high-density mid-rise, high-density low-rise, low-density high-rise, low-density mid-rise, low-density low-rise, and light-weight low-rise, mass low-rise, scattered buildings, industrial plants. The natural environment includes 7 classes: dense trees, sparse trees, bushes, low vegetation, hard paving, bare land, and water. Since some classifications are rare and inapplicable in China's urban areas, many studies have proposed revisions to the original classes. For example, high-density middle-rise buildings, scattered buildings, dense trees, and bushes were deleted in some studies, and 13 classes were retained. 11 classes were included after research reduction and integration, including 7 built class types and 4 nature class types. Considering that this study focuses on urban built-up areas, too detailed morphological classification of the natural environment will lead to too few samples per class, affecting the model's training effect. Therefore, based on the 11-class classification, this study further simplified the natural environment class, and only the vegetation class and water surface are retained.

To obtain LCZ data, it is necessary to download and get satellite remote sensing image data such as Landsat-8 from the official website of the United States Geological Survey (USGS) and then use the WUDAPT method to process and generate it. The WUDAPT method refers to using the band value of the remote sensing image as the classification basis for water, vegetation, nonvegetation, and other classes and then manually sampling each class in Google Earth, inputting the sample boundary position into the GIS software and comparing it with the satellite image. Get each class of samples based on satellite imagery. Based on these training samples, the random forest algorithm is used to further classify and discriminate the grids in the study area, supplemented by appropriate manual error correction operations, to obtain the final LCZ classification results.

(3) *Functional Elements of Traffic Connection.* In addition to the "content" of the plots, the relationship between plots, that is, traffic, needs to be described in urban design. Many factors affect the traffic connection in urban land use. This study selects point data based on the bus, subway, and other stations and line data related to road networks, such as road grades and road integration. After comprehensive calculation, it is used to characterize the traffic connection strength value of the grid. The site data is obtained through POI crawling, and the road network data is downloaded from the OpenStreetMap (OSM) open-source map website.

In summary, the data used in this study include five types of functional POI, land use status, Landsat-8 satellite remote sensing map, traffic station POI, and urban road network. They correspond to the three dimensions of land use, LCZ,

and traffic intensity of the dataset. Among them, Landsat-8 satellite images and road network data are downloaded from the corresponding website; the rest of the geographic data was obtained from the open map API using web crawling technology (Table 1).

2.2.2. Data Division and Processing. After obtaining the raw data, the following processing steps are performed to generate the dataset results.

(1) *Grid Division.* The study area is divided into grids in the GIS software, and the data of each dimension is superimposed on the grid at the corresponding location using the overlay analysis tool of GIS.

The following two criteria determine the grid size: one needs to match the grid size of the LCZ data as much as possible, and the other is to conform to the common urban block plot size. The grid size of LCZ data is generally between 200 m and 500 m in the early period, and 100 m is more common in recent years. The common size of urban blocks is between 50 m and 200 m. The grid size used in this study is determined according to the specific conditions of different urban instances.

(2) *Data Processing.* To ensure the effectiveness of the machine learning model, the data of the three dimensions need to be normalized.

(a) *Land use data.* This study divides land use properties into five basic classes: business, industrial, public, residential, and landscape, covering most functional land use classes. See Table 2 for specific descriptions and code abbreviations used in the text.

Integrate the crawled functional POIs into the above five classes and stack them on the grid. Considering the hybridity of functions, in order not to lose too much information, this study chooses to calculate the proportion data of five types of land in the grid to represent the land use properties of the grid area, rather than just taking the maximum value to obtain a single dominant class. Based on this, relative proportions of five classes of POIs are generated for each grid calculation. The continuous proportion data are discretized into 6 levels of 0%, 20%, 40%, 60%, 80%, and 100%. For the blank areas not covered by POI, use the current land use data as a supplement to reduce the number of blank grids as much as possible. Finally, a one-dimensional array of length 5 is generated for each grid, and the numeric type is float.

(b) *LCZ data.* The 11 classes of LCZ data generated by the WUDAPT method were integrated into the 9 classes defined for this study, superimposed into the grid, and the LCZ data of each grid was stored in the form of one-hot encoding (One-Hot), and the numerical type was an integer. One-hot encoding is an effective encoding method for dealing with discrete categorical features. For this study, it means initializing a one-dimensional all-zero array of length 9: [0, 0, 0, 0, 0, 0, 0, 0, 0], and change the value of the

corresponding LCZ type position to 1; for example, LCZ 3 can be expressed as [0, 0, 1, 0, 0, 0, 0, 0, 0].

(c) *Traffic intensity data.* This study defines the concept of “traffic intensity,” which describes the traffic situation of a grid by integrating the four factors of subway station distance, bus station distance, road level, and road integration degree. The distance data of two classes of stations are calculated and generated by the corresponding POI through the Euclidean distance tool in GIS. The road level is classified by the road property identification in the OSM road network data, which is divided into 4 levels; the integration degree is calculated based on the road network using the DepthMapX tool generated. The latter two are converted from line to raster data by kernel density weighted calculation.

The four indicators are reclassified according to certain standards, and the traffic intensity level of each grid is obtained after weighted summation. The specific calculation method and standard are shown in Table 3. Among them, the subway and bus stations are reclassified according to a certain radiation distance interval, and the radiation distance interval of the subway station is slightly larger than that of the bus station to reflect the more significant influence of the subway. The road level and road integration degree are reclassified based on the natural breakpoint classification method. In the weighted summation process, the station index and the road index account for 50% of the weight, and the weight of defining the subway station is slightly larger than that of the bus. The weight of the road level is somewhat more significant than the integration degree, which is 30% and 20%, respectively.

Then:

$$x = x_{\text{Subway}} \cdot 0.3 + x_{\text{Bus}} \cdot 0.2 + x_{\text{Road level}} \cdot 0.3 + x_{\text{Road integrity degree}} \cdot 0.2. \quad (1)$$

In formula (1), x is the comprehensive traffic intensity value, and x_{Subway} , x_{Bus} , $x_{\text{Road level}}$, $x_{\text{Road integrity degree}}$ represent the index value of the subway station distance, bus station distance, road grade, and road integration index after classification.

The summation results are divided into 4 levels, normalized to the 0-1 interval (Table 4). The final traffic intensity level data is obtained, represented by a one-dimensional array with a length of 1. The numerical type is a floating-point type.

2.2.3. Dataset Generation. Based on the first law of geography, this study attempts to explore the correlation between unknown grids and their surrounding known grids. Hence, a neighborhood range needs to be determined before data input. According to the definition of Moore’s Neighborhood 99, 3×3 is the minor neighborhood and is suitable as the basic unit of research. In contrast, the 5×5 neighborhood is one more grid distance than the 3×3 neighborhood, and it is

TABLE 1: Data explanation.

Influencing factors	Corresponding data	Data content	Class of data	Data sources	Method of obtaining
Land use function	Land use	Various functions POI	Latitude and longitude coordinates of the point	Open map API	Web crawler
		Status of land use	Latitude and longitude coordinates of each endpoint polygon	Open map API	Web crawler
City morphology	LCZ	Landsat-8 satellite remote sensing map	Raster image	The official website of the United States Geological Survey (USGS)	Download
Traffic connection	Traffic intensity	Traffic stop POI	Latitude and longitude coordinates of the point	Open map API	Web crawler
		Urban road network	The latitude and longitude coordinates of each endpoint of the line	OpenStreetMap (OSM) open-source map	Download

TABLE 2: Classification of land use.

ID	Abbreviation	Land use	Describe
0	B	Business	Entertainment, dining, shopping, hotel, business, etc.
1	M	Industrial	Campus, factories, etc.
2	A	Public	Medical, education, culture, sport, etc.
3	R	Residential	Residential area, etc.
4	G	Landscape	Park, attractions, city squares, etc.

TABLE 3: Traffic intensity level.

Original data		Subway POI		Bus POI		Urban road network			
Corresponding indicators		Subway station distance		Bus stop distance		Road level		Road integrity degree	
						3 Main roads, highways, etc.		DepthMapX calculation	
								Secondary road	
								Branch road	
								Sidewalk etc.	
Quantitative method		Euclidean distance analysis		Euclidean distance analysis		2			
						1			
						0			
						Kernel density weighted analysis			
						Kernel density weighted analysis			
Reclassification criteria		3	Within 500 m	Within 300 m	Natural breakpoint classification (Jenks)		Natural breakpoint classification (Jenks)		
		2	500 m–800 m	300 m–500 m					
		1	800 m–1200 m	500 m–800 m					
		0	Beyond 1200	Beyond 800					
Weights		0.3		0.2		0.3		0.2	

TABLE 4: Standardization method of calculation results.

Calculated value x	Reclassification
$2.25 < x \leq 3$	1
$1.5 < x \leq 2.25$	0.67
$0.75 < x \leq 1.5$	0.33
$0 \leq x \leq 0.75$	0

also a more comfortable theoretical walking distance, worthy of study.

This study chooses to “slice” the original grid based on the two neighborhood ranges of 3×3 and 5×5 . It defines the 8 grids in the 3×3 neighborhood of a grid as an “inner

circle”; the 16 grids extended from the 5×5 neighborhood are called “outer circle.”

After combining the data of the above three dimensions, express the spatial layout properties of each grid as a one-dimensional array of length 15; for example the array [0.2, 0, 0, 0.8, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0.67] means that 80% of the grid plot is residential land; 20% is commercial land, mainly high-density mid-rise buildings, and high traffic intensity (Table 5).

We slice the matrix grid data into 3×3 and 5×5 ranges using Python and remove the slices that contain blank grids without data to obtain a slice set that can be used for training. Extract the data of 8 (3×3 neighborhood) or 24

TABLE 5: Grid space layout data.

Land use					LCZ									Traffic
B	M	A	R	G	1	2	3	4	5	6	7	8	9	—
0.2	0	0	0.8	0	0	1	0	0	0	0	0	0	0	0.67

(5×5 neighborhood) grids around the slice, and connect them into a one-dimensional array as learning data; extract the data of 1 grid in the middle as a label data to compare with learning results to evaluate training accuracy. For the 5×5 neighborhood, it is necessary to extract the data of the 8 grids in the inner circle and bring it to the front to be consistent with the input order of the 3×3 neighborhood.

Each slice is transformed into a 1D array of length $15 \times 9 = 135$ (3×3 neighborhood) or $15 \times 25 = 375$ (5×5 neighborhood), and the first 120 (3×3 neighborhood) or 360 (5×5 neighborhood) values are learning data. The last 15 are labels, which are processed in turn, and the final dataset results of 3×3 neighborhood and 5×5 neighborhood are obtained based on the slice set.

2.2.4. Analysis and Handling of Dataset Imbalance. The scope of data collection selected in this study is urban built-up areas, which will inevitably encounter the problem of unbalanced dataset categories. For example, the proportion of business, public, and residential land use is obviously higher than industry and landscape. The proportion of medium- and high-rise building types corresponding to these types of land will also be higher than that of low-rise buildings, vegetation, and water surfaces.

Dataset imbalance is a common problem in machine learning. When the number of samples is not much different, it can be ignored, but if the gap is relatively large, such as class A: class B = 100 : 1, it will lead to a poor model training effect. Neural networks largely tend to predict outcomes as class A. This model looks very accurate, even reaching 99%, which fully meets the requirements of high scores, but in fact, it completely ignores a few classes, and the model is almost ineffective.

To solve this problem, on the one hand, it is necessary to choose a new evaluation criterion to accurately analyze the training and prediction of each class of samples to determine whether the high accuracy of a model is the result of being “cheated” by an imbalanced dataset. The confusion matrix was used as an additional evaluation criterion in this study. A confusion matrix is an effective tool for evaluating the accuracy of multiclassification problems in supervised learning and can calculate multiple evaluation metrics suitable for multiclassification problems.

On the other hand, after determining that the effect of a model has indeed been affected by the problem, action needs to be taken for it. The treatment of dataset imbalance problem is generally considered from two aspects: algorithm and data. The former refers to using some optimization methods in the machine learning algorithm to incorporate the difference in the number of classes into the impact on the parameters as much as possible. The latter refers to trying to

change the imbalance in the dataset itself. This study chose to approach this question from a data perspective.

Without considering the fundamental adjustment of the research scope and classification method, the proportion of the original categories of the dataset cannot be changed. It is necessary to adjust the number of various types of samples through resampling to realize the reconstruction of the dataset. Resampling methods include undersampling (reducing the number of samples) for large classes and oversampling (increasing the number of samples) for small classes. Still, in general, undersampling will result in the loss of more information for the class of samples. Therefore, this study only adopts the oversampling method to expand the number of small class samples to narrow the gap between classes and solve the imbalance problem. Of course, this method will change the distribution of the original category, and further, it will forcefully reverse the preferences of the original model, which will undoubtedly cause new problems. As a compromise choice, this study will not resample a total balance of the number of each class when reconstructing the dataset. Still, there is a relative balance so that the proportion gap between the classes is not too large.

Taking a noncomplete LCZ model that needs to be added to the adjacent grid filling algorithm as an example, the reconstruction process of the dataset is briefly explained, and the sample data is shown in Table 6. As an incomplete model, the corresponding dataset needs to be expanded in quantity to ensure that the total number of samples is not too small. Assuming that the original number of 9 classes of LCZ samples is unbalanced, the initial total number of samples is the sum of 9 types of 2475, and the original expansion ratio is 6 times, the total number of samples that need to be expanded is 14850. Suppose we want to achieve absolute equality of the sample sizes of all types. In that case, 1650 of the total is the target value of each class of samples. Before the correction, the resampling ratio can be obtained by dividing the target value by the original number. A specific manual correction is made to this group of magnification values in the original distribution of various proportions. There is a specific difference between the multiplied resampling quantities, and the multiple classes are relatively balanced. After resampling, the total number of samples is 12850, which is not much different from the total number after the original augmentation.

As for the specific source of sample expansion, a sample slice with a complete neighborhood grid, 90° rotation, mirroring, etc. can generate new samples, and one sample can be changed to a maximum of 8; that is, the maximum magnification is 8 times; for slices with incomplete neighborhood grids, the expansion space depends on the degree of “incompleteness”; for example, any one of the 8 grids in the inner circle lacks any one of the corresponding $C_8^1 = 8$ possibilities, lack any 2 corresponding $C_8^2 = 28$ possibilities, and so on, different incomplete cases have different expandable magnifications, and the minimum is 8 times. When the dataset is unbalanced, this study will set the corresponding resampling ratio for each dataset based on the above process. Reconstruct the distribution of the dataset to reduce the negative impact of imbalance and train to obtain a better model effect.

TABLE 6: Dataset reconstruction examples.

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9
Number of original samples	100	1000	100	400	400	200	50	200	25
Resampling ratio before correction	16.5	1.65	16.5	4.125	4.125	8.25	33	8.25	66
Corrected resampling ratio	13	3	13	4	5	6	25	8	40
Number of resampling	1300	3000	1300	1600	2000	1600	1250	1600	1000

2.3. Development of Single-Grid Basic Algorithm. ANN is generally composed of the input, hidden, and output layers; each layer contains several neuron nodes, and directed weighted arcs are used to connect each node. Build an ANN algorithm model and load the processed dataset for training. The input data is the three-dimensional (land property, LCZ, traffic intensity) data in the neighborhood of the unknown grid, and the output result and the corresponding label are the two-dimensional (land property, LCZ) data of the unknown grid. In reality, road traffic often exists before the construction of urban land. The subsequent urban design generally does not change the traffic conditions around the design land, so the traffic intensity data is only used as an input and not an output. In addition, to avoid the output results being too complicated to parse, this study separates the output of land use and LCZ and trains two types of models. The two datasets of 3×3 neighborhood and 5×5 neighborhood finally correspond to four models.

For the convenience of discussion, the numbering method of defining the dataset is neighborhood range_number of grids in the inner circle (_number of grids in the outer circle), the same below. Among them, the dataset corresponding to the 3×3 neighborhood is numbered by the first two groups of numbers: neighborhood range_inner circle grid number. For example, 3_8 means that, in the 3×3 neighborhood, the data of the 8 grids in the inner circle is used as the input dataset; the dataset corresponding to the 5×5 neighborhood uses 3 sets of numbers: neighborhood range_number of grids in the inner circle_number of grids in the outer circle; for example, 5_8_16 means that, in a 5×5 neighborhood, the data of 8 grids in the inner circle plus 16 grids in the outer circle, a total of 24 grids are used as input dataset.

In the specific training process, the dataset shall be randomly divided into training set and testing set in the ratio of 7 : 3, and the built ANN shall be input for certain epoch¹⁰³ times of training. The training set is used as the known data input to the neural network for learning, and the test set is used to evaluate the performance of the model on the unknown dataset. Through repeated training of known data, the network gradually adjusts and optimizes the weight value of the connection between nodes and learns the relationship between input and output. In addition to the weight parameters, there are also superparameters that need to be manually defined, such as the number of hidden layers and the number of neuron nodes in each layer. It is often impossible to find the parameter setting that can make the network play the best performance immediately when the network is initially built. It is necessary to evaluate the actual performance of the network on the dataset through the evaluation function. Based on this, the parameter setting of

the network is repeatedly adjusted and optimized, and finally a model that can reflect the internal law of urban spatial layout in the corresponding area of the dataset is obtained.

The evaluation function generally refers to the loss function and accuracy function of the model. The worse the weight of the neural network is, the worse the performance of the neural network is calculated automatically. In this study, the cross-entropy error function is used as the loss function:

$$E = - \sum_i t_i \log y_i. \quad (2)$$

In formula (2), E is the cross-entropy error, y_i is the neural network output of the i th sample, t_i is the correct unlabeled of the i th sample, and y_i and t_i are represented by one-hot coding.

The calculation of accuracy can more intuitively show the quality of network performance. Different tasks will define different accuracy functions. For some simple problems, it can be calculated directly by judging whether the generated result is "equal to" label. This method is called "equivalence" evaluation in this study. When the result is more complex, and the judgment of the original result will be affected by simply summarizing it with the word "right" or "wrong," the "Deviation" evaluation of the result can be obtained by calculating the difference between the generated result and the label data. This study combines the two standards of equivalence and deviation to score the two dimensions of output.

3. Analysis and Discussion

It is one of the important reasons for this study to explore the laws existing in urban spatial layout data from the perspective of computers. Given the use of an artificial neural network as the main model algorithm in this study, exploring the layout rule is equivalent to exploring the connection between the input and output data, that is, analyzing the possible relationships and laws between the current situation data of the surrounding environment input by the sample and the prediction results of the central grid output. Before conducting this analysis, three questions need to be clarified: What is the sample to be analyzed? What does surrounding data mean? What is the forecast result?

For question 1, it is evident that the model's performance on the unknown test set can better reflect the real learning situation than the training set, so the rule analysis is mainly based on the test set samples of 90 models generated by the training. Moreover, no matter whether the score is high or low, the model's prediction of the sample will follow certain internal logic and laws. Still, the laws embodied by the

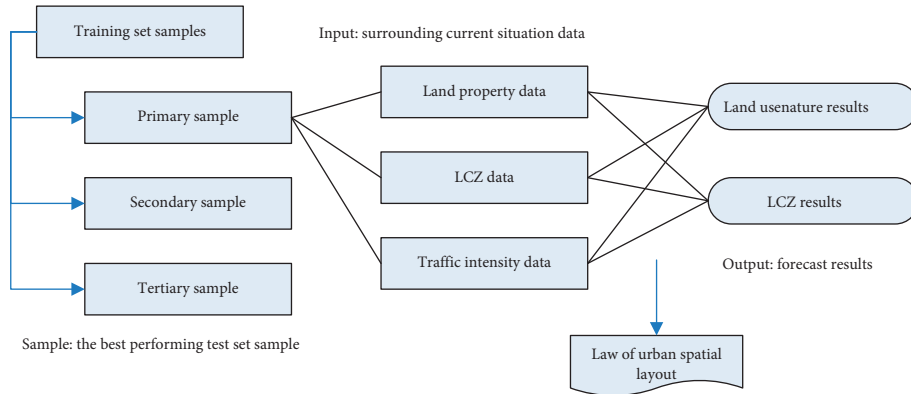


FIGURE 2: Law analysis process.

TABLE 7: Proportional distribution of test set results of the model.

	Score	Level	3 × 3 neighborhood		5 × 5 neighborhood	
			Number of samples	Proportion (%)	Number of samples	Proportion (%)
Land use	≥80	A	7856	58.88	169678	77.51
	60–80	B	2234	16.67	26088	11.47
	40–60	C	1955	14.45	15045	6.77
	20–40	D	1109	8.34	7266	3.81
	≤20	E	224	1.66	1076	0.44
LCZ	100	A	9322	47.11	168789	77.33
	0	B	10489	52.89	49672	22.67

samples with high scores conform to the real situation, while the samples with low scores do not. To explore the realistic part of the rules found by the model, in this study, the test set samples are divided into different levels according to the scores of the prediction results, and the in-depth analysis is performed based on the best performing part of the samples.

For question 2, the surrounding data refer to the grid's land use, LCZ, and traffic intensity data in the neighborhood.

For question 3, the prediction results refer to the land use properties and LCZ prediction results of the unknown grid in the middle. And the results of land use properties can be subdivided into 16 classes: there are only one dominant class (5 class), two dominant classes (10 class), and no obvious dominant class (1 class); LCZ prediction results can be subdivided into 9 classes, corresponding to 9 LCZ classes. Figure 2 shows the relationship between the above three answers and briefly illustrates the steps of law analysis.

After the analysis object is defined, the analysis is carried out according to the following steps: (1) divide the test set samples into different grades (grades) according to the prediction score, and briefly describe the general situation of samples at each grade. (2) Observe whether the samples with good performance have common neighborhood characteristics. (3) Take the best performing class A samples and briefly describe the general situation of the prediction results of each subdivision category. For (4) the nature of land use and (5) LCZ, deeply analyze the relationship between the surrounding current situation and the data of the prediction results in the middle, and summarize the possible laws in the urban spatial layout.

The test set samples are divided into different grades according to the result score, in which the land property results are divided into five grades, and LCZ has only two grades of correct or wrong prediction. Table 7 shows the specific number and proportion of samples at each level.

As can be seen in Table 7, the prediction performance of 5 × 5 neighborhood is better than 3 × 3 neighborhood, and the prediction performance of land property is better than LCZ, which is in line with the conclusions obtained from the analysis above.

Comparing the conclusions of land use property model and LCZ model, it is found that the samples with good prediction performance are the same, but some characteristics of their surrounding environment are opposite. For example, after the proportion of landscape land increases, the prediction effect of land use property is worse, but the prediction effect of LCZ is better. This shows that the model has great differences in the prediction law of land use properties and LCZ.

4. Conclusions

This study comprehensively analyzes and evaluates the artificial intelligence generation method of urban spatial layout from two aspects: algorithm and result. In the algorithm analysis, firstly, the 90 ANN models of the example city are analyzed and evaluated based on various scoring indicators, including the analysis of the overall performance of the model and the comparative analysis of the land use property model and LCZ model. The analysis

shows that the overall effect of the ANN algorithm is better, and the performance of the land use property model is better than LCZ model, and several factors affecting the performance of the model are summarized. The results show that the adjacent lattice algorithm is better than MCTS algorithm. In the result analysis, the three multigrid test results generated based on the adjacent lattice filling algorithm in the example application are briefly analyzed and interpreted, and then the sample data of the test set based on 90 ANN models are deeply discussed. The relationship between the surrounding current situation and the prediction results in the middle is analyzed, from which a series of more reasonable urban spatial layout laws in the research area are summarized. It is proved that this research method has certain practical value.

Data Availability

The raw data supporting the conclusions of this article can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declared that they have no conflicts of interest regarding this work.

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Retraction

Retracted: The Construction of Innovation and Entrepreneurship Incentive Mechanism for College Students Based on Hierarchical Analysis

Mathematical Problems in Engineering

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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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Research Article

The Construction of Innovation and Entrepreneurship Incentive Mechanism for College Students Based on Hierarchical Analysis

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Innovation and entrepreneurship (I&E) are of great significance to China's modern economic development, and college students are the most innovative and entrepreneurial potential group. I&E requires college students through the effective combination of various incentive methods on the basis of the individual differences and diversity of college students, so that the I&E enthusiasm of college students can be continuously and optimally exercised. Based on the theory of hierarchical analysis, this paper establishes the evaluation system of the implementation effect of college students' I&E incentive mechanism by setting the evaluation indexes of the effect of college students' I&E incentive mechanism, calculates and obtains the weights of each evaluation index, and provides a reference basis for the design of college students' I&E incentive mechanism. Our experiment demonstrate that the CR values of the judgment matrices calculated are less than 0.1, so the consistency test of the judgment matrix is passed.

1. Introduction

The call for “mass entrepreneurship and innovation” (referred to as “dual innovation”) was first proposed by Premier Li Keqiang and has since been mentioned at the First World Internet Conference, the State Council executive meeting, and other events, with a view to cultivate and give birth to a brand new driving force for national economic development, stimulate the innovation potential and entrepreneurial vitality of the whole society, realize the wealth of the people and the strength of the country, and, to a certain extent, provide a useful supplement to the employment issue. As an important way, I&E education has naturally become a new hot spot in China's higher education reform. It organically combines scientific research, educational teaching, and business training and prepares the majority of entrepreneurs to engage in innovative and entrepreneurial activities by first conducting theoretical research on innovative and entrepreneurial education and then putting the research results into simulation exercises, psychological quality, and innovative and entrepreneurial ability. However, in order to guarantee the effective development of I&E

education, it is imperative to establish a set of scientific and effective incentive and restraint mechanism to regulate the behaviors of universities.

The enthusiasm and risk prevention cannot be shirked, which requires colleges and universities to have scientific, standardized, complete, and operable incentive policies, means, and methods [1]. At present, the employment concept of most students still stays in the period when the pursuit of stable jobs is the ultimate goal. They think it is only a special educational activity for the benefit of every individual students with strong innovation ability and excellent theoretical study results, while the mass group finds it difficult to get involved in it. Coupled with the inactive overall environment constituted by society, school, and family, it also strangles the entrepreneurial thoughts of the majority of students in the cradle.

The survey shows that most domestic colleges and universities' I&E education work is led by the president in charge of student work who is in charge of the employment guidance department, student management department, league committee, or ideological and political research department, jointly responsible for completing education and

teaching work and organizing students to carry out activities, and there is no special management and research department yet. This messy management situation will inevitably lead to the lack of close connection between entrepreneurship education teaching and professional teaching, as well as the difficulty of effective cooperation between departments in the university [2]. In addition, it is not effectively combined with economic development, and the existing theoretical system only stays at the research level, with fragmented content forms, and is not combined with the existing education and teaching system of higher education to form a systematic theoretical and practical system [3].

Lack of Scientificity of the Incentive Scheme. At present, when universities manage the I&E activities of college students, they usually carry out the incentive work according to some rough indicators, lacking comprehensive and objective research on the incentive factors and lacking detailed analysis on the effectiveness of each incentive factor, so the incentive scheme and incentive measures lack scientificity [4].

From the perspective of reinforcement theory, the lack of scientificity of incentive programs in colleges and universities is as follows: not enough attention is paid to the spiritual motivation factor in positive reinforcement; not enough attention is paid to the role of negative reinforcement in correcting the bad behaviors and preventing the potential risks of I&E; not enough scientific analysis of the role of each subfactor in incentive factors; not enough evaluation of the effectiveness of incentive measures [5, 6].

Nowadays, due to the lack of intelligent data analysis methods and mining tools, colleges and universities cannot quickly and comprehensively grasp the information changes of college students' I&E when carrying out innovation management work affairs; cannot use big data intelligent facilities to grasp the latest intelligence in time; and cannot take the initiative to discover the bad phenomena or even illegal and unlawful behaviors of college students. We cannot accurately grasp the incentive timing and adjust the incentive strategy in time [7]. Therefore, this paper focuses on establishing the evaluation system of college students' I&E incentive mechanism based on the evaluation indexes with the theoretical basis of hierarchical analysis.

2. Current Situation of I&E Incentive Mechanism for College Students

I&E is a key factor, and it is of great significance to social and economic development. General Secretary Xi Jinping proposed "innovation is the first driving force to lead development" at the two sessions in 2015, and Premier Li Keqiang mentioned I&E at various events such as Davos Forum, World Internet Conference, and State Council executive meeting [8]. It has an important guiding significance in fostering and stimulating the innovation potential and entrepreneurial vitality of the whole society. College students have the most active dynamic factor of innovation drive [9–11]. Therefore, colleges should adjust their strategies to effectively guide college students' practices and cultivate

their innovative spirit. Motivation plays an indispensable management and guidance function in modern organizations [12]. Based on the incentive theory, the establishment of higher education I&E incentive mechanism will have a good promotion effect on effectively solving the problems of students' innovation education, employment, social adaptation, self-cognition, and career planning [13].

Psychologists believe that motivation is a state of mind of human beings, and all actions are caused by some motivational motives [14]. American psychologist Douglas McGregor's X-Y theory points out that X theory believes that human nature is lazy, puts personal interests and security first, does everything possible to avoid work and resist change, and must adopt coercion and implement both hard and soft management methods; Y theory believes that most people have certain imagination and creative talent [15–17]. The reason for college students' lack of enthusiasm and their weak innovation and entrepreneurial ability is that the school lacks an effective incentive mechanism to bring out their potential [18].

Maslow believed that people can have multiple needs at the same time in the same period, and in each period, each person has different needs. Of these five needs, not all can be met, the higher the level of needs, the more difficult to meet, the needs will determine human action, and not yet satisfied needs in the life stage occupy a major position [19], [20]. The difference between Theory X and Theory Y lies in the different understanding of human nature, so the motivation methods are also different.

3. I&E Incentive Mechanism

3.1. Overview of Hierarchical Analysis. Analytic Hierarchy Process (AHP) is a decision analysis method for quantifying qualitative problems firstly proposed by Thomas L. Saaty, an operations researcher at the University of Pittsburgh in 1977. The weight of each indicator or factor at each level is calculated by the quantification method of qualitative indicators as the decision basis for the solution of multiobjective optimization problems [21–23]. The specific steps are shown in Figure 1.

Where the consistency ratio CR consistency ratio, CR is the actual fluid that can be divided into Newtonian fluid and non-Newtonian fluid. All gases and most liquids are Newtonian fluids, and their shear stress is proportional to the velocity gradient; the scale coefficient is

$$CR = \frac{CI}{RI} \quad (1)$$

3.2. Determination of Evaluation Indexes. This paper adopts in-depth interviews and questionnaires to determine each evaluation index, and the selected experts are mainly enterprise leaders of various industries, university experts, and students. According to the hierarchical structure of hierarchical analysis, the ability is selected and the three-level target hierarchical structure evaluation system is determined. The first-level target level is the evaluation system X,

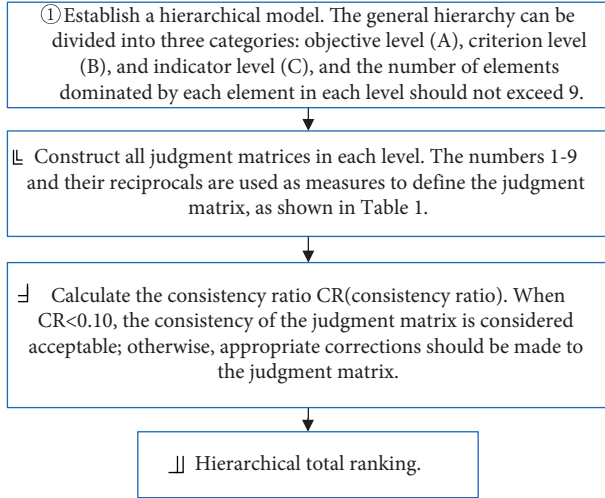


FIGURE 1: The flow chart of AHP.

TABLE 1: Evaluation model of the effect incentive mechanism of college students.

General objectives	Primary target	Secondary targets
Evaluation system of I&E incentive mechanism in higher education X	Incubation platform Y1	Return rate of special support funds for I&E Z11, utilization rate of I&E incubation platform Z12, coverage rate of students in I&E projects Z13
	Faculty level Y2	Award rate of I&E competition guided by teachers Z22, rate of successful transformation of teachers' innovation achievements Z23, success rate of I&E of students supervised by teachers Z24
	Student level Y3	I&E ability enhancement degree Z31, enhancement of I&E quality Z32, quality growth rate of I&E Z33, success rate of transformation of patent achievements Z34

and the second-level guideline level includes 3 parts as shown in Table 1 that incubation platform Y1, teacher level Y2, and student level Y3. The secondary evaluation indexes of Y1 are return rate of special support funds Z11, utilization incubation platform Z12, and student coverage rate of projects Z13. The secondary evaluation indexes of Y2 are number of I&E projects supervised by teachers Z21, award rate of I&E competition supervised by teachers Z22, success rate of transformation of teachers' innovation results Z23, and rate of transformation of teachers' innovation results supervised by students Z24. The secondary evaluation indexes of Y2 at teacher level are the number of I&E projects supervised by teachers Z21, the rate of winning I&E competition supervised by teachers

TABLE 2: Definition of judgment matrix measures.

Scale	Meaning
1	Indicates that two factors are of equal importance compared to each other
3	Indicates that the former is slightly more important than the latter when compared with the other
5	The former is significantly more important than the latter when compared to the other
7	The former is more important than the latter when compared to the other
9	The former is more extremely important than the latter when compared to the other
2, 4, 6, and 8	Indicates the middle value of the above adjacent judgments
Countdown	If the ratio of the importance of factor i to factor j is a_{ij} ; then the ratio of the importance of factor j to factor i is $a_{ji} = 1/a_{ij}$

Z22, the rate of successful transformation of teachers' innovation achievements Z23, and the rate of successful transformation of teachers' I&E Z24; the secondary evaluation indexes at student level are the enhancement ability Z31, the enhancement quality Z32, the growth rate quality Z33, and the rate of successful transformation of patent achievements Z34.

3.3. Calculation of Indicator Weights

Scoring of Indicators by Domain Experts. In this paper, we adopt interviews with business leaders and university experts to achieve comparative ratings of the relative importance of the three categories of criteria in the model in Table 2 and the 11 evaluation indicators. The ratings are based on a 1–9 scale as shown in Table 3.

We construct the comparison judgment matrix and normalized feature vector W . The results of the calculation of the feature vector W of the judgment matrix at each level are shown in Tables 4–6.

There may be some subjectivity in the scoring of the indicators of the effect of I&E incentive mechanism by experts in each field. The CR values of the judgment matrices calculated according to formula (1) are shown in Table 7. It can be seen that the CRs of the above four judgment matrices are less than 0.1, so the consistency test of the judgment matrix is passed [24, 25].

As can be seen from Table 8, the student level has the greatest weight among the 3 guideline level indicators.

4. Measures to Improve the Incentive Mechanism

To build a reasonable incentive mechanism, it is necessary to establish a smooth information communication channel so as to ensure that information users can get relevant information in time. If students get certain achievements in I&E, universities can give them certain credit rewards and make sure that there are records of credit increase in the relevant system.

TABLE 3: X-Y comparative judgment matrix and eigenvectors.

	Y1	Y2	Y3	W
Y1	1	1/3	1/5	0.0871
Y2	3	2	1/4	0.2649
Y3	7	2	2	0.6387

TABLE 4: Y1-Z comparison judgment matrix and eigenvectors.

	Z11	Z12	Z13	W
Z11	1	8/3	9	0.7687
Z12	3/8	2	5/4	0.1821
Z13	1/7	2/3	2	0.1019

TABLE 5: Y2-Z comparison judgment matrix and eigenvectors.

	Z21	Z22	Z23	Z24	W
Z21	1	2	5/6	2	0.3012
Z22	1/2	1	1/3	1/3	0.1277
Z23	6/5	3	2	2	0.4123
Z24	1	3	1/2	2	0.2118

TABLE 6: Y3-Z comparison judgment matrix and eigenvectors.

	Z31	Z32	Z33	Z34	W
Z31	1	5/4	1/3	9/8	0.2568
Z32	3/4	2	6/5	1	0.2528
Z33	2	5/6	1	9/8	0.4134
Z34	7/8	2	8/9	1	0.2339

TABLE 7: Consistency test results of the judgment matrix.

	X-Y	Y1-Z	Y2-Z	Y3-Z
γ_{\max}	3.0499	3.0224	4.1589	4.1324
CI	0.0269	0.0161	0.0525	0.0420
RI	0.5900	0.5900	0.9000	0.9000
CR	0.0459	0.0297	0.0569	0.0471

Improving the incentive mechanism of college students needs to be done step by step. In the process of improving the incentive mechanism, colleges and universities should continuously strengthen the establishment of internal reward and punishment mechanism and count I&E into the credit mechanism, so as to continuously improve the ability of college students in all aspects. Colleges and universities should first pay attention to cultivating college students' entrepreneurial consciousness.

For contemporary college students, it is necessary to achieve all-round development. The quality requirements of college students in the new era also cover the quality of I&E, requiring that college students should have a certain entrepreneurial spirit and innovation consciousness, which can only be cultivated through I&E education

TABLE 8: Table of weights of indicators.

Y to X weight	B1	B2	B3	Z to X weight
	0.0869	0.2737	0.6393	
Z11	0.7259	0	0	0.0598
Z12	0.1658	0	0	0.0152
Z13	0.1079	0	0	0.0089
Z21	0	0.2797	0	0.0778
Z22	0	0.1258	0	0.0342
Z23	0	0.3912	0	0.1032
Z24	0	0.2068	0	0.0576
Z31	0	0	0.2431	0.1518
Z32	0	0	0.2512	0.1555
Z33	0	0	0.2949	0.1879
Z34	0	0	0.2288	0.1496

because there is no way to cultivate them in their daily life. For colleges and universities, cultivating students' professional skill level so that they can better serve the society is an important part of education, but cultivating students' innovation and entrepreneurial ability is also one of the essential educational tasks of colleges and universities.

The university can give the students a certain amount of money for their achievements in I&E during their school years and can also use the money as a project fund for the students' research products. This can give students certain financial support, reduce their entrepreneurial risk, increase their interest in entrepreneurship, and further improve the construction of incentive mechanism.

The main way to provide college students with the opportunity to practice I&E is to open an I&E area and create an entrepreneurial atmosphere where college students can open their own stores, sell products, or develop products. Colleges and universities should not charge students for their stores and encourage them to try their hand at innovative entrepreneurship on campus, cultivating their sense of relevance and constantly making their businesses stronger and bigger with their own efforts.

5. Conclusion

In short, through a combination of rewards and punishments, we should build an incentive mechanism for I&E for teachers and students, which is based on the theme of "combining education with practical education" and runs through the whole process of talent cultivation in colleges and universities. This paper uses the hierarchical analysis method, combines qualitative and quantitative analysis, and establishes the evaluation system of I&E incentive mechanism for college students with 11 indicators in 3 aspects: incubation platform, teacher level, and student level. This not only provides a new way to evaluate the effect of I&E incentive mechanism of college students but also provides a reference basis for how to design an effective I&E incentive mechanism of college students.