Wireless Communications and Mobile Computing

Models and Methods for Opportunistic Mobile Social Network Computing

Lead Guest Editor: Kapil Sharma
Guest Editors: Christian Esposito and Dimitrios A. Karras

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Retraction

Retracted: Exploration of Regional Public Digital Culture Service Mode Based on Artificial Intelligence Technology

Wireless Communications and Mobile Computing

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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] Q. Yin and Y. Dong, "Exploration of Regional Public Digital Culture Service Mode Based on Artificial Intelligence Technology," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 1852502, 11 pages, 2022.

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Retraction

Retracted: The Application and Development Trend of Youth Sports Simulation Based on Computer Vision

Wireless Communications and Mobile Computing

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References

[1] T. Zhou and Y. Wang, "The Application and Development Trend of Youth Sports Simulation Based on Computer Vision," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 8500869, 9 pages, 2022.

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Research Article

Development and Application of Ceramic Cultural and Creative Products Based on Artificial Intelligence

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Ceramic cultural and creative products are creative products with ceramic cultural characteristics that have been concerned and loved by people since they entered the modern society. Various cultural and creative products represent the efforts of the ancients and the infusion of modern souls, and they have become a very memorable product. However, in the development of such products, it has always been a difficult problem to solve, and there are many difficulties in developing a product. It needs to consider the practicality of the product and must also combine cultural characteristics. It also makes innovative changes. It cannot blindly reproduce cultural relics. It must have its own design concept. Finally, it has to cater to the needs and preferences of consumers. Because there are so many factors to consider, designers spend a lot of energy and time in the process of developing new products. Therefore, in order to help designers get relevant and accurate data faster and more efficiently, we propose a method of artificial intelligence technology. It analyzes the development and application of such products and conducts experimental research on the role of artificial intelligence in product development and application. The results show that the technology is very suitable for product development and application, and it improves the effectiveness of product development and application. The pattern is the feature that can best show the uniqueness of the ceramic process. After using the algorithm in this paper, the extraction level can reach 0.73 and only 0.66 if it is not used. Therefore, in order to make the development and application of such products better, the application of artificial intelligence technology should be emphasized.

1. Introduction

Ceramics have always been a representative of traditional Chinese culture, it represents the wisdom and hard work of our ancient people. In recent years, the design of ceramic cultural and creative products has become a very hot topic. Many artists have spent a lot of thought in this area and are committed to promoting ceramic products. At present, there are quite a lot of ceramic products on the market, and the sales volume is very considerable. Whether it is for collection or personal use, these ceramics are very good choices. The development and application of ceramic cultural and creative products has always been a difficult problem to solve. Cultural and creative products have to meet people's needs, and they must also create benefits and bring nonmaterial services. It is slightly different from pure art ceramic products. Cultural and creative products are more like a souvenir that everyone can like and have. In addition, novelty and practicality must be considered in cultural and creative products. So even old artists are very troubled by the development and application of these products. Considering the quintessence of ceramics and the fact that it belongs to an era of intelligence, the development and application of this type of product is worthy of research and discussion by scholars.

Due to China's emphasis on traditional culture, more and more scholars have studied the subject of ceramic cultural and creative products. Among them, Rui and Liqun analyzed the application mode of design symbol theory in the development of cultural and creative products [1]. However, the data he used in this paper are very early data and are not novel enough for current research. Later, Wang argued that cultural identification and cultural determination determine how to best apply them to commercial

products, and for this to require the investigation and compilation of large amounts of cultural information [2]. But he did not take into account the possible existence of other influencing factors during the experiment. Li and Zhang studied the development of cultural products as a way to perfectly combine traditional materials with the spiritual needs of the new era [3]. But the theoretical framework he used in this paper is not very complete. Ngo et al. studied the use of the input-output table method and proposed a method to measure the development economy of cultural and creative products [4]. But when he described the relationship between the cultural industry and other economic sectors, he did not express their relationship very comprehensively.

In terms of artificial intelligence, Bin and Kumbier discussed how to summarize public interest through surveys and realize human-machine collaboration in product development and application [5]. But the case studies he lists in the article do not quite fit the theme of the article. Botega and Silva proposed a system using artificial intelligence (AI) to assist designers in knowledge management of designs [6]. But the model he used when designing the system was not very suitable for the system. Liu analyzed the construction of management performance model based on artificial intelligence technology, and he found that artificial intelligence can provide corresponding products according to customers' interests [7]. But he did not first explain the meaning of management performance in the text.

Artificial intelligence technology can be used flexibly in various professional fields, and its research is very technical and professional. It can quickly and correctly learn external data, and use this data to achieve the goals to be achieved. Its capabilities are even comparable to those of humans, and may surpass humans in some respects. This technology is also often used in product design and development applications, and the effect is very good. The innovation of this paper is to use a new method, artificial intelligence technology, to research the development and application of ceramic cultural and creative products. In the research process, a simple and effective method is used to investigate the existing data for detailed analysis, which attempts to prove that artificial intelligence technology and the research object of this paper are a perfect combination. It provides support for future research on similar topics.

2. Methods of Development and Application of Ceramic Cultural and Creative Products

This chapter mainly introduces the development and application methods of ceramic cultural and creative products. It also introduces the use of artificial intelligence algorithms to explore and identify the characteristics and influence of cultural and creative products. Cultural and creative products are currently very optimistic in China, and ceramics are the representative of Chinese tradition. There are a number of things that require special attention in the development of such products. Artificial intelligence technology has the ability to quickly extract and apply big data. These are all good factors that help product development and application, so it is necessary to conduct method research on ceramic cultural and creative product development and application before drawing conclusions.

2.1. Ceramic Cultural and Creative Products. The history and culture of ceramics is very long. After thousands of years of craftsmanship, the current technology of making ceramics is very mature. In the context of this new era, we should continue to carry forward the ceramic culture [8]. And ceramic cultural and creative products are ceramic products that are innovatively transformed by combining people's actual needs [9]. It is loved by people. According to the latest survey, it can be found that what people value most is whether ceramic products have particularly attractive ideas. As shown in Figure 1, ceramics can also be made into very delicate and lovely dolls. Like the rabbit in the picture, it is lifelike, small, and cute. The material looks very different from other materials and looks very transparent. Neither children nor adults can resist its charm. This type of product is also very good as a home decoration. The innovative combination of ceramics and metal is also very good. The cutting of modern craftsmanship and the fire refining of ceramics together create a cross-era spark from ancient times and modern times [10]. This type of new craft design is very popular with today's urbanites. Painting on ceramics is also a new idea. Because it is the trend and retains the traditional charm. Painting landscapes on ceramics makes the whole ceramic product very artistic. The moment seems to place one in a kind of poetry and painting from Chinese literati. And the panda is also a unique symbol of China and is very popular among the people. If the collision of metal and ceramics gives people a modern feeling, then the collision of geometric lines and ceramics gives people a feeling of breaking the stereotype and looking new. The use of geometric lines as ornaments makes these cups simple and atmospheric, as well as mathematically mysterious. All in all, innovation and meeting customer needs are very important for cultural and creative products.

As a result, with the development of technology, there are many innovative ways for such products. Designers can study the characteristics and special elements of each porcelain according to the achievements of the ancients and the different characteristics of each age. And in this process, combined with the needs of consumers, he will develop the artistic imagination of creation, injected his own inspiration into the porcelain, and let it reflect his own design concept and aesthetic point of view. But designers should strictly follow the development process design when creating such products, as shown in Figure 2. When developing a new product, it should first interpret the culture of a certain era required, and then extract the desirable elements. By giving play to the imagination, it endows this product with functions, subdividing new colors, new ideas, and user preferences. It then successfully developed a new product, which was finally marketed on the Internet. And in the process of creation, designers cannot break away from the background of the current era, so that the works have the unique characteristics of this era [11].

Figure 1: Ceramic cultural and creative products.

In fact, in the current ceramic product market, we can find that many products are replicas of the elements in the craftsmanship of the past. It is just a replica of the dial, and it does not have any design soul at all. It lacks aesthetic value and cultural heritage. Therefore, in the development of such products, we should deeply understand and explore the characteristics of various aspects of cultural relics, extract visual elements, and representative symbols, add our own understanding and artistic expression, and design products according to current people's needs. The cultural and creative products designed in this way can express artistic features and at the same time be widely welcomed by the public [12]. The method of its element extraction is shown in Figure 3. When extracting, attention should be paid to the user's emotions, that is, the user's interests. We should also focus on functional requirements, and we must determine the purpose of the product and what functions it should have. Then it combines the above two requirements to extract symbols. The products produced in this way can give users a functional user experience on the outside and bring a brand new emotional experience to users on the inside [13].

2.2. Artificial Intelligence Technology. As a technical science, artificial intelligence mainly studies the characteristics and laws contained in human intelligent activities. Based on these characteristic rules, it imitates and constructs artificial systems with a certain degree of intelligence and attempts to let computers use intelligent artificial systems to complete tasks and tasks that previously required human intelligence [14]. In short, artificial intelligence mainly studies how to apply the software and hardware of computers to simulate the basic theories, methods, and technologies of human intelligent behavior and simulate, extend, and expand human intelligence through intelligent algorithms, platforms, or machines. From another point of view, it is more like an interdisciplinary. As shown in Figure 4, AI brings together almost all disciplines.

It also has many application fields, as shown in Figure 5. A robot (such as PET chatbots) can understand human language. It can use human language to conduct a complete dialogue with humans, and it can use specific sensors to analyze the situation and adjust its actions to achieve the purpose of expression [15]. This aspect of language recognition has always been a unique capability of AI. This field has essentially the same part as robotics, which is designed to convert language and sound into information that can be processed. For example, the intelligent voice assistant that comes with the mobile phone now can help perform operations on the mobile phone through voice [16]. Image recognition can use a computer to process and analyze images. It can be used to identify different targets and objects, such as face recognition and automatic license plate number recognition, which are often used now. Expert system refers to a computer intelligent program system with considerable professional knowledge and experience. The database it uses is similar to the human brain, the storage capacity and calculation capacity are very good, and it can simulate experts to solve some difficult problems.

The core of artificial intelligence is mainly machine learning and deep learning. The artificial intelligence algorithms are mainly deep learning algorithms and artificial neural network algorithms [17].

2.2.1. Deep Learning Algorithms. The deep learning algorithm is mainly for further research on artificial neural network algorithm in order to improve the learning ability of the algorithm model. It was proposed mainly for algorithms to learn to think like humans [18]. Below we mainly introduce the deep learning model with the RBM model as the main structure. It is a model of energy minimization theory. Its probability formula can be expressed as:

$$Q(C,J)=\frac{R^{-energy(C,U)}}{X},X=\sum_{C,J}R^{-ENERGY(C,U)}, \tag{1}$$

where energy (C, U) represents the energy of the model, and C and J mean the variables in the model, as shown in Figure 6.

As shown in the figure, the same level of the model is independent, so the energy formula of the model can be expressed as:

$$ENERGY(C,J)=-N^{Y}C-B^{Y}J-J^{T}EC, \tag{2}$$

where E, B, and N represent the parameters between layers. From the above two formulas, we can infer that the conditions of the hidden nodes are independent.

$$Q(J|C)=\frac{R^{N^{Y}+V^{Y}J+J^{Y}EC}}{\sum_{J'}R^{N^{Y}+V^{Y}J'+J'^{Y}EC}}, \tag{3}$$

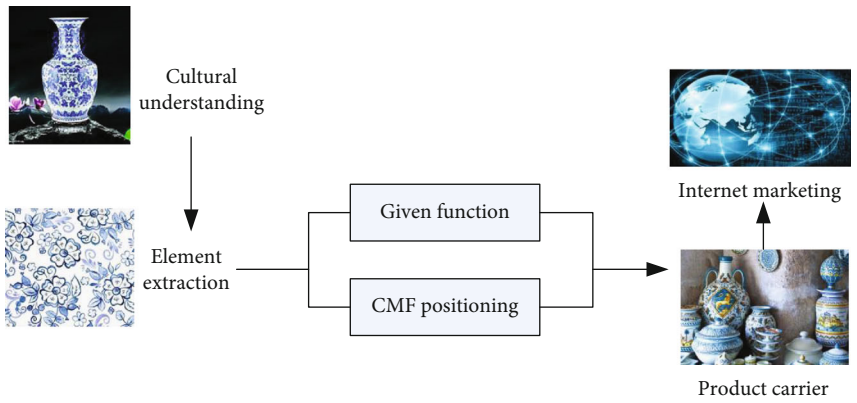


Figure 2: Development design flow.

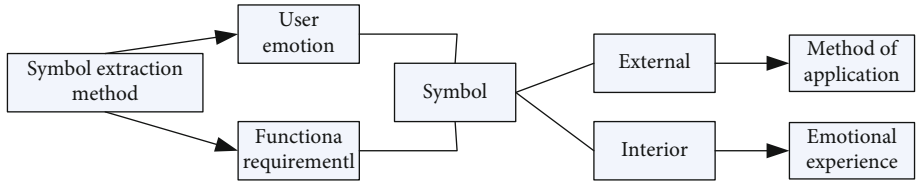


Figure 3: Visual element and representative symbol extraction method.

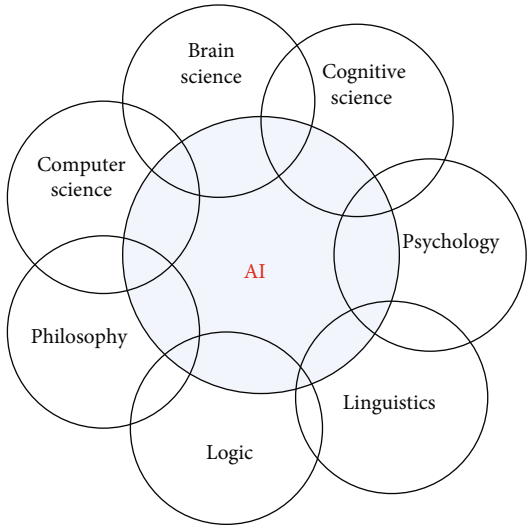


Figure 4: Relationship diagram.

$$Q(J|C) = \prod_{O} \frac{R^{J_O(V_O+E_OC)}}{\sum_{J''} R^{J''_O(V_O+E_OC)}}, \tag{4}$$

$$Q(J|C) = \prod_{O} Q(J_O|C). \tag{5}$$

If J_O falls within the range of 0 or 1, the probability of the 0th node can be expressed as:

$$Q(J_O = 1|C) = \frac{R^{V_O+E_{0C}}}{1 + R^{V_O+E_OC}}, \tag{6}$$

$$Q(J_O = 1|C) = \frac{1}{1 + R^{V_O+E_OC}}, \tag{7}$$

$$Q(J_O = 1|C) = SIGM(V_O + E_OC). \tag{8}$$

Because C and J are two variables, they are also symmetric in the formula, E_K represents the Kth column of the E matrix, and we can get:

$$Q(C|J) = \prod_{O} Q(C_O|J), \tag{9}$$

$$Q(C_O|J) = SIGM\left(N_O + E_K^Y J\right). \tag{10}$$

In order to obtain effective results in the process of product development and application, feature extraction is also a very important link in deep learning. C^{ORI} represents the original eigenvector, and N and D represent the mean and variance.

$$C^{NOR} = \frac{C^{ORI} - N}{D}. \tag{11}$$

2.2.2. Artificial Neural Network Algorithm. This algorithm has a good learning ability to represent the relationship between the feature vector and the target value [19]. To create a good model of this type, one must determine the variable parameters in the data to get the number of neurons per hidden node. Although there is no good system to explain so far, we can make changes based on previous research by scholars to obtain the formula:

$$Z = \sqrt{M + L} + S. \tag{12}$$

This algorithm also has some modes of learning and training. The input value for the Nth neuron node of the

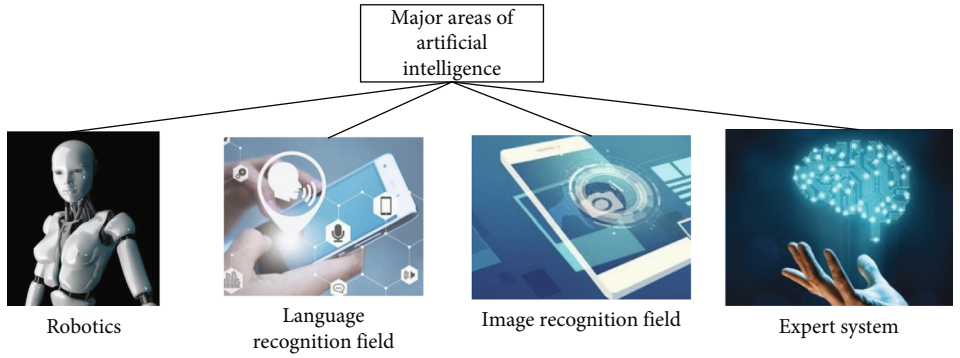


Figure 5: Major areas of artificial intelligence.

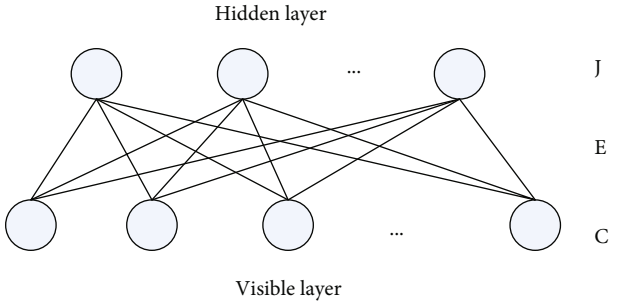


Figure 6: Schematic diagram of the RBM model.

hidden layer is mainly the weighted sum M of the calculated values of each bottom layer:

$$M = \sum_{M=1}^{M} C_M E_{MN} + \vartheta_N. \tag{13}$$

After activation, the output Q of the Bth node can be obtained:

$$Q = J_N(M) = G(M) = \frac{1}{1 + R^{-\left(\sum_{B=1}^{B} E_B + \theta_N\right)}}. \tag{14}$$

However, for the Lth node of the final layer, the corresponding output weighted summation formula can be:

$$P_L = \sum_{N=1}^{N} ME_{NL} + N_L. \tag{15}$$

Then according to the data of the input sample, assuming it is the Fth input sample data, it can know that the error formula is:

$$E_F = \frac{1}{2}\sum_{L=1}^{L}\left(U_L^F - P_L^F\right)^2. \tag{16}$$

If the training set has a total of F sample sets, then the overall error of the algorithm can be expressed as:

$$E = \sum_{F=1}^{F} E_F = \frac{1}{2}\sum_{F=1}^{F}\sum_{L=1}^{L}\left(U_L^F - P_L^F\right)^2. \tag{17}$$

In order to reduce the error value, it is assumed that $\nabla\vartheta_n$ is the offset correction amount, ∇e_{mn} represents the weight correction amount, and ∇n_l is the final correction amount. Finally, the formulas can be obtained:

$$\nabla\vartheta_n = -\frac{\exists e}{\exists\vartheta_n}, \tag{18}$$

$$\nabla e_{mn} = -\frac{\exists e}{\exists e_{mn}}, \tag{19}$$

$$\nabla n_l = -\beta\frac{\exists e}{\exists n_l}. \tag{20}$$

3. Experiment on Development and Application of Ceramic Cultural and Creative Products Based on Artificial Intelligence

This chapter mainly talks about the current situation of ceramic cultural and creative products and uses the survey method to conduct statistical analysis on them. Then, the main influencing factors of the current cultural and creative products are known, and then the artificial intelligence algorithm of this paper is used for experimental research. This paper attempts to dig deeper into the effectiveness of artificial intelligence in product development and application.

3.1. Current Situation

3.1.1. The Status Quo of Cultural and Creative Works in the Palace Museum. Due to the rapid development of China's cultural industry, cultural and creative products in the Palace Museum have also emerged. Next, we will conduct a current research on the status quo of cultural creativity in the Palace Museum [20]. The development of cultural and creative products in the Palace Museum is also quite representative. At the beginning, its cultural and creative works were relatively normal, lacking in new ideas, and sales were not very good. After bold changes were made, new

products were designed according to the needs of consumers, and the sales volume soared [21]. This article takes the ceramic cultural and creative products mainly based on the tableware of the Forbidden City as an example.

As shown in Figure 7, currently in the Tmall Palace Museum Cultural and Creative Flagship Store, the highest-selling mug is this Jingui Fuyue mug. As shown in the figure, it adopts the theme of the jade rabbit flying to the moon, and adopts the collision of two colors of gold and black. There is also a small rabbit on the lid, which is very cute. The pattern on the cup body is the jade rabbit flying to the moon. It is very representative of traditional Chinese stories. It has very Chinese characteristics. And it can be found that the price of ceramic cultural and creative products in the online store is not set very high, and the price is still very close to the people. And practicality and aesthetics are also high. And there are many classifications of ceramic tableware, which greatly meets people's diverse needs [22]. Moreover, it can be seen from the picture that the sales of such products sold by online stores are also very considerable. Among them, the best-selling is the mug, followed by the ceramic bowl and plate, and the least selling is the saucer. It shows that when people buy cultural and creative products, the most important thing is practicality. And it can also be found that the sales in the official flagship store are still higher than other stores. It shows that customers still pay more attention to the channel and formality of products, and many people may just buy for traditional culture.

After statistics of cultural and creative tableware products, we want to study the sales of other cultural and creative products [23]. Therefore, the top 6 online sales of cultural and creative products of the Forbidden City are presented in the form of a table, as shown in Table 1. First of all, we can find that the unit price of the top six cultural and creative products does not exceed 150 yuan, the price is very close to the people, and it can be seen that the top six products are mostly bought by women. This shows that the majority of consumers are women. Among them, the highest-selling product is the matte lipstick. Its monthly sales volume has reached 12,000+, and the monthly sales revenue is 14.44 million+, which is enough to prove the success of this product design. The sixth kitten ornament is a ceramic cultural and creative product. Its unit price is very low, only 20 yuan. Its monthly sales are also very impressive, with 9,000+ and monthly sales income of 171,000+. The popularity is also very high. In short, a product with good ideas and high practicability will not have low sales, so when we develop new products, we should consider how to develop this product from the perspective of consumers.

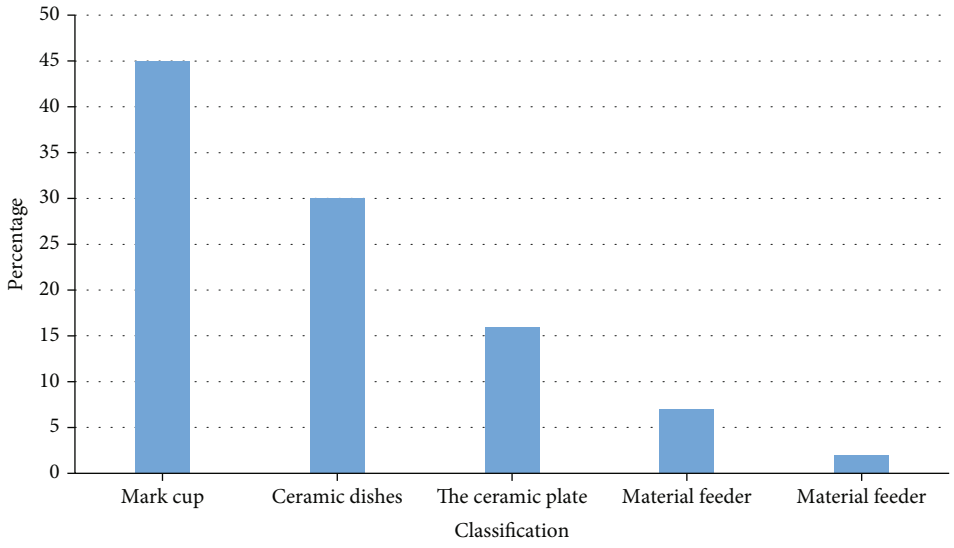
Below, the author selects four museums to conduct research on their cultural and creative products and try to find out the properties of ceramic products inside. As shown in Table 2, some relevant information can be obtained from the table. The general types of museums are mainly teacups, coasters and tea sets. The main reason is that these products are more practical and convenient for development and application [24]. Among them, some museums also designed related skin care products and cosmetics, which shows that the cultural and creative industry has paid attention to the purchasing power of female consumers. It began to shift its center to female consumers and designed many products that cater to the current needs of women. In addition to the above, we can also find that the museum also designed a lot of small things, such as sticky notes, refrigerator magnets and decorative ornaments. This shows that the design range of cultural and creative products is very wide, and almost anything can be designed into cultural and creative products. Then, in terms of design ideas, we can find that the first choice of many museums is the shape of the product, and then the pattern. Some also focus on function and meaning. These are also very important for a cultural and creative product.

In addition to investigating the cultural and creative products of the four museums, the author also investigated the collections of several famous porcelain factories in Jingdezhen (# indicates the number of items in the collection, and X indicates none, as shown in Table 3). It can be found that the Jianguo Porcelain Factory has the most collections, and it has collections of three types of porcelain. However, the Xinhua Porcelain Factory is a new factory, so it does not collect some of the more historically valuable porcelain. Xinhua Porcelain Factory mainly manufactures the porcelain of the present craft. There are also many collections in the People's Porcelain Factory. It has collections of national ceremony porcelain and celebration porcelain. All in all, from their collections, it can be seen that the craftsmanship of these porcelain factories is mainly concentrated, and then designers can use these traditional cultural elements to design new cultural and creative products.

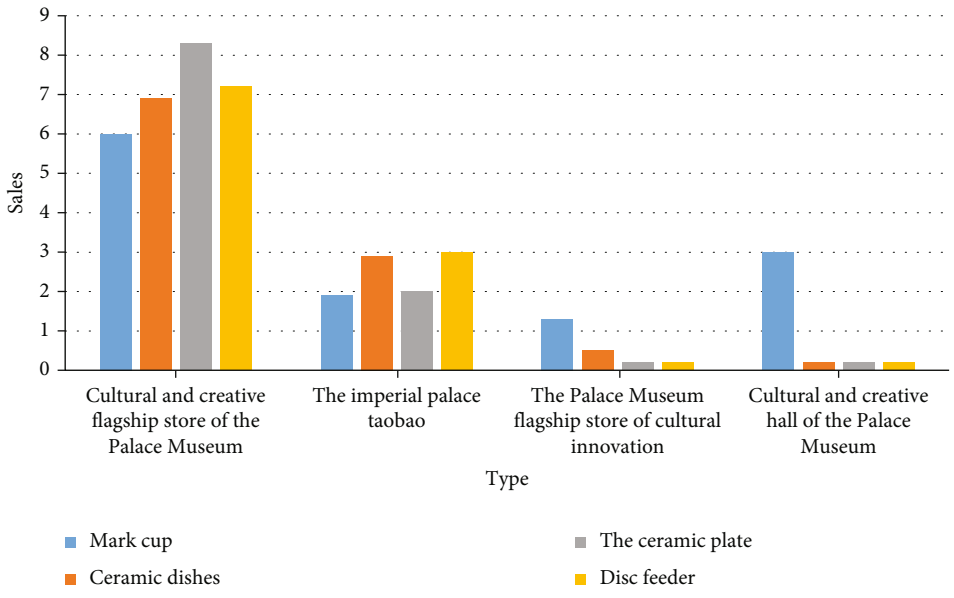
3.1.2. Questionnaire Survey. In order to gain an in-depth understanding of consumer demand for cultural and creative products, we conducted a questionnaire survey. The survey questions are what are must-haves for a cultural and creative product. It produces questionnaires through paper questionnaires and questionnaires.

The survey results are shown in Figure 8. In terms of cultural connotation, 123 think it is very important. 109 respondents believed that commemorative significance is very important, because when buying a cultural and creative product, it is hoped that it has a collection value and can be kept as a memorial forever. In terms of unique ideas, 90 people chose unique ideas, because when buying a product, it is important that it is different, unique, and can attract people's attention. 80 people chose high quality, because if the quality of a product is not good enough, it will not be pleasant to buy it again, so quality is also very important for cultural and creative products. In other respects, there are also many people who choose green environmental protection, high quality and low price, and fashion and beauty, and they think these characteristics are also very important. However, in terms of design style, we simply divided three styles, one simple, one traditional, and one cartoon. From Figure 8, it can be found that 60% of people choose the traditional style. It seems that people's pursuit of traditional culture is still very profound, to pass on traditional culture and support the trend of traditional culture. 28% of people chose the cartoon style, but the combination of ceramics and cartoons is

(a) Jingui Floating Moon Mug



(b) Classification of cultural and creative ceramic tableware



(c) Sales volume of different online platforms of Ceramic Culture and Creation

Figure 7: Ceramic tableware cultural and creative products.

also very innovative, and it is a style that young people like very much now. 12% chose the simple style. It seems that although this style may be very fashionable when combined with ceramics, it has always lost a little quaint charm. Therefore, it can be concluded that the development and design of ceramic cultural and creative products still have to be designed and developed according to consumers' preferences, and then add the designer's design concept so that it is better to design.

Table 1: Details of the top six cultural and creative products in sales.

Name of commodity	The unit price	Monthly sales	Monthly sales revenue
Crane matte lipstick	121	1300+	1440000+
Moist lipstick	121	8600+	1020000+
Monochromatic eye shadow	67	6100+	396000+
Take capsule bracelet	81	5600+	440000+
Key chain	52	7100+	357000+
Cat ornaments in the palace museum	20	9100+	171000+

Table 2: Design and arrangement of related museum cultural and creative products.

The museum	Species	Design ideas
China Ceramics Museum	Hanfu, coasters, mirrors, cups, replica disks, decorative ornaments	Shape pattern color
Palace Museum	Necklaces, teacups, cushions, tea sets, filing bags, porcelain carvings	Shape design function color implication
National Museum of China	Fridge magnets, protective covers, notepads, lamps	Modeling design meaning
The Summer Palace	The notebook	Modelling design

Table 3: Collections of Porcelain Factory.

Porcelain factory name	Country gift porcelain	Celebration of porcelain	To commemorate the porcelain
The founding of the porcelain industry	#Sanyang Kaitai glaze flat belly bottle	##azure pile plum blossom earth bottle, blue and white glaze red hundred words figure bottle	#azure pile plum blossom earth bottle
Porcelain factory names	#blue and white Wutong tableware	#blue and white and sunflower tableware	X
Xinhua porcelain factory	X	X	X

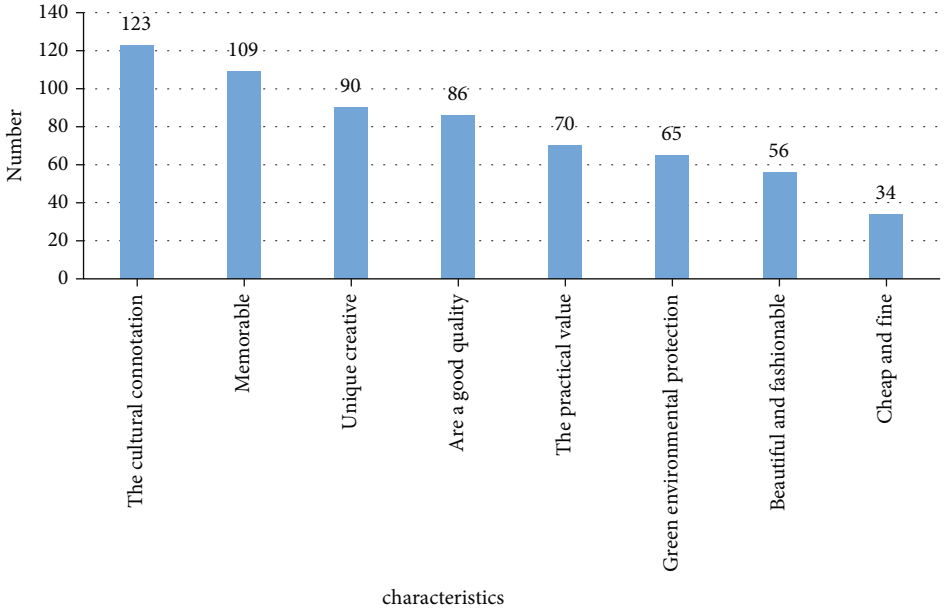
3.2. Experiment

3.2.1. Feature Extraction Experiment. In order to verify the feasibility of the above AI algorithm, we will compare the experimental results between the features processed by the deep learning algorithm and the features processed without it. Using the two sets of experimental data of A and B, the algorithm is used to perform feature extraction experiments on these two sets of data, and finally Figure 9 is obtained.

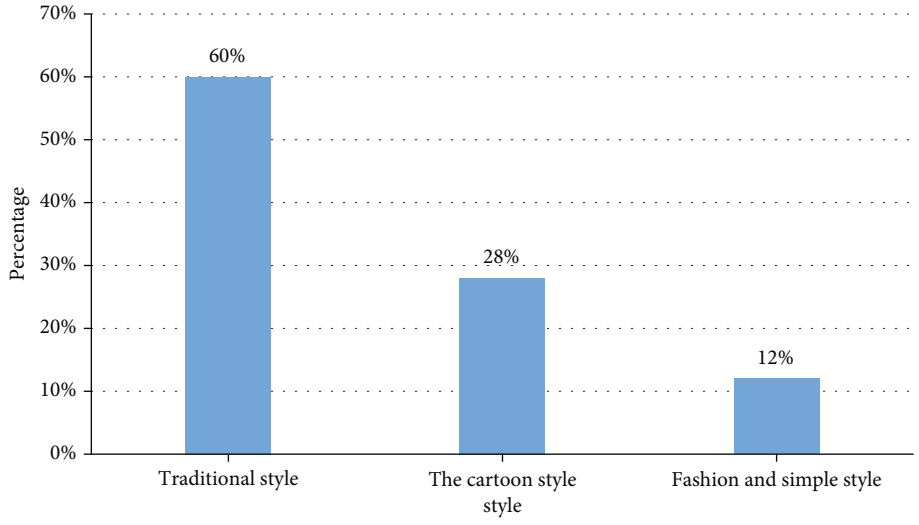
As shown in Figure 9, two sets of data that need feature extraction are given. For different extraction expectations, the feature vectors that use and do not use the algorithm are used as different visual element indicators. As can be seen from the figure, when the expected value is 5%, a maximum value is obtained. And it can be found that the eigenvalues extracted by the algorithm are higher than the eigenvalues extracted by no practical algorithm. This shows that the algorithm proposed in this paper is very suitable for the development and application of cultural and creative products. Artificial intelligence technology can well discover the inherent characteristics of products through appearance. Among them, it can also be seen that when the designers hope that the extraction feature rate is higher, the feature extraction value of the product is lower. It shows that the designer will forget to extract the essence of cultural relic features when they are eager for success. Feature extraction is not just a one-to-one replication, but a new feature display with thinking.

In order to know more clearly the effectiveness of using the algorithm in this paper for product development and application, we refine the eigenvalues. It is divided into four indicators to prove the superiority of the algorithm in this paper. The experiment is also carried out on the two sets of data of A and B. The result is shown in Figure 10.

As can be seen from the figure, whether it is on data A or data B, the effect of feature extraction through algorithm is better than that without algorithm extraction. And on the four feature indicators, the algorithm extracts features very well. Taking A data as an example, in terms of shape, the shape is the first step to determine the trend of the entire product for a ceramic product. It can achieve a complete extraction rate of 0.71 after extraction by the algorithm and only 0.65 without the use of the algorithm. In terms of color, color is the first impact for people. After using the algorithm, the extraction of color can reach the extraction of 0.74, and the efficiency can only be 0.7 without using it. In the extraction of texture, texture is the most difficult step to reproduce. The difference of ceramic refining temperature and materials will affect its texture trend. Using this algorithm, texture can reach the extraction level of 0.76. It can only have a level of 0.7 without using it. On the pattern, the pattern is the feature that can best show the uniqueness of the ceramic craft. It can reach the extraction level of 0.73 after using the algorithm for extraction, and only 0.66 without using it. This shows that the use of artificial intelligence technology can play a very important role in the development and application of ceramic cultural and



(a) Indispensable features of cultural and creative products



(b) A love of design style

Figure 8: Questionnaire results.

creative products, which can make the development process very smooth and greatly improve the efficiency.

3.2.2. Program Digitization. With the rapid development of technology, there are many ways to survey consumers, and all text solutions can be converted into data and then researched. The case we used this time is the comment area about porcelain cultural and creative products, which is based on the comments of netizens to conduct a survey of consumers' demand for products. Among them, we use a, b, c, d, and e to express the customer's emotion or demand intensity, which means like, agree, neutral, endure, and disgust. For example, a means a like, and then artificial intelligence is used to automatically determine different emotional values based on the content of the four netizens' comments. Therefore, the preliminary digitized table is obtained as shown in Table 4. From the Table, we can know that in terms of creativity, the four users basically maintain a neutral attitude, and two are not very satisfied with the current cultural and creative products, they feel that they do not have very unique ideas. Therefore, the creativity of cultural and creative products is really very important. In terms of practicality, users are basically satisfied. There is almost no objection in terms of price, but in terms of cultural connotation, the three users are not very satisfied, because they feel that these products have lost the cultural soul of ceramics and do not have a real cultural connotation.

Later, this article can be modified according to this scheme, which uses an evaluation algorithm to test the feasibility of artificial intelligence in the development and application of ceramic cultural and creative products. It uses the PHGH method to quickly and scientifically convert the

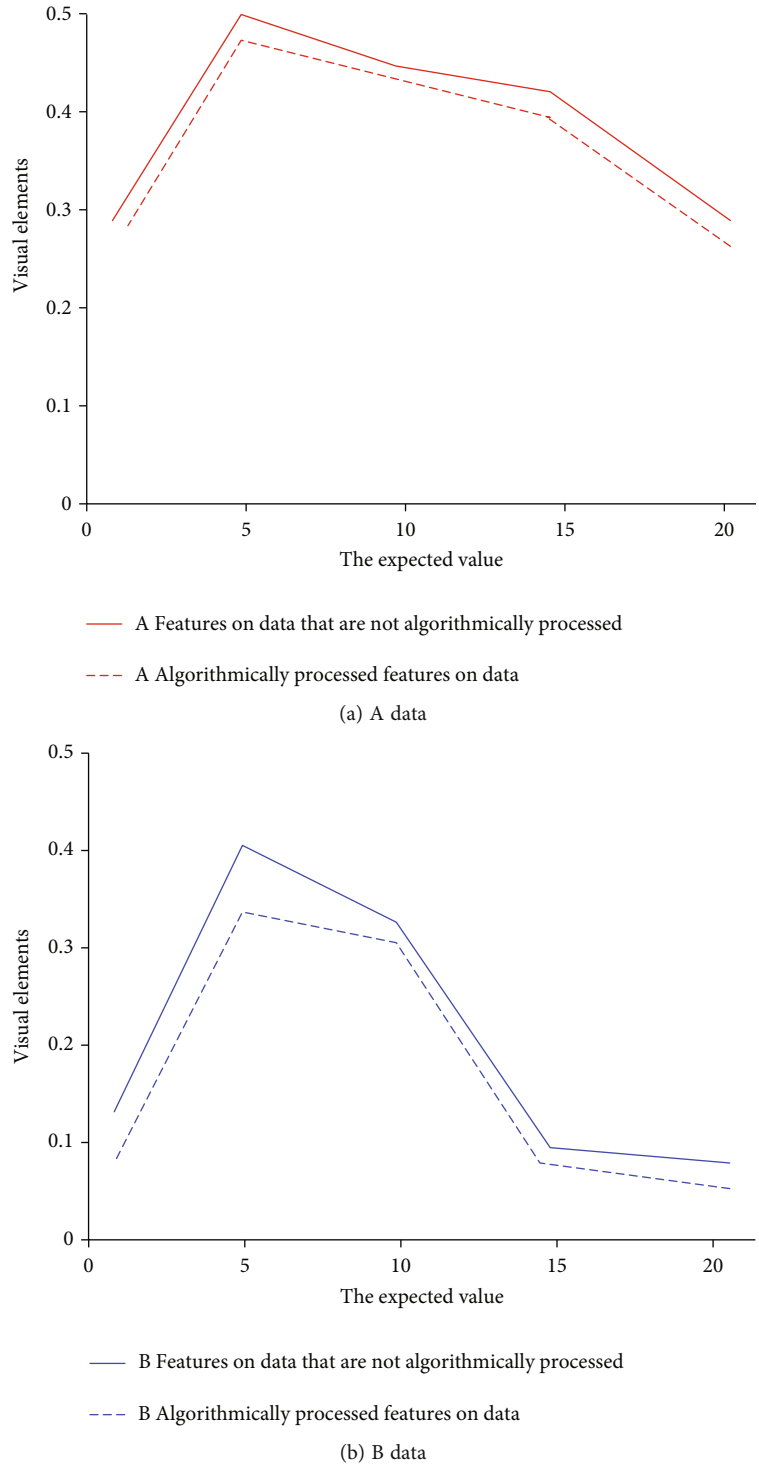
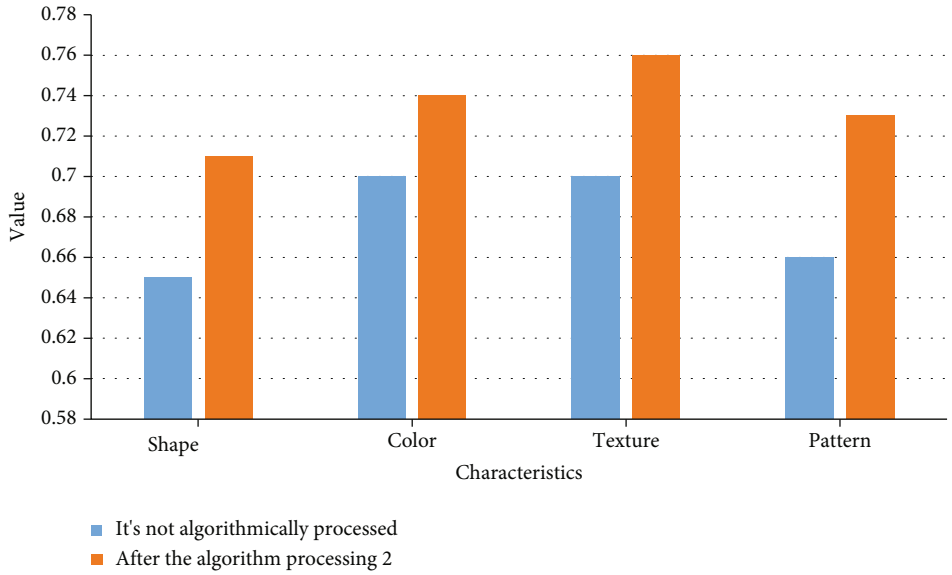
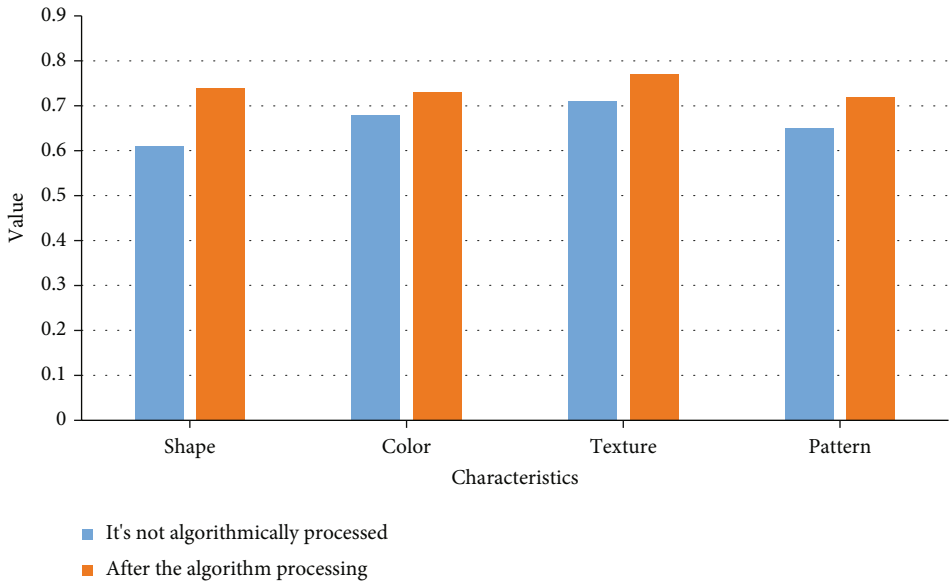


Figure 9: Feature extraction comparison of two data.

opinions of the design team into evaluation indicators, focusing on how to select the product that best meets the user's needs and user experience from many design schemes. The evaluation process using the PUGH matrix is mainly divided into three steps. The first step is to determine a benchmark scheme, which is one of all schemes. The selection criteria are based on the evaluation indicators formulated by experts and selected by members of the professional group. In the second step, the evaluation team compares the other schemes in turn with the benchmark scheme. When the compared scheme outperformed the benchmark scheme in terms of current evaluation factors, it was marked as "+", and the compared scheme with the same performance as the benchmark scheme was marked as "0". When the comparison scheme performs worse than the benchmark scheme in the current evaluation factors, it



(a) Feature extraction of A data



(b) Feature extraction of B data

Figure 10: Feature index comparison.

Table 4: Examples of digitization scenarios.

	Creative	Practical	The price	The cultural connotation
1	c	b	b	d
2	d	c	b	d
3	b	b	b	c
4	c	c	c	d

Table 5: Example of PUGH evaluation.

	Plan 1	Plan 2	Plan 3	Plan 4
1	0	0	—	0
2	0	0	0	0
3	0	0	—	—
4	0	+	0	—
5	0	0	0	—
6	0	0	0	0

is recorded as step 3. After the evaluation team completes the evaluation and scoring of the programs, count the number of "0" and "+" of the optional programs, and calculate the evaluation ranking of all the programs.

As shown in Table 5, with scheme 1 as the benchmark scheme, all other schemes from A to G are compared with scheme 1, and the scores from high to low are scheme 2, scheme 1, scheme 3, and scheme 3, respectively. As a result, the optimal or better solution can be quickly selected as

solution 2. It is also the artificial intelligence algorithm scheme of this paper.

4. Conclusion

This paper studies and analyzes ceramic cultural and creative products through artificial intelligence technology and concludes that artificial intelligence technology is of great help to promote the development of cultural and creative products. In general, artificial intelligence technology should be used to conduct a preliminary investigation and evaluation when developing and applying cultural and creative products. China attaches great importance to the promotion of traditional culture. The development and application of ceramic cultural and creative products is also the best way to express cultural connotations so that the public has a new understanding of these traditional things. Due to the limited space of this paper, there is no detailed analysis in various aspects of product development and application. And there are not enough examples used in this study, which is also the limitation of this paper. In the future, it is hoped to use more real data to conduct in-depth research so as to explore the role of artificial intelligence technology in cultural and creative products.

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 they have no conflicts of interest.

References

[1] W. Rui and G. Liqun, "Research on application model of design symbol theory in cultural and creative product development," *Revista de la Facultad de Ingenieria*, vol. 32, no. 9, pp. 514–520, 2017.

[2] M.-F. Wang, "A study on fuzzy C-means application in Austronesian language cultural and creative product colors," *Color Research & Application*, vol. 43, no. 3, pp. 375–386, 2018.

[3] H. Li and Z. Zhang, "Cultural and creative product design based on biology characteristics of wood," *Wood Research*, vol. 63, no. 3, pp. 525–532, 2018.

[4] T. L. Ngo, T. Tran, M. D. Tran, Q. H. Nguyen, and V. H. Hoang, "A study on relationship between cultural industry and economic growth in Vietnam," *Management Science Letters*, vol. 9, no. 6, pp. 787–794, 2019.

[5] Y. U. Bin and K. Kumbier, "Artificial intelligence and statistics," *Frontiers of Information Technology & Electronic Engineering*, vol. 19, no. 1, pp. 6–9, 2018.

[6] L. Botega and J. Silva, "An artificial intelligence approach to support knowledge management on the selection of creativity and innovation techniques," *Journal of Knowledge Management*, vol. 24, no. 5, pp. 1107–1130, 2020.

[7] L. Liu, "Construction of e-commerce management performance model based on artificial intelligence technology," *Revista de la Facultad de Ingenieria*, vol. 32, no. 12, pp. 389–396, 2017.

[8] A. M. D. Souza and M. F. Ownby, "Re-assessing middle Nubian cultural constructs through ceramic petrography," *African Archaeological Review*, vol. 39, no. 1, pp. 35–58, 2022.

[9] G. Balasubramanian, M. T. Nimje, and V. V. Kutumbarao, "Conversion of aluminium industry wastes into glass-ceramic products," *Social Science Electronic Publishing*, vol. 2000, no. 9, pp. 285–291, 2017.

[10] R. Y. Popov, I. R. Gula, E. M. Dyatlova, A. N. Shimanskaya, E. O. Bogdan, and I. A. Kulish, "Prospects for using clayey raw materials of the Krupeiskii sad deposit for producing heat-resistant ceramic products," *Glass and Ceramics*, vol. 78, no. 9-10, pp. 362–368, 2022.

[11] J. A. Goronado and A. G. Santos, "Parameters that influence the chromatic variation of porous face ceramic waterproofed with organosilicic products," *Revista De La Construcción*, vol. 16, no. 2, pp. 295–306, 2017.

[12] P. Mata, A. Coulon, A. Filhol, and G. Pillet, "Effects of the use of biocides on the properties of ceramic products," *Interceram-International Ceramic Review*, vol. 71, no. 1, pp. 18–27, 2022.

[13] E. Saadi, A. Azbouche, and F. Benrachi, "Spatial distribution of natural radioactivity and statistical analyses of radioactive variables in Algerian ceramic products," *International Journal of Materials and Product Technology*, vol. 10, no. 2, pp. 47–54, 2020.

[14] Y. D. Nurcahyanie and T. Koesdijati, "Disabled analysis of ceramic products on the glass process using the seven tools method (Case study: PT. NJMX Surabaya)," *Tibuana*, vol. 3, no. 1, pp. 53–60, 2020.

[15] V. Z. Poilov, V. V. Pun'Kaev, K. E. Kalugina, and M. V. Cherepanova, "Development of an organic binder for ceramic products obtained by additive technology," *Glass and Ceramics*, vol. 77, no. 7-8, pp. 247–250, 2020.

[16] V. Y. Kuzmin, S. V. Kancher, and V. A. Perevalov, "Modernization of tunnel dryers of ROSSTROMPROEKT design. innovative solutions in the technology of drying ceramic products in single-track dryer units," *Stroitel'nye Materialy*, vol. 777, no. 12, pp. 25–27, 2019.

[17] A. S. Brejo, M. Morais, O. Vendrametto, E. A. Ferigatto, and M. B. Araújo, "Industrial waste application with silicon as an aggregate in ceramic products," *Journal of Sustainable Construction Materials and Technologies*, vol. 4, no. 1, pp. 286–295, 2019.

[18] K. S. Yavruyan, V. D. Kotlyar, Y. O. Lotoshnikova, and E. S. Gaishun, "Investigation of medium-fraction materials processing of terriconics for production wall ceramic products," *Stroitel'nye Materialy*, vol. 758, no. 4, pp. 17–20, 2018.

[19] H. Talab and M. Marza, "Study of effect TiO 2 additive on the properties of glass-ceramic products from soda lime glass," *Advances in Natural and Applied Sciences*, vol. 11, no. 9, pp. 34–44, 2017.

[20] E. S. Pikalov, O. G. Selivanov, V. Y. Chukhlanov, and M. A. Sukharnikova, "Application of regional technogenic wastes in the production of ceramic products," *Ecology and Industry of Russia*, vol. 21, no. 6, pp. 24–29, 2017.

[21] H. Zouaoui and J. Bouaziz, "Performance enhancement of the ceramic products by adding the sand, chamotte and waste brick to a porous clay from Bir Mcherga (Tunisia)," *Applied Clay Science*, vol. 143, no. JUL., pp. 430–436, 2017.

[22] V. N. Leitsin, S. V. Ponomarev, M. A. Dmitrieva, I. V. Ivonin, and I. M. Tyryshkin, "Simulation of sintering of low-temperature ceramic products formed by additive

technology," *Physical Mesomechanics*, vol. 20, no. 4, pp. 465–471, 2017.

[23] H. Zouaoui, G. L. Lecomte-Nana, M. Krichen, and J. Bouaziz, "Structure, microstructure and mechanical features of ceramic products of clay and non-plastic clay mixtures from Tunisia," *Applied Clay Science*, vol. 135, no. JAN., pp. 112–118, 2017.

[24] A. V. Ryabova, E. A. Yatsenko, L. V. Klimova, E. V. Filatova, and A. Y. Velichko, "Synthesis and investigation of white glass-ceramic enamel coatings for steel products," *Glass Physics and Chemistry*, vol. 43, no. 1, pp. 34–42, 2017.

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Research Article

Toward Sequential Recommendation Model for Long-Term Interest Memory and Nearest Neighbor Influence

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Sequential recommendation can make predictions by fitting users' changing interests based on the users' continuous historical behavior sequences. Currently, many existing sequential recommendation methods put more emphasis upon users' recent preference (i.e., short-term interests), but simplify or even ignore the influence of users' long-term interests, resulting in important interest features of users not being effectively mined. Moreover, users' real intentions may not be fully captured by only focusing on their behavior histories, because users' interests are diverse and dynamic. To solve the above problems, we propose a novel sequential recommendation model for long-term interest memory and nearest neighbor influence. Firstly, item embeddings based on item similarity and dependency are constructed to alleviate the problem of data sparsity in users' recent interest history. Secondly, in order to effectively capture long-term interests, the long sequence is divided into multiple nonoverlapping subsequences. For these subsequences, the graph attention network with node importance factor is designed to fully extract the main interests of subsequences, and LSTM is introduced to learn the dynamic changes of interest among subsequences. Long-term interests of users are modeled through complex structure within subsequences and sequential dependencies among subsequences. Finally, the user's neighbor representation is introduced, and a gating module is designed to integrate the user's neighbor information and self-interests. The influence of users' short-term and long-term interests on prediction is dynamically controlled by considering nearby features in the gating network. The experimental results on two public datasets show that the proposed sequential recommendation model can outperform the baseline methods in hit rate (HR@K) and normalized discounted cumulative gain (NDCG@K).

1. Introduction

With the rapid development of information technology, complex and diverse data are flooding people's lives. To deal with the problem of information overload, recommender systems have emerged as a pervasive part of online platforms. Different types of recommendation model have been developed, e.g., collaborative filtering recommendation [1], sequential recommendation [2], social recommendation [3], and group recommendation [4]. Among these models, sequential recommendation can effectively learn the changing of user's interests and provide more accurate recommendations, which has become a research hotspot in recent years [5, 6].

Nowadays, deep learning models (e.g., convolutional neural networks (CNN) [7], recurrent neural networks (RNN) [8], attention mechanisms [9], and graph neural networks (GNN) [10]) are widely used in sequential recommender systems. However, the existing sequential recommendation models based on deep learning mainly focus on the users' behavioral interactions in the recent period and use the users' short-term interests to predict their subsequent choices, while the rich feature information contained in the users' long-term historical behaviors has not been further explored. In fact, people usually have stable and dynamically changing interests though user interests are complex and diverse. Previous studies [11–14] also showed that the selection of users in recommender systems is not only affected by their recent intentions but also related to their long-term stable interests. However, due to the long length of user behavior sequences and the complex

relationship between items, it is difficult to effectively learn users' long-term interests. Therefore, in sequential recommendation, the recommendation performance can be improved if we can further excavate the stable features of users' long-term interests on the basis of the dynamic changes of short-term interests.

In addition, the gating network can adaptively control the degree of information retention; the short-term interests and long-term interests of users can be dynamically fused through the gating network in sequential recommendation [15, 16]. However, if the prediction is only based on the user's own historical behaviors, the attention of the model is limited to the interest memory in the user's historical behaviors, which affects the recommendation effect. In fact, users are also interested in items selected by their similar neighbors [17]. The existing recommendation methods considering the nearest neighbor influence [18, 19] lack the dual attention to user behavior sequence and neighbor users or adopt a simple fusion approach [20] ignoring the interaction between the two aspects.

To address the above problems, we propose a sequential recommendation model for long-term interest memory and nearest neighbor influence (SRLIN for short). The proposed model deeply mines the user's long-term interests on the basis of learning the user's recent interests and incorporates the user's neighbor influence into the gating network. Specifically, based on the two different perspectives of item similarity and dependency, the item embeddings are first generated. Interest changes within recent sequences are learned by using a bidirectional LSTM (i.e., BiLSTM), and then, the self-attention network is used to obtain the user's short-term interests. Secondly, to effectively capture long-term interests, we propose a long-term interest modeling method including the interest extraction layer and the interest fusion layer. For each user, its long sequence is divided into multiple disjoint subsequences. In the interest extraction layer, the graph attention network with node importance factor (NIF_GAT for short) is designed, which can fully extract the main interest features of subsequences by learning the importance of different items in each subsequence and the complex relationship between items. In the interest fusion layer, we use the LSTM to learn the sequential dependencies of interest features in different time periods. The user's long-term interest representation is obtained through this hierarchical structure. Finally, the neighbor features of each user are extracted based on the ordered user sequences of the items, and the gating network that considers the neighbor features is introduced to adjust the influence of short-term interest representation, long-term interest representation, and nearest neighbor representation on prediction.

The main contributions of this paper are summarized as follows:

(1) To effectively alleviate the sparsity problem of sequence recommendation, we propose an item embedding method based on item similarity and dependency

(2) To more accurately capture user stable and changing long-term interests, we propose a long-term interest modeling method including the interest extraction layer and the interest fusion layer. In the interest extraction layer, we first model the complex structure of subsequences and learn the main interest features within different subsequences by the improved graph attention network with node importance factor. Then, we use LSTM to learn the sequential dependencies of interests among different subsequences in the interest fusion layer

(3) To further improve the recommendation performance, we design a gating fusion module based on the influence of neighbors, which can automatically adjust the weights of short-term and long-term interests by considering the neighbor information and deal with the situation where it is difficult to fully capture the user's intention only by relying on the user's own interests

(4) Experimental results on two public datasets, i.e., MovieLens 1M and JD, show that our SRLIN model can outperform the state-of-the-art sequential recommendation methods

2. Related Work

2.1. General Sequential Recommendation. Ding et al. [21] and Lathia et al. [22] studied recommendation models based on time awareness. Based on the collaborative filtering algorithm, a time decay factor was introduced to describe the change of user interests over time. Subsequently, Rendle et al. [23] proposed an FPMC model based on matrix factorization and Markov chains, which combined the sequential behaviors of different users by establishing a three-dimensional transformation matrix, and used a first-order Markov model to model the user's historical behaviors. The FPMC model fully integrates the advantages of matrix factorization and Markov chains and improves the accuracy of sequential recommendation method. He et al. [24] extended on FPMC, which adopted a higher-order Markov chain to learn the complex relationship of data [25]. In addition, Sahoo et al. [26] proposed a collaborative filtering recommendation method based on hidden Markov model. Considering that the traditional Markov chain is difficult to model long-term historical sequences of users, Lonjarret et al. [27] proposed the REBUS model which uses frequent sequences to capture the most relevant parts of user history for recommendations.

2.2. Deep Learning-Based Sequential Recommendation. Deep learning can automatically learn features, which has attracted extensive attention in sequence recommendation in recent years. Tang et al. [7] transformed sequence data into "images" with temporal information and used convolutional filters to learn sequence features. Kang et al. [9] adopted a stacked self-attention mechanism to effectively capture the high-order features of the sequence, in which the model structure is similar to the Encoder of the Transformer. Hidasi et al. [8] proposed a new loss function used in the recurrent neural network model, which can alleviate

the gradient vanishing problem of sequential recommendation. Among many deep learning models, recurrent neural networks have received extensive attention due to their unique properties of sequential learning. The recurrent neural network uses the output of the previous node as a new part of the input and does not add additional biases, which can track the user's interest changes in essence. However, these methods only take random initialization of item numbers as input, which cannot clearly describe the relationship between items and have poor interpretability. Therefore, Huang et al. [28] proposed the ATST-LSTM model for the next POI recommendation, which applies the time interval and distance interval as auxiliary information on the time steps of the LSTM. The application of auxiliary information can greatly alleviate the problem of data sparsity and improve the prediction effect. However, this kind of auxiliary information only relies on the user's own historical behaviors, which cannot help to fully capture the user's implicit interests. Therefore, we measure the similarity and dependency between items from a global perspective; based on which, item embeddings can be generated.

In addition, the above models mainly focus on users' recent behaviors. However, some studies have shown that in addition to the recent interactions, the user's interests are also affected by her/his early choices [2]. Therefore, some scholars divided user history records into recent sequences and global sequences and proposed long-short term interests fusion models. Gan et al. [29] proposed an R-RNN model, which uses LSTM to focus on user's recent behaviors and applies MLP to fuse long-term and short-term interests. Ying et al. [30] proposed a hierarchical attention network, which uses the attention mechanism to learn short-term interests and fuse long-term with short-term interests. The fusion of long-term and short-term interests comprehensively considers long-term and short-term features, which can improve the accuracy of recommendation. But the above methods just adopt some simple ways to learn the users' long-term interests. To make better use of the rich information contained in long sequences and improve the problem of imperfect long-term interest modeling, Lv et al. [15] used an attention mechanism to learn different aspects of long-term interests and introduced a gating module to extract features related to short-term interests in long-term interests. Lin et al. [31] improved the attention mechanism in long-term interest learning, which improved the recommendation performance. However, it is difficult to track the dynamic change trend of user interests by directly modeling the whole long sequence, which is prone to the phenomenon of recommendation performance degradation. Quadrana et al. [32] proposed a hierarchical RNN model HRNN. For long sequences, the model implements RNN-based session modeling at the bottom layer for each session and uses RNN at a higher level to track the evolution of user interests for cross-sessional learning. The splitting of long sequences can reduce the difficulty of overall modeling and simplify complex problems. The experimental results of HRNN model also prove that the hierarchical model can obtain better recommendation performance than the overall modeling of long sequences. However, the model is susceptible to noise. The reason is that the underlying RNN of HRNN model performs the strict order in the session. For example, when a user is browsing the shopping page, he or she may click some products out of curiosity. The interest offset caused by noise makes it difficult to track the real interests of users in the session, while the inaccuracy of this low-level interest learning further reduces the learning effect of user interests at higher levels and affects the recommendation performance. Different from the above research, we divide the long sequence into subsequences in different time periods and use the improved graph attention network and LSTM to learn the complex structure within subsequences and the sequential dependencies among the subsequences, respectively. The graph attention network with node importance factor can fully extract the interests of users in different time periods, and LSTM can learn the dynamic changes of interests among different time periods. Unlike short-term interests, which are modeled based on sequential dependencies of recent interactions, long-term interests are modeled on long and complex sequences. Therefore, for long sequence, the strict order within subsequences not only has little effect on the entire sequence but also is prone to noise effects. And due to the complexity of long sequences, the use of graph attention network with node importance factor can effectively learn the importance of different items in the subsequence and the complex association between items, which reduces the noise effect and highlights the extraction of main interests.

For the fusion of long-term interests and short-term interests, Feng et al. [33] used the hyperparameter to control the addition of long-term and recent interests. However, the simple combination is difficult to capture the correlation of interests, and it is easy to make the model lose universality. Previous studies have shown that gating modules have more obvious advantages than simple concatenation or addition [15]. Tan et al. [2] proposed a dynamic memory-based attention network and used a gating module to adaptively adjust the importance of long-term and short-term interests. Tang et al. [16] proposed a mixture model M3, which fuses feature representations from different time scales based on the gating mechanism of Mixture-of-Experts (MOE). The above methods usually only consider the user's own information, ignoring the influence of neighbor users. Li et al. [18] proposed an FNUS model for finding similar neighbors from multiple perspectives, which divides the item set into three subspaces and searches for neighbor users from different subspaces, respectively. Banerjee et al. [19] used social network information to measure the correlation between users and combined it with scoring data and project characteristics. However, social network information is difficult to obtain. In order to further improve the recommendation performance, we integrate the neighbor features into the gating network and adaptively balance the influence of the users' short-term interests and long-term interests by aggregating neighbor information.

3. The Proposed Approach

Figure 1 shows the overall framework of the model proposed in this paper, which contains three main components, i.e., a

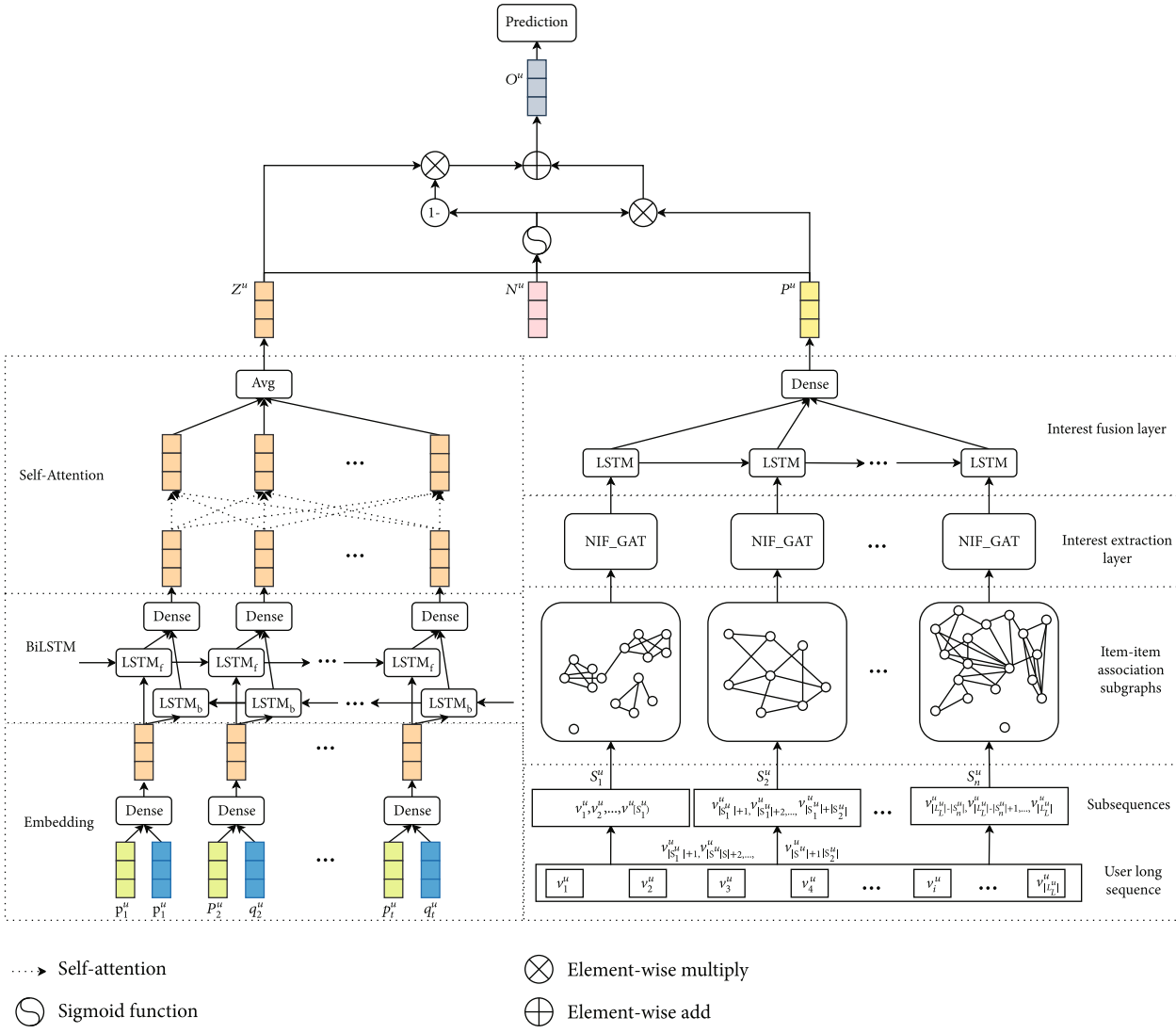

Figure 1: The overall framework of SRLIN.

short-term interest module based on BiLSTM and self-attention network, a long-term interest module based on the interest extraction layer and interest fusion layer, and a gated fusion module based on neighbor influence.

3.1. Notations and Problem Formulation. Let $U = \{u_1, u_2, \cdots, u_m\}$ and $V = \{v_1, v_2, \cdots, v_n\}$ denote the user set and the item set, respectively. For $\forall u \in U$, the behavior sequence of u refers to an ordered item set, which is sorted according to the interaction time of items selected by u in ascending order and denoted as $L^u = \{v_1^u, v_2^u, \cdots, v_{|L^u|}^u\}$, where $v_i^u \in V$ represents the ith item on L^u. In order to facilitate interest extraction, the user behavior sequence is further divided into multiple subsequences if its sequence length exceeds the length threshold lenthrs or time span exceeds the time interval threshold Δt. Moreover, for two adjacent items on L^u, they are split into different subsequences if their time interval is greater than Δt or the length of the subsequence is greater than lenthrs. Let $S_k^u = \{v_{k,1}^u, v_{k,2}^u, \cdots, v_{k,|S_k^u|}^u\}$ be the kth subsequence on L^u, and S^u be the partition of L^u which is composed of all these subsequences. For $\forall u \in U$, let the latest subsequence before prediction time t be the short-term interest sequence L_S^u, and the set of subsequences on the behavior sequence be the long-term interest sequence L_L^u.

3.2. Item Embedding Based on Item Similarity and Dependency. Embedding is a common technique which transforms discrete values of data into numerical vectors that can be processed by the model. The neural network is usually used to convert sparse feature data into dense embeddings on the basis of one-hot embeddings. However, the method that only takes random initialization of item numbers tends to limit the focus of the model to historical records and ignores the potential relationship between items, which makes it difficult to capture the implicit interest features of users. In particular, on sparse datasets, it is difficult to achieve a good recommendation effect only by encoding the item numbers. Therefore, we learn item embeddings

from the perspectives of item similarity and dependency in the paper.

On the one hand, the item attribute information is the static features of the item itself, which can reflect the similarity between items. It shows that the corresponding feature vectors of items with the same attributes are also similar. Let $\mathscr{F}$ be the item attribute set; we get one-hot embedding $\mathbf{x}_i^f$ for $\forall f \in \mathscr{F}$ of item v_i and convert $\mathbf{x}_i^f$ to dense embedding $\mathbf{p}_i^f \in \mathbb{R}^{d_f}$ according to the learnable embedding matrix $\mathbf{W}_f$. Next, these dense embeddings are concatenated to obtain the similarity embedding for item v_i, which is denoted as $\mathbf{p}_i \in \mathbb{R}^d$ and defined as follows:

$$\begin{aligned} \mathbf{p}_i^f &= \mathbf{W}_f \mathbf{x}_i^f, \\ \mathbf{p}_i &= \text{concat\_func}\left(\left\{\mathbf{p}_i^f | f \in \mathscr{F}\right\}\right), \end{aligned} \tag{1}$$

where concat_func$(\cdot)$ means to connect the dense embedding $\mathbf{p}_i^f$ of different attributes f.

On the other hand, inspired by association rules [34], we learn the item dependency embeddings from the global dependency of user history. Item dependencies not only reflect the similarity of users in their selection but also reflect the complementarity and cooccurrence relationship between items. For $\forall u \in U$, v_i and v_j on $L^u = \{v_1^u, v_2^u, \cdots, v_{|L^u|}^u\}$ represent two dependent items. The item dependencies on all user history sequences are extracted, and a global dependency graph $\mathscr{G} = \langle V, \mathscr{E} \rangle$ is constructed accordingly. The global dependency graph is a directed graph. The nodes in the graph represent items, the directed edge $\boldsymbol{e}_{ij} \in \mathscr{E}$ represents the successive clicks of items v_i to v_j, and the edge weight represents the cooccurrence degree between items, which is the number of times v_i to v_j appears repeatedly on different user sequences. Let $\mathbf{q}_i \in \mathbb{R}^d$ be the dependency embedding of item v_i on the global dependency graph $\mathscr{G}$, which is generated by using the Node2vec algorithm. By reflecting the characteristics of each node's neighbors through BFS, the probability of adjacent items appearing can be maximized.

Finally, the item embedding of $\forall v_i \in V$ is obtained by combining the two perspectives of the item similarity embedding $\mathbf{p}_i$ based on static attributes and the dynamic item dependency embedding $\mathbf{q}_i$, which is defined as follows:

$$\mathbf{g}_i = \sigma\left(\mathbf{W}_g[\mathbf{p}_i, \mathbf{q}_i] + b_g\right), \tag{2}$$

where $\mathbf{W}_g \in \mathbb{R}^{d \times 2d}$ is the learnable weight matrix, σ is the *sigmoid* activation function, $\mathbf{g}_i \in \mathbb{R}^d$ is the item embedding of v_i, and d is the item embedding dimension.

3.3. Short-Term Interest Representation Based on BiLSTM and Self-Attention Network. Recurrent neural network [35] plays a prominent role in modeling sequential dependencies and is widely used in sequence recommendation, which can transmit and memorize the association among information to track the changing trend of user interests. Therefore, we make full use of the forgetting and remembering properties of recurrent neural networks over time here. However, the simple RNN is difficult to deal with relatively long data due to its own structure, which makes it unable to meet the memory function of sequence data. In addition, considering that all user interactions in the recent period have an effect on predicting the choice of the next time. In order to take full advantage of the effect of different behaviors, we adopt BiLSTM to obtain the features of each time step in the users' recent sequences bidirectionally, which can model the dynamic changes of the users' short-term interests by mining the sequential dependencies of recent sequences.

The LSTM unit includes an input gate $\mathbf{i}_t^u$, a forgetting gate $\mathbf{f}_t^u$, an output gate $\mathbf{o}_t^u$, and a memory unit $\mathbf{c}_t^u$ for state update. The calculation formulas are as follows:

$$\begin{aligned} \mathbf{i}_t^u &= \sigma\left(\mathbf{W}_{gi}\mathbf{g}_t^u + \mathbf{W}_{hi}\mathbf{h}_{t-1}^u + b_i\right), \\ \mathbf{f}_t^u &= \sigma\left(\mathbf{W}_{gf}\mathbf{g}_t^u + \mathbf{W}_{hf}\mathbf{h}_{t-1}^u + b_f\right), \\ \mathbf{o}_t^u &= \sigma\left(\mathbf{W}_{go}\mathbf{g}_t^u + \mathbf{W}_{ho}\mathbf{h}_{t-1}^u + b_o\right), \\ \widehat{\mathbf{c}}_t^u &= \tanh\left(\mathbf{W}_{gc}\mathbf{g}_t^u + \mathbf{W}_{hc}\mathbf{h}_{t-1}^u + b_c\right), \\ \mathbf{c}_t^u &= \mathbf{f}_t^u \mathbf{c}_{t-1}^u + \mathbf{i}_t^u \widehat{\mathbf{c}}_t^u, \\ \mathbf{h}_t^u &= \mathbf{o}_t^u \tanh\left(\mathbf{c}_t^u\right), \end{aligned} \tag{3}$$

where the input of LSTM is the item embeddings $\{\mathbf{g}_1^u, \mathbf{g}_2^u, \cdots, \mathbf{g}_{|L_S^u|}^u\}$ in the recent sequence of user u and $|L_S^u|$ is the length of the recent sequence. The gate structure of LSTM is learned from the hidden state $\mathbf{h}_{t-1}^u \in \mathbb{R}^d$ of the previous output and the item embedding $\mathbf{g}_t^u \in \mathbb{R}^d$ of the current input, which is used to control the reception of current information, the memory of historical information, and selective output features. σ is the *sigmoid* activation function, $\mathbf{W}_{gi}$, $\mathbf{W}_{hi}$, $\mathbf{W}_{gf}$, $\mathbf{W}_{hf}$, $\mathbf{W}_{go}$, $\mathbf{W}_{ho}$, $\mathbf{W}_{gc}$, $\mathbf{W}_{hc} \in \mathbb{R}^{d \times d}$ are learnable weight matrices, and b_i, b_f, b_o, b_c are biases.

BiLSTM includes forward and backward LSTM. They have the same structure and the same input data, but the direction of the sequence input is different. At time t, BiLSTM can be expressed as

$$\mathbf{h}_{ct}^u = [\mathbf{h}_{\text{ft}}^u, \mathbf{h}_{bt}^u], \tag{4}$$

where $\mathbf{h}_{\text{ft}}^u$ is the output of the forward LSTM, $\mathbf{h}_{bt}^u$ is the output of the backward LSTM, and $\mathbf{h}_{ct}^u \in \mathbb{R}^{2d}$ is obtained by connecting $\mathbf{h}_{\text{ft}}^u$ and $\mathbf{h}_{bt}^u$.

We input $\mathbf{h}_{ct}^u$ into a fully connected layer, and the resulting $\mathbf{H}_t^u \in \mathbb{R}^d$ is regarded as the output of the BiLSTM layer at time t:

$$\mathbf{H}_t^u = \sigma(\mathbf{W}_H \mathbf{h}_{ct}^u + b_H), \tag{5}$$

where $\mathbf{W}_H \in \mathbb{R}^{d \times 2d}$ is the learnable weight matrix and σ is the *sigmoid* activation function.

However, there may be random or accidental behaviors in the recent sequence of users, which affect the learning effect of the recurrent neural network on the users' interests

and deviate from the users' true intention. Different from the recurrent neural network, the attention network regards the input content as a whole, which alleviates the influence of noise by assigning higher weights to the important interests of users. Therefore, on the basis of using BiLSTM to model the sequential dependencies of users' short-term interests, we use the self-attention network to amplify the key parts of users' short-term interests that are conducive to prediction.

To further extract the important information of users' short-term interest representations, we input $\mathbf{H}^u = \{\mathbf{H}_1^u, \mathbf{H}_2^u, \cdots, \mathbf{H}_{|L_S^u|}^u\}$ into the self-attention network.

The self-attention network can be described as

$$\mathbf{Z}_{L_S^u}^u = \text{attention}(\mathbf{Q}^u, \mathbf{K}^u, \mathbf{V}^u) = \text{soft max}\left(\frac{\mathbf{Q}^u(\mathbf{K}^u)^T}{\sqrt{d}}\right)\mathbf{V}^u, \tag{6}$$

where $\mathbf{Z}_{L_S^u}^u \in \mathbb{R}^{|L_S^u| \times d}$ is the output of the self-attention network, $|L_S^u|$ is the recent sequence length, $\mathbf{Q}^u$, $\mathbf{K}^u$, $\mathbf{V}^u \in \mathbb{R}^{|L_S^u| \times d}$ are obtained from the input $\mathbf{H}^u$ through the linear transformation of the weight matrices $\mathbf{W}_Q$, $\mathbf{W}_K$, $\mathbf{W}_V \in \mathbb{R}^{d \times d}$, respectively, that is, $\mathbf{Q}^u = \mathbf{H}^u\mathbf{W}_Q$, $\mathbf{K}^u = \mathbf{H}^u\mathbf{W}_K$, and $\mathbf{V}^u = \mathbf{H}^u\mathbf{W}_V$.

Finally, short-term interest representation $\mathbf{Z}^u \in \mathbb{R}^d$ of user u is calculated by average pooling on $\mathbf{Z}_{L_S^u}^u$:

$$\mathbf{Z}^u = \text{Avg}\left(\mathbf{Z}_{L_S^u}^u\right). \tag{7}$$

3.4. Long-Term Interest Representation Based on Interest Extraction Layer and Interest Fusion Layer. As the user's long-term behavior sequence often contains noise and has a relatively large time span, it is difficult to directly model the overall long-term sequence, resulting in unsatisfactory recommendation results. Therefore, we divide the long sequence into multiple subsequences. Each subsequence reflects the user's interests over a period of time. By using the hierarchical mechanism of interest extraction layer and interest fusion layer, the different associations between items in subsequences and the sequential dependencies among subsequences are modeled to jointly generate long-term interest representations of user. The interest extraction layer can effectively extract the main interests in the subsequences, and the interest fusion layer can dynamically learn the order changes of user interests among different subsequences.

3.4.1. Interest Extraction Layer. Each subsequence corresponds to a time period. Users have different interests in different periods and may also have multiple interests in the same period. In order to highlight the important parts that affect prediction in different time periods, we use the graph attention network with node importance to extract the main interests in different subsequences, respectively.

The graph attention network is a graph neural network combined with attention mechanism, which uses self-attention to learn the graph structure and has efficient parallel computing capabilities. The update of the feature of each node in the graph relies on the attention calculation of its neighbor nodes, which is realized by assigning different weights to the neighbor nodes.

Different from the simple sequential structure, the graph attention network can more clearly model the complex correlation between items. By analyzing the internal structure of the item graph, the more complex and implicit connections between user clicks can be captured. Unlike the features of each item in the recent sequence, which have an impact on the learning of short-term interests, the graph attention network does not consider the sequential association between items. The reason is that the main interests of the subsequences are more emphasized in the subsequence interest extraction stage. For example, in the online shopping system, users may have multiple needs at the same time, and the purchase order may be "a shirt, a bunch of flowers, a basket of apples, a bunch of bananas, a vase." The relationship between "flower" and "vase" should be closer, but it is interrupted by "apple" and "banana" in the actual purchase. If we follow the strict order of the subsequences, it is difficult to extract the main interest of the subsequence. Therefore, the sequential relationship within the subsequence is a negative effect on the long sequence composed of multiple subsequences. It not only reduces the model efficiency but also easily affects the recommendation effect.

In addition, since there may be behaviors deviating from the user's interests in the subsequences, adopting a graph attention network can further reduce the influence of noise while learning the relationship between items. The reason is that the attention mechanism can amplify the features that are helpful for decision-making and ignore unimportant or irrelevant information.

It can be said that the graph attention network can model the complex relationship between different items, automatically learn the important features in the graph, and suppress the influence of noise. The attention mechanism enables the graph structure to better achieve neighbor aggregation, and the graph structure also provides a degree of interpretability for the attention mechanism.

For any subsequence S_k^u on the long sequence L_L^u, the items of the subsequence S_k^u are regarded as nodes. Considering that almost no items in the short sequence are clicked repeatedly, we use the similarity between items to describe the connection relationship between nodes. In this way, the subsequence data $S_k^u = \{v_{k,1}^u, v_{k,2}^u, \cdots, v_{k,|S_k^u|}^u\}$ is transformed into a subgraph structure $G_k^u = \langle V_k^u, E_k^u \rangle$, where item $v_{k,i}^u$ is represented as node $i \in V_k^u$. For the sake of simplicity, there exists an edge between two item nodes only if their similarity is more than 0. The input data of the graph attention network is the node features $\{\mathbf{g}_{k,1}^u, \mathbf{g}_{k,2}^u, \cdots, \mathbf{g}_{k,|S_k^u|}^u\}$, where $\mathbf{g}_{k,i}^u \in \mathbb{R}^d$ represents the feature of the ith node in the subsequence and $|S_k^u|$ is the length of the subsequence.

In the graph attention network, the importance of the neighbor node j to the current node i is defined as

$$e_{ij}^u = \text{LeakyReLU}\left(\mathbf{W}_a^T\left[\mathbf{W}\mathbf{g}_{k,i}^u \middle\| \mathbf{W}\mathbf{g}_{k,j}^u\right]\right), \tag{8}$$

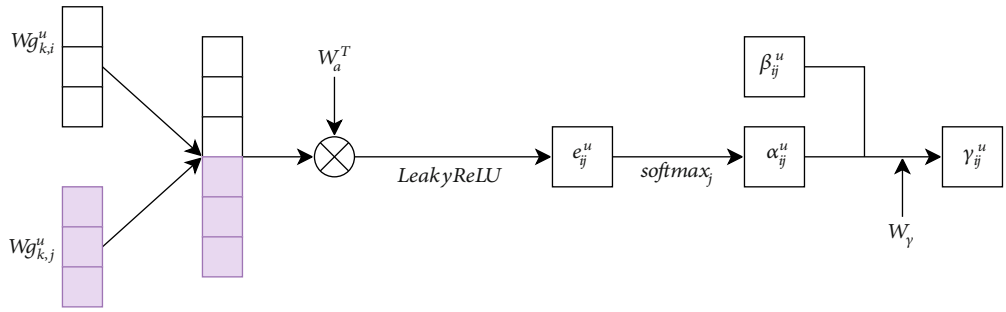

Figure 2: Attention coefficients.

where $\mathbf{W} \in \mathbb{R}^{d\times d}$ represents a learnable shared weight matrix which is used to improve the expressive ability of item feature $\mathbf{g}^u_{k,i}$ and $||$ represents connecting the features of node i and node j. The attention function is a single-layer feedforward neural network. $\mathbf{W}_a \in \mathbb{R}^{2d}$ is used to learn the influence of node j on node i, and LeakyReLU denotes nonlinear activation.

The attention coefficient is calculated by considering the first-order aggregation of all neighbor nodes on node i, which is defined as follows:

$$\alpha^u_{ij} = \text{softmax}_j\left(e^u_{ij}\right) = \frac{\exp\left(e^u_{ij}\right)}{\sum_{x\in N_i}\exp\left(e^u_{ix}\right)}, \tag{9}$$

where N_i is the neighbor set of node i (including i).

The feature vector of node i can be obtained by applying the attention coefficients to the corresponding neighbors of node i and combining the features, which is denoted as

$$\tilde{\mathbf{g}}^u_{k,i} = \sigma\left(\sum_{j\in N_i}\alpha^u_{ij}\mathbf{W}\mathbf{g}^u_{k,j}\right). \tag{10}$$

The weights of nodes in the graph attention network are learned through weighted aggregation of their neighboring nodes. However, due to the normalization of *softmax*, the importance attribute of nodes in the whole graph is not better highlighted. For subsequences, the importance of different item nodes has a great influence on the extraction of main interests. Generally speaking, the more adjacent nodes a node is associated with, the higher the importance of the node. Therefore, we improve the attention coefficient of the graph attention network to more clearly distinguish the importance of different nodes.

The calculation process of the new attention coefficient is shown in Figure 2.

In Figure 2, the importance of nodes is reflected by the degree of nodes. By normalizing the degree values of all nodes in the subsequence, the importance β^u_i of any node i can be obtained. $\mathbf{W}_\gamma \in \mathbb{R}^{1\times 2}$ means that the information of node importance β^u_i and attention coefficient α^u_{ij} is fused to obtain a new attention coefficient γ_{ij}.

$$\gamma^u_{ij} = \mathbf{W}_\gamma\left[\alpha^u_{ij}, \beta^u_i\right]. \tag{11}$$

After applying the new attention coefficient γ^u_{ij} to the feature combination, the final output features $\hat{\mathbf{g}}^u_{k,i} \in \mathbb{R}^d$ of node i is obtained.

$$\hat{\mathbf{g}}^u_{k,i} = \sigma\left(\sum_{j\in N_i}\gamma^u_{ij}\mathbf{W}\mathbf{g}^u_{k,j}\right). \tag{12}$$

$\{\hat{\mathbf{g}}^u_{k,1}, \hat{\mathbf{g}}^u_{k,2}, \cdots, \hat{\mathbf{g}}^u_{k,|S^u_k|}\}$ denotes the output of the subsequence data through the graph attention network.

Finally, the output is aggregated into a vector $\mathbf{r}^u_k \in \mathbb{R}^d$ by average pooling, which represents the main interests of the kth subsequence.

3.4.2. Interest Fusion Layer. In the interest fusion layer, the subsequence feature $\mathbf{r}^u_k \in \mathbb{R}^d$ of each time period is regarded as the basic unit, and we use LSTM to learn the sequential dynamic changes of user interests among different time periods because there is a relative order among different periods. In period k, the LSTM unit can be abbreviated as

$$\hat{\mathbf{h}}^u_k = \text{LSTM}\left(\mathbf{r}^u_k, \hat{\mathbf{h}}^u_{k-1}\right), \tag{13}$$

where $\{\mathbf{r}^u_1, \mathbf{r}^u_2, \cdots, \mathbf{r}^u_{|S^u|}\}$ is the feature set of subsequences obtained through the graph attention network, $|S^u|$ is the number of subsequences, and $\hat{\mathbf{h}}^u_{k-1} \in \mathbb{R}^d$ is the output of the previous period.

The outputs of all time steps of LSTM are fused to obtain the long-term interest representation $\mathbf{P}^u \in \mathbb{R}^d$ of user u:

$$\begin{aligned}\hat{\mathbf{H}}^u &= \Big|\Big|_{k=1}^{|S^u|}\hat{\mathbf{h}}^u_k,\\ \mathbf{P}^u &= \sigma\left(\mathbf{W}_P\hat{\mathbf{H}}^u + b_P\right),\end{aligned} \tag{14}$$

where $||$ means to connect the outputs of different subsequences of LSTM and σ is the *sigmoid* activation function.

3.5. Gating Fusion Mechanism Based on Neighbor Influence. The interests of users change dynamically over time and the degree of change varies for different users, which indicates that the long-term and short-term interests of different users

have different degrees of influence on their interest predictions [36]. However, in addition to relying on their own interests, user intentions may also be affected by their neighbors. Thus, we introduce the gating network to fuse the user's own interests and neighbor features, which adaptively adjust the weights of long-term and short-term interest features by considering the influence of neighbors.

In a real system, users may keep some of their attributes secret out of privacy; that is, users may obscure information such as gender and age. Considering the defect of incomplete user attribute information, we learn the nearest neighbor representations of users from the perspective of historical behavior data. First, for each item, all users who interact with the item is regarded as a text, and each user is regarded as a word in the text. The user's word embedding is obtained by using the word2vec algorithm. Then, these user embeddings are clustered by using the K-means [37] algorithm, where the number of clusters K is determined according to the elbow method. Finally, the average of user embedding in each class is calculated and denoted as the nearest neighbor embedding $\mathbf{N}^u \in \mathbb{R}^d$.

The user's short-term interest representation $\mathbf{Z}^u \in \mathbb{R}^d$, the long-term interest representation $\mathbf{P}^u \in \mathbb{R}^d$, and the nearest neighbor representation $\mathbf{N}^u$ are used as the input, and the gating network is designed as follows:

$$\mathbf{G}^u = \sigma(\mathbf{W}_G[\mathbf{Z}^u, \mathbf{P}^u, \mathbf{N}^u] + b_G), \tag{15}$$

where $\mathbf{W}_G \in \mathbb{R}^{d\times 3d}$ is the weight matrix of linear transformation, σ is the *sigmoid* activation function, and the gate vector is $\mathbf{G}^u \in \mathbb{R}^d$.

Finally, by adaptively allocating the proportion of long-term and short-term interest through the gate vector, the user interest representation vector is obtained, which is denoted as $\mathbf{O}^u$ and defined as follows:

$$\mathbf{O}^u = \mathbf{G}^u \odot \mathbf{Z}^u + (1 - \mathbf{G}^u) \odot \mathbf{P}^u, \tag{16}$$

where $\odot$ denotes element-wise multiplication.

3.6. Model Optimization. To obtain the user's recommendation list, the predicted probability distribution is generated through the softmax layer, and the cross-entropy is used as the loss function to train the predicted probability of the target item v^u_{tar}. Considering the large number of items in the real system and the high computational cost, we use sampled-softmax [2] to speed up training, which is defined as follows:

$$\mathscr{L} = -\sum_{\mathscr{N}} \log \frac{\exp\left((\mathbf{g}^u_{\text{tar}})^T \mathbf{O}^u\right)}{\sum_{j\in\mathscr{K}} \exp\left(\mathbf{g}_j^T \mathbf{O}^u\right)}, \tag{17}$$

where $\mathscr{K}$ is the sampling subset selected from the item set V according to the sampling function, $\mathbf{g}^u_{\text{tar}}$ is the embedding vector of the target item v^u_{tar}, and $\mathbf{O}^u$ is the user interest vector.

4. Experimental Results and Analysis

4.1. Datasets and Parameter Settings. We conduct experiments on two public datasets, i.e., MovieLens 1M dataset and JD dataset.

(1) MovieLens 1M: the MovieLens dataset is a rating dataset provided by the GroupLens group of the Minnesota Computer Institute, which includes user statistics, movie information, rating time, and rating values. The MovieLens 1M dataset contains 1,000,209 ratings of 3,952 movie items by 6,040 users, and each user has rated at least 20 items. The higher the user's rating on an item, the more the user likes it

(2) JD: the JD dataset records the user shopping behavior data of the JD e-commerce operation platform from February 1, 2018, to April 15, 2018. It is a relatively sparse dataset with a relatively short time span, which contains 37,214,269 records of 378,457 commodity items by 1,608,707 users

On the datasets, the user history records are sorted by time, and each sequence is divided into multiple subsequences according to the division rules. The data is preprocessed with reference to the experimental setting of the model DMAN [2], the last and penultimate interactions of each user are used as testing and validation, respectively, and the rest is used for training. We run five experiments repeatedly and take the average of the five results as the experimental results.

The model is optimized using Adam with a learning rate of 0.001, and the batch size is 512. In order to ensure the consistency of the experiments, the item embedding dimensions are set to 128. In the gating network based on the influence of neighbors, the number of user clusters k is determined according to the elbow method. To quickly and effectively determine the range of neighbors, the elbow method is used to calculate the degree of distortion. The degree of distortion is the sum of the squared errors (SSE) of the distance between the particle in each class and the sample points in the class. By constructing the distortion degree image of the number of clusters, the elbow position with the most obvious distortion degree change is taken as the best cluster k value. Figures 3 and 4 show the variation of the distortion degree SSE with the cluster k value on the MovieLens 1M and JD datasets, respectively. It can be seen from Figure 3 that the change of SSE is most obvious when k value is between 25 and 50 on MovieLens 1M dataset; we set the number of user clusters k to 40. In Figure 4, when the cluster k value on the JD dataset is around 25, the change of SSE is the most obvious. Therefore, the number of user clusters k is set to 25 on the JD dataset.

4.2. Comparison Methods. In order to verify the effectiveness of the proposed model, the following methods are selected for experimental comparison:

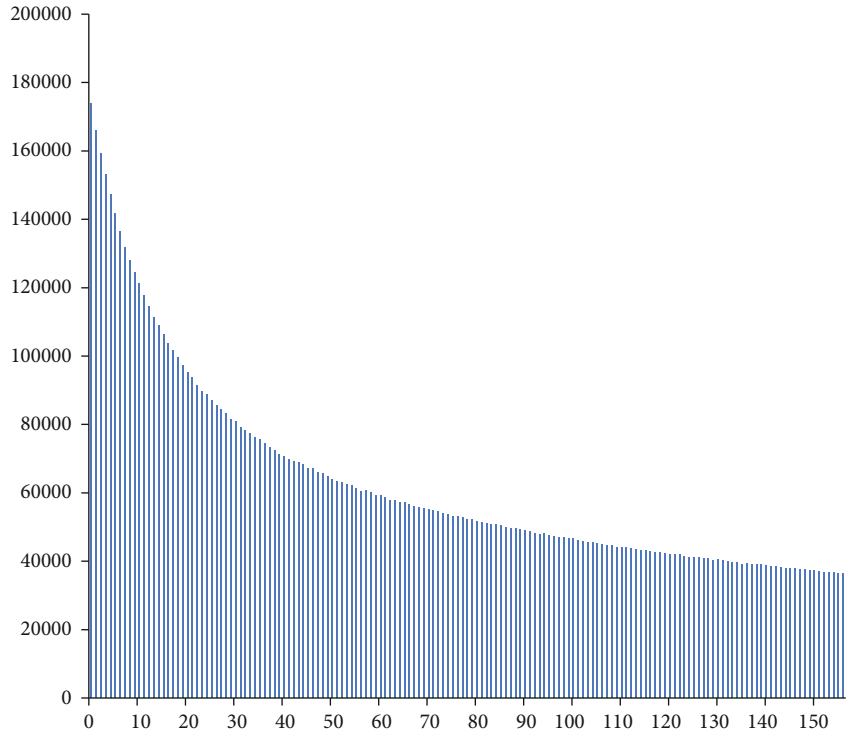

Figure 3: SSE of different number of k on MovieLens 1M.

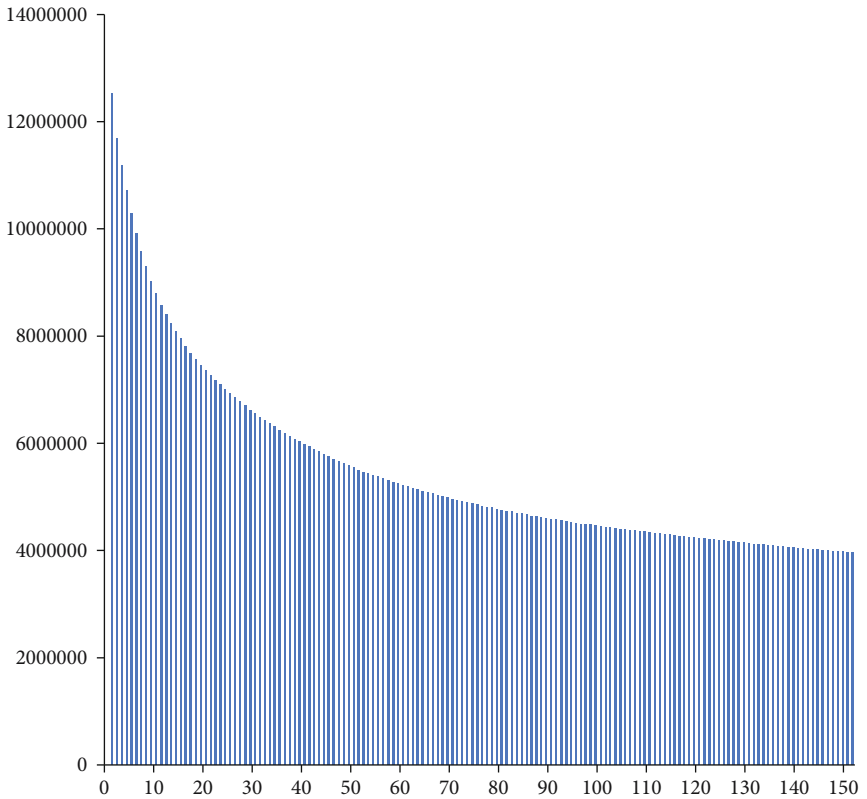

Figure 4: SSE of different number of k on JD.

(1) GRU4Rec+ [8]: GRU4Rec [38] is a classic RNN-based model for session recommendation. Based on GRU4Rec, GRU4Rec+ proposes a new ranking loss function and improves the sampling strategy

(2) Caser [7]: it models the user's recent behaviors as an "image" based on time and latent features and learns the image through CNN. Applying both horizontal and vertical convolutional filters to image learning can capture complex features such as point-level, union-level sequence patterns, and skipping behaviors in sequences

(3) SASRec [9]: SASRec is a neural network model composed of stacked self-attention which uses the self-attention mechanism to assign different weights to sequence data and learn more complex feature transformations through the hierarchical network

(4) SHAN [30]: SHAN is a sequential recommendation method based on hierarchical attention network. The first layer learns the user's long-term interests, and the second layer comprehensively considers the user's long-term interests and short-term interests. Both layers of attention network use user embedding vector as attention query for interest learning, which realizes personalized recommendation

(5) SDM [15]: SDM is a novel sequence deep matching model which used the multihead self-attention mechanism to obtain the recent diverse interests of users and learned the long-term interests of users by modeling long-term features of different categories. In this model, according to the obtained user's personalized interests, a gating module is used to fuse the short-term interest related parts of the complex and diverse long-term interests

(6) DMAN [2]: the DMAN model designs the recursive self-attention network to model users' short-term interests and preserves the important content of long-term interests as much as possible by maintaining a set of dynamically updated memory blocks. This model also used a gating network to combine long-term and short-term interests for recommendation

4.3. Comparison Methods. In order to evaluate the recommendation performance of different methods, we use hit rate (HR@K) and normalized discounted cumulative gain (NDCG@K) as evaluation metrics.

HR@K (Hit Rate@K) represents the percentage of items in the top-K of the ranking list in the test case, which is used to measure the accuracy of recommendation and defined as

$$\mathrm{HR@}K = \frac{1}{N}\sum_{i=1}^{N}\mathrm{hit}(i), \tag{18}$$

where N is the number of test cases and $\mathrm{hit}(\cdot)$ is the indicator function. $\mathrm{hit}(\cdot) = 1$ means that the item selected by the user appears in the top-K recommendation list; otherwise, $\mathrm{hit}(\cdot) = 0$.

NDCG@K (normalized discounted cumulative gain (NDCG)) is an evaluation metric about ranking. The higher the ranking of the correctly recommended item, the better the recommendation effect and the higher the NDCG value. This metric considers the order of recommendation results and denoted as

$$\mathrm{NDCG} = \frac{1}{N}\sum_{n\in N}\frac{\mathrm{DCG}}{\mathrm{IDCG}}. \tag{19}$$

DCG is the cumulative gain of loss and defined as

$$\mathrm{DCG} = \sum_{i=1}^{K}\frac{2^{r_i}-1}{\log_2(i+1)}, \tag{20}$$

where r_i is the correlation of the item at position i. If the recommended item is in the test case, $r_i = 1$; otherwise, $r_i = 0$. The higher the ranking of related items, the higher the value of DCG. IDCG is the DCG that rearranges the items in the recommendation list according to their relevance. Considering that the DCG values of different users may vary greatly, IDCG is used to normalize the DCG of different users to obtain the evaluation metric NDCG.

4.4. Comparison with Baseline Methods. Table 1 lists the experimental results of our model and six baselines on MovieLens 1M and JD datasets, where the bold ones represent the best results and the underlined ones are the second best results.

As listed in Table 1, we can make the following observations.

(1) For GRU4Rec+, Caser, and SASRec, which focus on short-term interest modeling, they do not perform well on two experimental datasets. GRU4Rec+ has the worst recommendation, which may be because the recurrent neural network of sequential modeling cannot effectively deal with the interest offset behaviors in the sequences and is easily affected by noise. Caser has better results due to considering more user personalization information. The performance of SASRec is significantly better than that of GRU4Rec+ and Caser. On the one hand, it shows that the attention network with position bias is beneficial to extract users' dynamic interests and alleviate the influence of noise. On the other hand, it shows that the stacked hierarchical attention network has significant advantages in dynamic modeling, which also explains the effectiveness of our model using a hierarchical structure

(2) For SHAN, SDM, and DMAN, which consider longer interaction sequences, the recommendation performance of these models is generally higher than those of the short-term interest models, i.e., GRU4Rec+, Caser, and SASRec. These results show that the long-term interests of users are also important for predicting users' choice. Therefore,

Table 1: Performance evaluation of different recommendation models (%).

Models	MovieLens 1M			JD		
	HR@10	HR@50	NDCG@100	HR@10	HR@50	NDCG@100
GRU4Rec+	17.69	43.13	16.90	27.65	38.73	23.40
Caser	18.98	45.64	17.62	29.27	40.16	24.25
SASRec	21.02	47.28	19.05	33.98	44.89	27.41
SHAN	21.34	49.52	19.55	37.72	50.55	29.80
SDM	23.42	51.26	20.44	40.68	55.30	34.82
DMAN	25.18	53.24	22.03	44.58	58.82	**36.93**
SRLIN	**26.97**	**55.84**	**22.66**	**44.97**	**59.44**	34.96

considering long-term interests based on short-term interests modeling can further improve the performance of recommendation

(3) For SHAN, SDM, and DMAN, which consider long-term interests and short-term interests, the recommendation results of SDM consistently outperform those of SHAN in evaluation metrics HR@10, HR@50, and NDCG@100. This is mainly due to the difference between the two models in the fusion of long-term and short-term interests. SHAN adopts a hierarchical attention network to integrate long-term and short-term interests, while SDM adopts a gating network. The gating network is more effective than the hierarchical attention network for learning the interest expression. In addition, the attribute feature extraction of the input data by SDM further improves the expressive ability of the model. DMAN can achieve better recommendation results than SDM because DMAN employs a dynamic memory-based attention network to continuously aggregate long-term representations into a set of memory blocks. By dividing subsequences, complex problems can be simplified. It is easier and more effective than SDM that directly extracts interests from the whole long-term sequence and can better express the users' long-term interest features

(4) For our proposed model SRLIN, it shows excellent recommendation results on both datasets. Compared with SDM, SRLIN has an average improvement of 3.92% in HR@10, 4.36% in HR@50, and 1.18% in NDCG@100. Compared with DMAN, SRLIN improves by 1.79% and 0.39% in HR@10, and 2.6% and 0.62% in HR@50, respectively. The overall effectiveness of our model can be attributed to several aspects. First, embedding representations of items are learned from multiple perspectives, which helps alleviate data sparsity issues. Second, in the long-term interest modeling, the graph attention network with node importance is used to learn the main features of the subsequences, which can not only accurately and fully extract stable changing long-term interests but also effectively eliminate the noise influence in the subsequences. Third, the long-term and short-term interests of users are comprehensively considered, and the interests are fused through the gating network together with the neighbor user information. The application of neighbor user features makes the model consider the influence of neighbor information while focusing on the user's own personalized data, which can enrich the prediction of user intention and improve the recommendation performance

(5) It is noted that the SRLIN model can achieve the best recommendation effect in the metric of NDCG@100 on the MovieLens 1M dataset, while the experimental result on the JD dataset is suboptimal. This is because the time span of the JD dataset is relatively short and the average sequence length of users is not long, which makes it difficult to fully learn stable changing long-term interests when modeling long-term representations. Comparing the HR@K metrics on the two datasets, we find that SRLIN achieves the average improvement of 1.09% on HR@10 and 1.61% on HR@50. It shows that the recommendation effect of the SRLIN model can be improved compared with the baselines as the length of the recommendation list increases, which further explains the reason why the ranking metric NDCG of SRLIN on the JD dataset is not the best

4.5. Effect of Graph Attention Network with Node Importance Factor. To explore the advantages of SRLIN using graph attention network with node importance factor in the interest extraction layer, we design three additional variants, i.e., SRLIN-RNN, SRLIN-AT, and SRLIN-GAT.

(1) SRLIN-RNN: LSTM is used to learn the interests of subsequences. Because of the order-dependent property of LSTM itself, the order relationship within subsequences is considered when extracting interests

(2) SRLIN-AT: the attention network is used to learn the interests of subsequences, and the attention mechanism can capture the main features of subsequences

(3) SRLIN-GAT: the main interests of subsequences are learned using graph attention network without considering the importance of nodes

Table 2 lists the experimental results in the evaluation metric of HR@50 for different subsequence interest extraction methods on MovieLens 1M and JD datasets.

By observing the results in Table 2, the following can be found:

(1) The SRLIN-RNN method, which uses LSTM to learn subsequence interests, performs the worst among the four models. This is because the interest offset caused by random, combined, jumping, and other behaviors in the historical sequences, which makes the recurrent neural network susceptible to noise when modeling subsequence sequential dependencies. The information loss of the bottom layer LSTM can further affect the learning of the upper layer interest changes, resulting in poor recommendation effect

(2) The performance of SRLIN-AT with attention network is better than that of SRLIN-RNN. The reason is that the attention mechanism pays more attention to important interest features, which alleviates the noise effect caused by interest offset in subsequences to a certain extent

(3) SRLIN-GAT uses graph attention network to extract the main interests of subsequences and can obtain better results than SRLIN-AT, which shows the effectiveness of modeling complex associations of items. The graph structure of the graph attention network visually draws the neighbor aggregation of items, which can capture more implicit connection relationship between items and help the attention mechanism to extract the main interests

(4) These results show that our SRLIN model outperforms the three variants. The reason why SRLIN is better than the best variant SRLIN-GAT is the introduction of the importance of item nodes. It shows that in a period of time, the importance of different items has a strong impact on user interests, reflecting users' different degrees of preferences. The more the number of nodes related to a node, the higher the importance of the node, and the contribution of the node to the subsequence is also greater. Therefore, considering the importance of different items in the subsequence is beneficial to the extraction of the main interests

4.6. Effects of Individual Components. To verify the effectiveness of each part of the model, we design two additional variants, i.e., SRLIN-S and SRLIN-G. SRLIN-S removes the long-term interest modeling module of SRLIN, while the gating module of SRLIN-G only considers the user's long-term and short-term interests.

Table 3 lists the experimental results in the evaluation metric HR@50 for the three methods on MovieLens 1M and JD datasets.

By analyzing the experimental results in Table 3, we find that the experimental results of interest fusion models SRLIN-G and SRLIN are always significantly better than those of SRLIN-S, which indicates the effectiveness of modeling long-term interest representations for recommendation results. The user interest information carried by long-term interest representation and short-term interest representation plays an important role in the recommendation. They complement and correlate with each other, which can further improve recommendation performance. In addition, compared with SRLIN-G, our SRLIN model can capture the influence of neighbor user feature, which makes it achieve better recommendation effect. These results show that the gating network considering the neighbor features can better balance the users' long-term interests and short-term interests so that it can obtain more accurate user interest representations.

Table 2: Comparison of hit rate for different interest extraction methods (%).

Models	MovieLens 1M	JD
SRLIN-RNN	49.15	51.16
SRLIN-AT	53.02	54.64
SRLIN-GAT	55.66	56.18
SRLIN	55.84	59.44

Table 3: Comparison of hit rate for three methods with different components (%).

Models	MovieLens 1M	JD
SRLIN-S	46.56	42.30
SRLIN-G	54.83	57.41
SRLIN	55.84	59.44

Table 4: Comparison of hit rate for two methods with different embedding methods (%).

Models	MovieLens 1M	JD
SRLIN-RD	50.15	51.42
SRLIN	55.84	59.44

4.7. Effect of Item Embeddings from Multiple Perspectives. To show the recommendation effect of different item embedding methods, we design an additional variant SRLIN-RD, which randomly encodes item embeddings based on item numbers. We compare the variant with our SRLIN that fuses item embeddings from multiple perspectives and validate them using the evaluation metric HR@50. The experimental results are shown in Table 4.

It can be seen from Table 4 that SRLIN has significant advantages. In contrast, the performance of SRLIN-RD is significantly reduced. In particular, on the JD dataset, the effect of SRLIN-RD is much lower than that of SRLIN, because the JD dataset has higher sparsity than the MovieLens 1M dataset. These experimental results show that learning item embeddings from multiple perspectives can effectively alleviate the problem of data sparsity, thereby improving recommendation performance.

4.8. Effect of Time and Length Thresholds. The time interval threshold Δt and the subsequence length threshold lenthrs

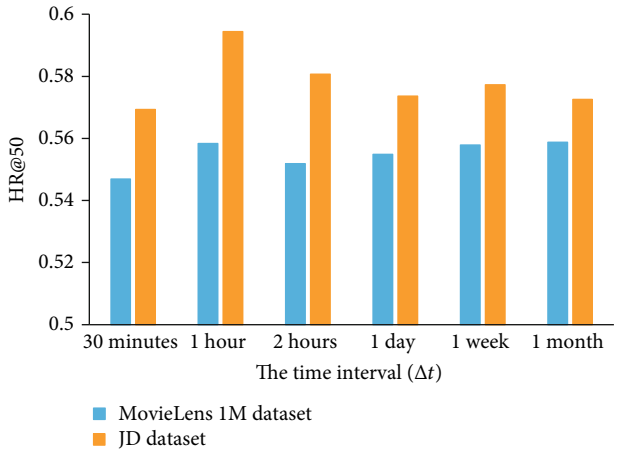

Figure 5: Effect of different time interval threshold Δt on hit rate.

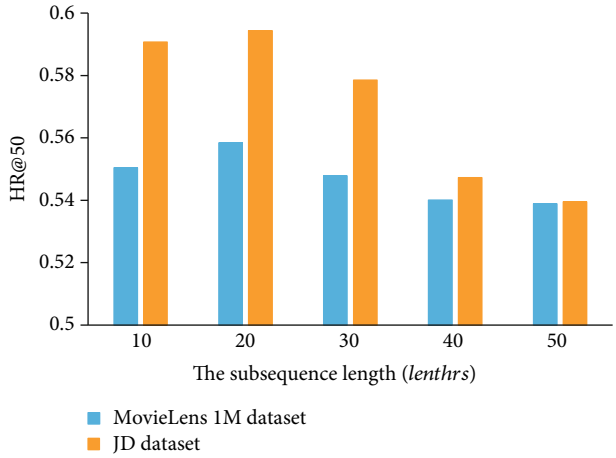

Figure 6: Effect of different length threshold lenthrs on hit rate.

are used in the sequence division. We verify the influence of different time interval sizes and sequence lengths on the recommendation performance through experiments. In order to intuitively show the effect of different thresholds, one parameter is fixed to verify the effect of another parameter, and the following experiments are designed for comparative analysis.

For a user history sequence, the sequence is divided if the time interval between adjacent items is more than the threshold Δt. The time interval Δt is used to distinguish the interests of users in different time periods. First, we fix the subsequence length threshold lenthrs = 20 and set the time interval threshold Δt to different values. The experimental results are shown in Figure 5.

By analyzing the results in Figure 5, it can be seen that the experimental result is optimal when the time interval threshold is set to 1 hour on the JD dataset, which indicates that most users choose products compactly within a period of time. When the time interval exceeds 1 hour, the occurrence of the next behavior is highly likely to indicate that the user reopens JD page, and the user may have new needs at this time. On the MovieLens 1M dataset, we find that the time interval has little effect on the recommendation results. This is because user preferences tend to be stable in movie selection, and the time interval does not clearly distinguish user interest changes. For uniformity, we set the time interval threshold Δt to 1 hour on both datasets.

Then, in order to more accurately reflect the main interests of users in a period of time, we further divide the subsequences that meet the time interval requirements. When the subsequence length exceeds the threshold lenthrs, it is considered that the user has started the next selection. Figure 6 shows the effect of the length threshold lenthrs on the recommendation effect when the time interval is set to 1 hour. As shown in Figure 6, the hit rate decreases as the subsequence length increases when the subsequence length exceeds 20. These results show that the user's demand is usually determined within 20 selection items. The observation also illustrates that the user's interests change dynamically over time. Therefore, we set the subsequence length threshold to 20.

5. Conclusions

In this paper, we propose a sequential recommendation model for long-term interest memory and nearest neighbor influence. The model learns item embeddings from multiple perspectives, which alleviates the problem of data sparsity by capturing the implicit relationship between items. For the case of long and complex behavior sequences of users, a hierarchical processing method is introduced to capture users' long-term interests by modeling complex structure within subsequences and sequential dependencies among subsequences, which deals with the problem of imperfect long-term interests modeling. In the interest extraction layer, we design the graph attention network with node importance factors which can fully learn the importance of different items in the subsequence and the complex relationship between the items and can focus on the important interests of each subsequence. In addition, we also design a gating network that considers the features of user neighbors. It comprehensively learns the relationship among each user's neighbor representation, long-term interest representation, and short-term interest representation, so as to solve the inadequacy of user interest prediction only relying on its historical behaviors. Extensive experiments on the MovieLens 1M and JD datasets show that our model outperforms baselines in prediction performance.

On the JD dataset, many user sequences are short or have a short time span, in which it is not suit for learning the long-term stable interests. Therefore, in the future, we will further explore the latent features of long-term interests and strive to reduce the time cost of the model. In addition, knowledge graph can provide more relevant information, which is also worthy of further consideration.

Data Availability

The data used to support the findings of this study can be downloaded from https://grouplens.org/datasets/movielens/ and https://jdata.jd.com/html/detail.html?id=8.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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References

[1] X. He, K. Deng, X. Wang, Y. Li, Y. Zhang, and M. Wang, "Lightgcn: simplifying and powering graph convolution network for recommendation," in *Proceedings of the 43rd International ACM SIGIR conference on research and development in Information Retrieval*, pp. 639–648, Virtual Event China, 2020.

[2] Q. Tan, J. Zhang, N. Liu et al., "Dynamic memory based attention network for sequential recommendation," 2021, http://arxiv.org/abs/2102.09269.

[3] B. Paudel and A. Bernstein, "Random walks with erasure: diversifying personalized recommendations on social and information networks," in *Proceedings of the Web Conference 2021*, pp. 2046–2057, Ljubljana Slovenia, 2021.

[4] Z. He, C. Y. Chow, and J. D. Zhang, "GAME: learning graphical and attentive multi-view embeddings for occasional group recommendation," in *Proceedings of the 43rd International ACM SIGIR Conference on Research and Development in Information Retrieval*, pp. 649–658, Virtual Event China, 2020.

[5] S. Wang, L. Hu, Y. Wang, L. Cao, Q. Z. Sheng, and M. Orgun, "Sequential recommender systems: challenges, progress and prospects," 2019, http://arxiv.org/abs/2001.04830.

[6] S. Wang, L. Cao, Y. Wang, Q. Z. Sheng, M. A. Orgun, and D. Lian, "A survey on session-based recommender systems," *ACM Computing Surveys (CSUR)*, vol. 54, no. 7, pp. 1–38, 2022.

[7] J. Tang and K. Wang, "Personalized top-n sequential recommendation via convolutional sequence embedding," in *Proceedings of the eleventh ACM International Conference on Web Search and Data Mining*, pp. 565–573, Marina Del Rey CA USA, 2018.

[8] B. Hidasi and A. Karatzoglou, "Recurrent neural networks with top-k gains for session-based recommendations," in *Proceedings of the 27th ACM international conference on information and knowledge management*, pp. 843–852, Torino Italy, 2018.

[9] W. C. Kang and J. McAuley, "Self-attentive sequential recommendation," in *2018 IEEE International Conference on Data Mining (ICDM)*, pp. 197–206, Singapore, 2018.

[10] S. Sang, N. Liu, W. Li, Z. Zhang, Q. Qin, and W. Yuan, "High-order attentive graph neural network for session-based recommendation," *Applied Intelligence*, pp. 1–15, 2022.

[11] J. Zhang, X. Mu, P. Zhao, K. Kang, and C. Ma, "Improving current interest with item and review sequential patterns for sequential recommendation," *Engineering Applications of Artificial Intelligence*, vol. 104, article 104348, 2021.

[12] T. Bai, P. Du, W. X. Zhao, J. R. Wen, and J. Y. Nie, "A long-short demands-aware model for next-item recommendation," 2019, http://arxiv.org/abs/1903.00066.

[13] C. Xu, J. Feng, P. Zhao et al., "Long- and short-term self-attention network for sequential recommendation," *Neurocomputing*, vol. 423, pp. 580–589, 2021.

[14] Z. Pan, F. Cai, W. Chen, C. Chen, and H. Chen, "Collaborative graph learning for session-based recommendation," *ACM Transactions on Information Systems*, vol. 40, no. 4, pp. 1–26, 2022.

[15] F. Lv, T. Jin, C. Yu et al., "SDM: sequential deep matching model for online large-scale recommender system," in *Proceedings of the 28th ACM International Conference on Information and Knowledge Management*, pp. 2635–2643, Beijing China, 2019.

[16] J. Tang, F. Belletti, S. Jain et al., "Towards neural mixture recommender for long range dependent user sequences," in *The World Wide Web Conference*, pp. 1782–1793, San Francisco CA USA, 2019.

[17] J. Sun, Y. Zhang, W. Guo et al., "Neighbor interaction aware graph convolution networks for recommendation," in *Proceedings of the 43rd International ACM SIGIR Conference on Research and Development in Information Retrieval*, pp. 1289–1298, Virtual Event China, 2020.

[18] Z. Li and L. Zhang, "Fast neighbor user searching for neighborhood-based collaborative filtering with hybrid user similarity measures," *Soft Computing*, vol. 25, no. 7, pp. 5323–5338, 2021.

[19] S. Banerjee, P. Banjare, B. Pal, and M. Jenamani, "A multistep priority-based ranking for top-N recommendation using social and tag information," *Journal of Ambient Intelligence and Humanized Computing*, vol. 12, no. 2, pp. 2509–2525, 2021.

[20] Y. Guo, Y. Ling, and H. Chen, "A time-aware graph neural network for session-based recommendation," *IEEE Access*, vol. 8, pp. 167371–167382, 2020.

[21] Y. Ding and X. Li, "Time weight collaborative filtering," in *Proceedings of the 14th ACM international conference on Information and knowledge management*, pp. 485–492, Bremen Germany, 2005.

[22] N. Lathia, S. Hailes, and L. Capra, "Temporal collaborative filtering with adaptive neighbourhoods," in *Proceedings of the 32nd international ACM SIGIR conference on Research and development in information retrieval*, pp. 796-797, Boston MA USA, 2009.

[23] S. Rendle, C. Freudenthaler, and L. Schmidt-Thieme, "Factorizing personalized Markov chains for next-basket recommendation," in *Proceedings of the 19th international conference on World wide web*, pp. 811–820, Raleigh North Carolina USA, 2010.

[24] R. He and J. McAuley, "Fusing similarity models with Markov chains for sparse sequential recommendation," in *2016 IEEE 16th International Conference on Data Mining (ICDM)*, pp. 191–200, Barcelona, Spain, 2016.

[25] S. Kabbur, X. Ning, and G. Karypis, "Fism: factored item similarity models for top-n recommender systems," in *Proceedings of the 19th ACM SIGKDD international conference on Knowledge discovery and data mining*, pp. 659–667, Chicago Illinois USA, 2013.

[26] N. Sahoo, P. V. Singh, and T. Mukhopadhyay, "A hidden Markov model for collaborative filtering," *MIS Quarterly*, vol. 36, no. 4, pp. 1329–1356, 2012.

[27] C. Lonjarret, R. Auburtin, C. Robardet, and M. Plantevit, "Sequential recommendation with metric models based on frequent sequences," *Data Mining and Knowledge Discovery*, vol. 35, no. 3, pp. 1087–1133, 2021.

[28] L. Huang, Y. Ma, S. Wang, and Y. Liu, "An attention-based spatiotemporal lstm network for next poi recommendation," *IEEE Transactions on Services Computing*, vol. 14, no. 6, pp. 1585–1597, 2019.

[29] M. Gan and K. Xiao, "R-RNN: extracting user recent behavior sequence for click-through rate prediction," *IEEE Access*, vol. 7, pp. 111767–111777, 2019.

[30] H. Ying, F. Zhuang, F. Zhang et al., "Sequential recommender system based on hierarchical attention network," in *IJCAI International Joint Conference on Artificial Intelligence*, Sweden, Stockholm, 2018.

[31] J. Lin, W. Pan, and Z. Ming, "FISSA: fusing item similarity models with self-attention networks for sequential recommendation," in *Fourteenth ACM Conference on Recommender Systems*, pp. 130–139, Virtual Event Brazil, 2020.

[32] M. Quadrana, A. Karatzoglou, B. Hidasi, and P. Cremonesi, "Personalizing session-based recommendations with hierarchical recurrent neural networks," in *Proceedings of the Eleventh ACM Conference on Recommender Systems*, pp. 130–137, Como Italy, 2017.

[33] Y. Feng, B. Zhang, B. H. Qiang, Y. Y. Zhang, and J. X. Shang, "MN-HDRM: a novel hybrid dynamic recommendation model based on long-short-term interests multiple neural networks," *Chinese Journal of Computers*, vol. 42, no. 1, pp. 16–28, 2019.

[34] K. Hu, L. Qiu, S. Zhang, Z. Wang, and N. Fang, "An incremental rare association rule mining approach with a life cycle tree structure considering time-sensitive data," *Applied Intelligence*, pp. 1–25, 2022.

[35] H. Wang, P. Li, Y. Liu, and J. Shao, "Towards real-time demand-aware sequential POI recommendation," *Information Sciences*, vol. 547, pp. 482–497, 2021.

[36] C. Ma, L. Ma, Y. Zhang, J. Sun, X. Liu, and M. Coates, "Memory augmented graph neural networks for sequential recommendation," *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 34, no. 4, pp. 5045–5052, 2020.

[37] A. Mirzal, "Statistical analysis of microarray data clustering using NMF, spectral clustering, Kmeans, and GMM," *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, vol. 19, pp. 1173–1192, 2020.

[38] B. Hidasi, A. Karatzoglou, L. Baltrunas, and D. Tikk, "Session-based recommendations with recurrent neural networks," 2015, http://arxiv.org/abs/1511.06939.

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Research Article

Cloud Computing Based on Big Data-Driven Robot Walking Route and Real-Time Positioning Intelligent Determination

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With the continuous development of technologies such as sensors, computers, and artificial intelligence, intelligent mobile robots with thinking, perception, and dynamics functions are widely used in military, political, and scientific research. Its development has had a significant impact on national defense, society, economy, science, and technology and has become a strategic research goal in the high-tech field of various countries. Robot positioning technology is one of the key research technologies for portable robots, and reliable posture is the key prerequisite for completing various tasks. This article aims to study the robot walking route driven by big data and the intelligent determination of real-time positioning based on cloud computing. This paper proposes an active general positioning algorithm based on real-time positioning function, which can improve the convergence speed and robustness of general positioning when different map scenes do not have clear geometric features and contain map noise. The most basic requirement for robots to perform autonomous operations is to have reliable positioning performance. The experimental results in this paper show that dynamic global positioning and adaptive behavior tracking are effective. Compared with the traditional algorithm, the improved algorithm increases the convergence speed of the global layout by 41.59%.

1. Introduction

An intelligent mobile robot is a comprehensive system that integrates environmental perception, dynamic decision-making and planning, behavior control, and execution. Over the years, with the development of science and technology, the improvement of computer performance, and the fusion of artificial intelligence and control theory, mobile robotics, as an interdisciplinary subject, has involved multiple research fields, which has attracted more and more public attention. In this field, we mainly focus on the "motion" characteristics of mobile robots and combine many functions, such as perception of environmental and self-state, execution and control of actions, dynamic planning, and decision-making. The research on mobile robots began in the late 1960s. From 1966 to mid-1972, researchers at the Stanford Research Institute developed a mobile robot called "Shakey" whose basic functions include perception, environment modeling, and motion design. At the same time, the Soviet Union and the United States also developed the first unmanned lunar rover. In 1997, the American rover Soiner who successfully landed on Mars took as many as 500 photos related to the Martian landscape and sent them back to Earth. This should be a major success in the actual application of wheeled robots. Since its establishment, mobile robots have made considerable progress in engines and architectures, integrating multi-sensor information, positioning, route planning, and navigation monitoring and control. These technologies can be applied not only in the military field but also in private and scientific research fields. Especially in the private sector, portable robot technology can be used to control the automatic and semi-autonomous driving of vehicles to improve safety, and it can be applied to smart wheelchairs to improve the elderly and the disabled quality of life. In the long run, these technologies can also benefit from disaster search and rescue, emergency rescue, and other dangers and difficult opportunities faced by humans. This paper aims to study the robot walking route driven by big data and the intelligent determination of real-time positioning based on cloud computing,

in order to make a certain contribution to the real-time positioning of robots.

For a series of related research on artificial intelligence robot technology, my country has also successively carried out major special projects of the "15th Five-Year Plan." For example, many studies, such as robots based on bionics, service-oriented application robots, and robots that can operate in hazardous environments, have produced many effective results. During the 863 Program, Tsinghua University developed an intelligent robot platform that has multifunctional functions that can be used for outdoor experiments. As the first Frontier-ITM mobile autonomous robot to represent a Chinese university in the RoboCup medium-sized football match, it was independently developed by Shanghai Jiao-tong University. Shanghai Jiao-tong University and Harbin Institute of Technology have also jointly developed a hotel service robot, which has been exhibited at industrial fairs in recent years. At the same time, in the RoboCup China Open Home Service Robot Competition in recent years, home service robots such as "Jiao-long" from Shanghai Jiao-tong University, "Ke-jia" from University of Science and Technology of China, and "Amanda" from Shanghai University have all achieved success and great improvement. They have some basic functions, such as environment modeling, independent installation, automatic navigation, face recognition, voice interaction, and object capture. Among related mobile robot technologies, positioning technology has always been one of the most basic technologies in the research field. For autonomous robot mobile devices, reliable positioning results are the most basic condition for accomplishing various tasks.

Rezaee A uses an algorithm that continuously assigns PID coefficients based on an online algorithm, depending on the system characteristics based on fuzzy logic. The welding robot used in this system is used to weld oil and gas pipelines. Place the robot on the pipe and move it to weld. The motor is used to move the robot around the pipe to adjust the speed. Although the author used the above method to simulate, but did not analyze the results of the realization [1]. Soon-Joe proposed a cleaning robot motion mode method based on grammatical evolution. The optimization program is generated by using the motion mode grammar defined by the Backus-Naur form. In addition, in the process of program creation, conditional probabilities are used between each syntax element. However, after the simulation evaluation of the robot, it is found that the proposed method is not superior to the comparison algorithm. At present, the aging problem is becoming more and more serious, and the demand for nursing is increasing year by year. Nursing robot is a solution to meet the demand [2]. Kawai R developed a controllable, movable, low-cost nursing robot through the operator's hand movements and conducted an evaluation to verify its effectiveness. At first, the experiment participants felt that they could not operate the robot the way they wanted, but eventually they were able to do it the way they wanted. The disadvantage is that with regard to the robot arm, some participants find it difficult to control it with the developed controller [3].

The innovations of this paper are as follows: (1) The research on the robot less planning method and the robot positioning technology is carried out. (2) An active general positioning algorithm based on real-time positioning function is proposed. (3) Experiments are carried out on the big data-driven robot walking route and real-time positioning intelligent judgment cloud computing.

2. Big Data-Driven Robot Walking Route and Real-Time Positioning Intelligently Determine Cloud Computing Research Methods

2.1. Robot Gait Planning Method. The earliest surviving robot is a teenage doll from the Historical Museum in Nusatier, Switzerland. It was made 200 years ago. The ten fingers of two hands can press the keys of the organ to play music, and it is also played regularly for visitors to enjoy, showing the wisdom of the ancients. Compared with developed countries such as the United States and Japan, the exploration time for biped robots in our country is shorter, and most of them started in the mid-1980s. Among them, Tsinghua University, Harbin Institute of Technology, National University of Defense Technology, Beijing Institute of Technology, and other universities have done a lot of research in this field [4, 5]. Robots can improve social efficiency. The application of robots reduces the workload of human beings and solves some problems that humans cannot solve. For example, Ali's city brain can optimize the time allocation of intersections, improve traffic efficiency, and make busy cities more intelligent. Although it started late compared to other countries, due to the gradual improvement of my country's economic strength and scientific research level, on the other hand, government departments are paying more and more attention to robots. Our country has obtained certain results and experience in the field of biped robots and launched our country's own advanced biped robot [6]. In the 1980s, National Science and Technology University embarked on the development of biped robots and successively developed KWD-1, KWD-2, and KWD-3. Then, in 2000, the country's first biped robot "Forerunner" was developed [7, 8], as shown in Figure 1.

The forerunner can realize most of the actions of ordinary people, such as turning, forwarding, backing up, and going upstairs. And in the following years, the National University of Science and Technology introduced a new generation of robot pioneers, which are basically similar to humans in terms of appearance and function [9]. At present, domestic and foreign researchers have many methods to study the dual-robot hiking plan, but the general methods are similar [10].

2.2. Robot Positioning Technology. The most basic requirement for robots to perform autonomous operations is to have reliable positioning performance. Its direct performance is the ability to accurately obtain the current position coordinates of the robot in the global coordinate system [11]. According to various methods of sensor information fusion, the existing positioning methods for mobile robots can be roughly divided into the following three types. Relative positioning: refers to the offset of the element relative to the original position of the document layout; absolute

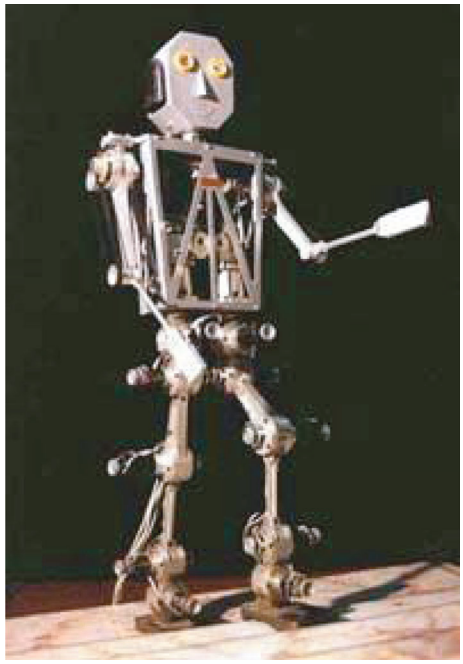

Figure 1: Forerunner robot (this picture is borrowed from Baidu Encyclopedia).

positioning: refers to the arbitrary positioning of the element in the original page separation.

(1) Relative positioning method

It measures the current posture of the robot by measuring the distance and direction of the movement relative to the initial posture based on the built-in sensors of the robot (such as odometer and penetrating navigation) [12]. This method will accumulate inevitable path errors, which will increase with the increase of time and distance, but at the same time, it needs to take the initial stop as a reference and is not suitable for general positioning of robots. Relative positioning methods can be divided into static relative positioning and static relative positioning.

(2) Absolute positioning method

The central idea is to use artificial road signs, active or passive signs, map matching points, or global positioning systems to place them immediately. Position calculation methods include algorithms for trimming, triangulation, or model matching. This type of method has many environmental requirements and usually requires manual changes to the environment, resulting in high maintenance costs. At the same time, certain matching algorithms are slowing down. The concept of absolute positioning is mainly divided into two types: the first is satellite absolute positioning, and the second is absolute positioning in CSS positioning.

(3) Combined positioning method

It is a combination of the first two methods. Taking into account the shortcomings of the first two positioning methods, most portable robot positions are now based on a combination of trajectory estimation and absolute information correction, that is, a combination of positioning methods [13].

2.3. Fisher's Information. Fisher's information is a measure of the amount of information an observable random variable X carries about unknown parameters of the distribution of a model X. Variance is evaluated by mathematical statistics of information, that is, information variance will have a certain impact. To evaluate this impact, we can rely on Fisher's information, which has been verified in mathematical statistics and information theory [14, 15]. People often misunderstand that the prior probability determines the asymptotic distribution of the posterior probability, but this is a misunderstanding. It is Fisher's information that determines the asymptotic distribution of posterior probability. This fact can be obtained by the Bernstein-von Mises theorem in Bayesian statistics [16, 17]. This also shows that Fisher's information plays an important role in the maximum likelihood estimation of asymptotic theory. By extension, the robot's observation information is z, and its possible pose is p. We know that the distribution of z is closely related to p, and Fisher's information can be used to connect the observation information z with the possible pose p relationship [18].

Specifically, the likelihood function of p is represented by $f(z;p)$. When a certain value of p is given, assuming a random variable z corresponds to it, then the probability density of z can be represented by the likelihood function $f(z;p)$, which is the likelihood intuitive explanation of the function. For the likelihood function, first take its natural logarithm; and then obtain the partial derivative of the pose, a function similar to the nature of the score (Score) can be obtained. Under certain conditions (these conditions are regular and follow-able), the scoring consists of two parts, one is the part with a score of 0, and the other non-zero part is defined as Fisher's information:

$$\mathfrak{I}(p) = E\left[\left(\frac{\partial}{\partial p}\log f(z;p)\right)^2 \middle| p\right]. \tag{1}$$

In the above formula, for any given p value, the expression $E[\bullet|p]$ represents the conditional expectation of z in the probability density function $f(z;p)$, where $0 \le \mathfrak{I}(p) < \infty$, and it can also be seen that the absolute value of the score is proportional to Fisher's information [19]. It should be noted that the observation function targeted by Fisher's information here is not specific, and the random variable z can reflect any situation. Furthermore, we pointed out that when the score is 0 as the expectation, then its variance or covariance can be represented by Fisher's information [20, 21].

If there is a precondition, that is, $\log f(z;p)$ is two-order derivable to p, then Fisher's information can be expressed by the following formula under some specific conditions:

$$\mathfrak{I}(p) = -E\left[\frac{\partial^2}{\partial p^2}\log f(z;p) \middle| p\right]. \tag{2}$$

This formula shows that Fisher's information can also be obtained by inverting the natural logarithm of the probability density function $f(z;p)$ to the second derivative of p. It can be seen that this expression reflects the curvature of the curve and can be very conveniently used to evaluate the curve corresponding to the likelihood estimation function of p. When the curve is relatively convex, it is reflected in the larger second-order partial derivative and larger Fisher's information; on the contrary, when the curve is relatively flat, it is reflected in the smaller second-order partial derivative and smaller Fisher's information.

If there is no correlation between the two sets of observations, the sum of the amount of information obtained from each observation is the same as the total amount of information obtained from the two observations [22, 23]. Fisher's information also follows this cumulative property, which is a very good property for the application of this article, which is expressed by the formula:

$$\mathfrak{J}_{z_1,z_2}(p) = \mathfrak{J}_{z_1}(p) + \mathfrak{J}_{z_2}(p). \tag{3}$$

The above results can be proved by the following derivation: the variance of the sum of the variables obtained by adding the random variables is equal to the sum of the variances of each variable, if and only if these random variables are independent of each other, that is: if a random sample of the size is 1, and there is another random sample with the same attribute, and its size is n, so the result of sampling n times in the former and 1 sampling in the latter is the same.

2.4. Cramer-Rao Bound Inequality. From the introduction in the previous section, we can know that in the related asymptotic theory based on maximum likelihood estimation, the amount of information can be obtained from the probability density distribution of the parameters, and this can be described by Fisher's information, which is a very meaningful one thing [24, 25]. In particular, we can find the lower limit of information estimation through CRB inequality. The following is a brief introduction to CRB inequality [26].

The CRB inequality was proposed by Harald Cramér and Calyampudi Radhakrishna Rao. This inequality can be used to determine the lower bound of the estimated variance (covariance) of the parameters. Combining the background of robot positioning, the derivation method of the classic CRB inequality is given below [27, 28].

Assuming that p is an unknown certain pose, it can be estimated by observing the z, and $f(z;p)$ is the probability density function corresponding to observing z. Then, when we estimate the pose p, Fisher's information $\mathfrak{J}(p)$ will reflect the limitation of the value range of its variance (covariance), namely:

$$Var(\hat{p}) \geq \frac{1}{\mathfrak{J}(p)}. \tag{4}$$

Among them, the validity of Fisher's information $\mathfrak{J}(p)$ unbiased estimation is defined as follows:

$$e(\hat{p}) = \frac{\mathfrak{J}(p)^{-1}}{Var(\hat{p})}. \tag{5}$$

It can be seen that the range of $e(\hat{p})$ is (0,1], $Var(\hat{p})$ represents the true variance (covariance), and $\mathfrak{J}(p)^{-1}$ represents the minimum variance (covariance) of the unbiased estimate. We can use the ratio of the two, that is, $e(\hat{p})$ to express the estimator. The minimum variance of that is the lower bound of variance, and the difference between its actual variance (covariance).

The derivation process is as follows: usually, the parameter p that cannot be directly obtained can only be estimated by the observation z, and the parameter p determines the current value of the observation z. We know that due to measurement errors and other factors, the observations z must also have errors and have certain uncertainties. Therefore, in order to link the two together, a probability distribution function $p(z|p)$ needs to be introduced into the parameter p and the observation z. Let the estimated information $T(z)$ of p be the real function of the measured data z, let $\Delta T = T(z) - T_p$, where:

$$T_L = \int p(z|p)T(z)dz. \tag{6}$$

If $T_p = p$ is estimated on average, it is called unbiased estimation. For unbiased estimation, any T and m independent observations $z_1, z_2, \cdots, z_m$ have:

$$\int p(z|p) \cdots p(z_m|p)\Delta T dz_1 \cdots dz_m = 0. \tag{7}$$

To find the partial derivative of p in the above formula, we get:

$$\sum_{i=1}^{m} \int p(z_1|p) \cdots p(z_m|p) \frac{1}{p(z_i|p)} \frac{\partial p(z_i|p)}{\partial p} \Delta T dz_1 \cdots z_m - \frac{dT_p}{dp} = 0. \tag{8}$$

Because p is dependent on T_p instead of T, the above formula can be converted to:

$$\int p(z_1|p) \cdots p(z_1|p) \frac{1}{p(z_i|p)} \left(\sum_{i=1}^{m} \frac{\partial \ln p(z_i|p)}{\partial p} \right) \Delta T dz_1 \cdots dz_m - \frac{dT_p}{dp} = 0. \tag{9}$$

Using Cauchy-Schwarz inequality

$$\left[\int f(x)g(x)dx \right]^2 \leq \int f(x)^2 dx \int g(x)^2 dx. \tag{10}$$

Available:

$$\int p(z_1|p)\cdots p(z_m|p)\left(\sum_{i=1}^{m}\frac{\partial \ln p(z_i|p)}{\partial p}\right)^2 dz_1\cdots dz_m \times \int p(z_1|p)\cdots p(z_m|p)(\Delta T)^2 p(z_1|p)\cdots p(z_m|p) \geq \left|\frac{dT_p}{dp}\right|^2. \tag{11}$$

Introduce Fisher's information $\mathfrak{I}(p)$ and get 引入 Fisher's 信息 $\mathfrak{I}(p)$,

$$m\mathfrak{I}(p)(\Delta T)^2 \geq \left|\frac{dT_p}{dp}\right|^2. \tag{12}$$

For the unbiased estimator, $(\Delta T)^2$ is the variance (covariance) square $Var(\widehat{p})^2$ of the estimated pose $\widehat{p}$, and $dTp/dp = 1$, the CRB inequality can be finally obtained.

The CRB inequality uses the inverse of Fisher's information to give the smallest variance (covariance) that may occur when estimating the pose. It can be seen that the smaller Fisher's information indicates the lack of observational information in the pose, which means that the estimation of the current pose is biased, and the measurement variance (covariance) is larger. Therefore, the amount of observation information is crucial to whether a parameter can be accurately estimated. Based on people's basic cognition, the more information, the more accurate the estimation result will be. What needs to be explained here is that Fisher's information is usually in the form of a matrix, because the parameters that need to be estimated often contain multiple variables; in addition, the lower limit of the variance (covariance) calculated by the CRB inequality is only theoretical. The actual variance (covariance) usually deviates from the theoretical value. This is due to the different methods of evaluating parameters through observation information, the error or lack of observation information, etc., but this deviation is usually within the allowable range.

2.5. Discretization Observation Model. In recent years, in the research of mobile robot positioning, scholars generally believe that it is an effective positioning method to correct the error of the odometer through the sensor to perceive the surrounding environment, and it has had many successful practical applications [29, 30]. The algorithm used in this paper is a laser rangefinder that perceives the distance of the environment. The laser observation model is shown in Figure 2:

The pose of the robot is expressed by $p_t = [x_t, y_t, \theta_t]$, $r_{iE}(p_t, \phi_i)$ is the expected distance scanned by the i laser ray, and the total number of laser rays is N_o. Then, the laser observation model equation can be defined as:

$$r_i = r_{iE}(p_t, \phi_i) + \varepsilon_i, i = 1, 2, \cdots, N_o. \tag{13}$$

Among them, ε_i represents Gaussian random noise with a mean value of 0 and a variance of σ_i^2. In practical applications, the analytical map of the real environment is usually not available. Therefore, r_{iE} cannot be accurately calculated. ε_i is a partial item that reflects physical influence factors, such as robot speed, obstacle distance, orientation, and surface material. Therefore, ε_i and its variance σ_i^2 cannot be directly calculated.

3. Big Data-Driven Robot Walking Route and Real-Time Positioning Intelligently Determine Cloud Computing Experiments

3.1. The Positioning and Environment Construction of Mobile Robots

(1) Positioning

The positioning system is designed for a specific location and should describe the characteristics of the environment. Most positioning systems operate in a structured environment, but other positioning systems rely on GPS for placement, so they can only operate in an outdoor environment. Some robots need to make real-time mapping anytime and anywhere, while other robots only need to be placed on the map created by the robot.

For indoor installation systems, most positioning algorithms come from indoor installation systems. In a structured environment, it is necessary to simplify the structure of the environment, such as a flat ground, without considering the obstacles of potholes. These methods are to align external objects such as doors and glass to determine their location and orientation.

The outdoor installation system uses GPS as the main installation method for outdoor robots. However, GPS may not always be able to receive enough satellite signals. In other words, GPS cannot produce accurate results. This requires the use of other sensors (such as rangefinders) to improve system accuracy and correct GPS errors.

Indoors and outdoors, there are few methods that can be used in both environments at the same time. This is because indoor methods are highly structured environments and therefore not suitable for outdoor work. In addition, GPS does not work indoors. It is difficult to find a suitable method indoors and outdoors. In addition to using signs in the environment, cameras can also be used to capture the terrain and structure of the environment using positioning methods based on surface features.

(2) Map construction

For the positioning problem, there are two ways to build a map. Under normal circumstances, it is to complete the construction of the map before the implementation of positioning. Another way is to continuously complete the map as the robot moves in the environment, that is, SLAM.

SLAM is the main research topic of robotics. These methods can help robots run in unknown environments and display the number of robots running on service robots (such as wheelchair robots, cleaning robots, and search and rescue robots).

In order to realize the construction of the robot map, it is necessary to solve some problems of communication, dynamic environment, and robot search. Communication problems refer to the consistency of information detected

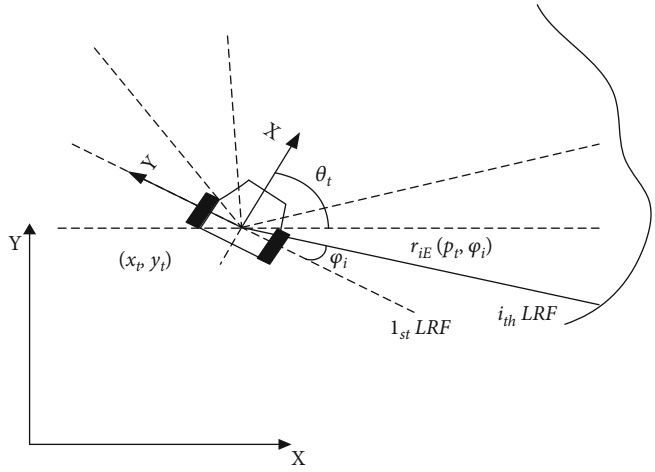

Figure 2: Laser observation model.

Table 1: Judgment conditions for different convergence states.

State of convergence	Judgment condition
a	(1) More than 80% of the particles converge to 10 convergent cluster centers (2) M_p>10 grids, and M_r>10 grids
A	(1) More than 80% of the particles converge to 10 convergent cluster centers (2) M_p<2 grids, and M_r<2 grids
B	(1) More than 80% of the particles converge to 10 convergent cluster centers (2) M_p<2 grids, and M_r>20 grids

by different sensors on the same object. The dynamic environment includes moving objects such as people and cars, and other factors also cause natural changes. Robot exploration is the function of robots navigating while mapping the map. The advantage of this method is that the robot can be placed in an environment that has not been visited before, the environment map is constantly changing, and the robot can also be placed in a changing environment.

3.2. Simulation Test. For simulation, the hardware platform is an Intel personal computer (Intel Core2 Duo E7200 2.5G CPU, DDR2-800 2G RAM). For the experiment, the hardware platform is the "Jiao-long" smart wheelchair independently developed by the laboratory. On the "Jiao-long" wheelchair platform, the positioning algorithm is executed on an industrial computer (Intel Core Duo T2500 2.0G CPU, DDR2-667 3G RAM); the wheelchair adopts two-wheel differential drive, and the controller is self-designed DSP motion control board; meanwhile, the wheelchair is equipped with an odometer, which is calibrated in advance, and equipped with a laser rangefinder (SICK LMS111).

For simulation and experiment, the software platform uses CARMEN, an open source robot simulation platform under Linux SUSE system. When comparing different positioning algorithms, standard algorithms, such as the standard particle filter algorithm with "roulette" re-sampling process, are implemented based on CARMEN standard code; and for improved algorithms based on positioning capabilities, and other needs to be compared. The algorithm is implemented by the secondary development of the standard code under CARMEN. For smart wheelchairs, the main sensors are odometer and laser rangefinder. The errors brought by these sensors will inevitably have an impact on the algorithm. In the following, how to simulate these sensor errors in the simulation will be specifically explained. The odometer uses a photoelectric encoder to record the mileage data. Although it has been pre-calibrated, it still has a certain error. Mainly include system errors such as small precision errors, driver errors, and non-system errors caused by wheel slip caused by uneven road surface. In addition, as the weight of the user carried by the "Jiao-long" smart wheelchair is different, the deformation of the wheel changes, and its kinematics model will also change to a certain extent.

For active global positioning algorithms based on positioning capabilities, before simulation and experimentation, a global probability grid map needs to be established first. Furthermore, based on the known map, the positioning ability in each pose can be calculated offline in advance and stored. Because the laser rangefinder used in this article is not omnidirectional scanning, when we calculate the positioning capability offline, we need to discretize the observation direction, that is, to discretize a different observation direction. In addition, the greater the system sampling interval, the greater the sensor error introduced. Therefore, this

Table 2: Simulation and experimental parameters of the global positioning algorithm.

Description	Parameter
Map resolution (raster size)	$0.1 \times 0.1m^2$
Static positioning capability discrete step size	$\Delta x = \Delta y = 0.1m, \Delta\theta = 1^\circ$
Maximum scanning distance of laser rangefinder	$D_{\max} = 20m$
Laser rangefinder scanning range, resolution, and number of rays	$0 - 180\circ, 1\circ, N_o = 181$
Simulated odometer error	$[10\circ/m10cm/m20\circ/360\circ]$
Number of actions	$N_a = 5$
Linear velocity of motion	$\vec{v} = 0.4m/s$
Linear velocity coefficient	$k_v = 1.0$
Angular velocity of action	$\vec{w} = 20\circ/s$
Angular velocity coefficient	$k_w = 1.0$
Action execution time	$\Delta t = 2.0s$
High weight judgment threshold	$w_t^{(k)} = 0.7$

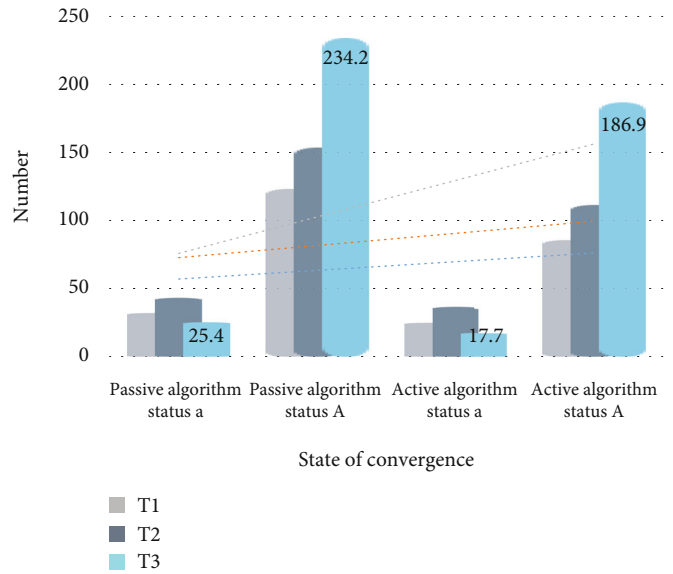

Figure 3: Comparison of average convergence steps between active and passive global positioning algorithms.

article sets the effective sampling time of the simulation to 400 ms in order to reserve the necessary and possible sampling time consumption for future practical applications.

In the simulation, we can know the real pose of the robot, so we can make good use of it when analyzing the simulation results (here the real robot pose is not used in the active global positioning algorithm, but only used for the analysis of the positioning results). Specifically, based on the real robot pose, K-mean algorithm, and Mahalanobis distance (Mahalanobis distance), the convergence state of the particles can be clearly classified. The particle convergence state a indicates that the pre-convergence has been completed, and the particles have been clustered into several more obvious particle piles; the particle convergence state A indicates that most of the particles are clustered into one particle pile, and the estimated robot pose and the real robot position the pose is close; the particle convergence state B indicates the state of convergence failure, that is, although most of the particles are clustered into a particle pile, the robot pose estimated by the particles is the judgment condition of three different convergence states that deviate from the real robot pose as shown in Table 1:

Table 3: Comparison of active and passive global positioning algorithm state B.

Cycle	Passive algorithm status B	Active algorithm status B
T1	2/80	0/80
T2	15/80	6/80
T3	49/80	28/80

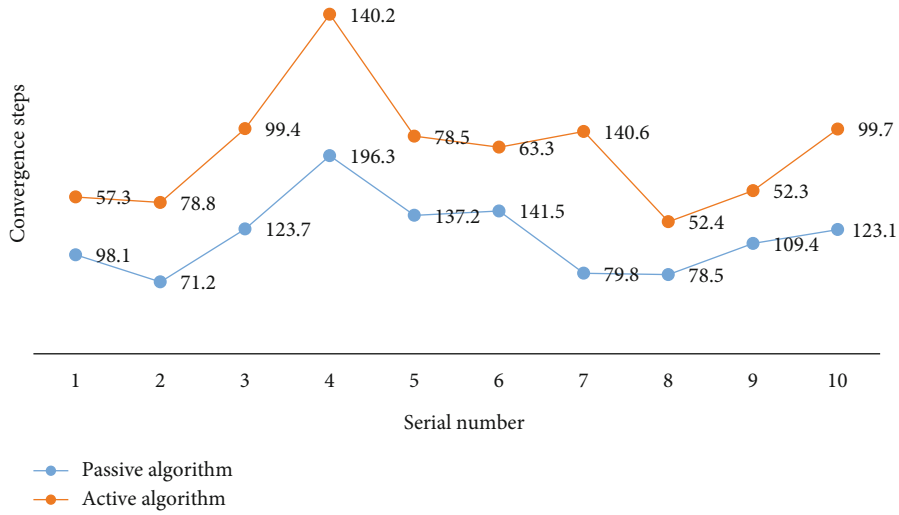

Figure 4: T1 area simulation serial number.

In Table 1, M_p is the Mahalanobis distance between the center point of all convergent clusters and the estimated pose of the robot; M_r is the Mahalanobis distance between the center point of the convergent cluster and the real pose of the robot; one of the grids represents 0.1 m. In addition, the parameters used in the simulation and experiment of the global positioning algorithm (including the required number of particles, etc.) are given below, as shown in Table 2.

4. Big Data-Driven Robot Walking Route and Real-Time Positioning Intelligent Determination of Cloud Computing Experimental Analysis

In the simulation, the algorithm based on the positioning capability proposed in this paper was compared in a wide range of environments and in different scenarios, with all parameters (such as the number of particles, etc.) and the simulation environment of different scenarios. In comparison, the scene has a small number of environmental structures with unclear geometric characteristics and a number of map noises, but looking at the global map, its observation characteristics are relatively clear; the scene is an office, and looking at the global map, its observation characteristics are relatively similar. And there are many environmental structures and map noises with unclear geometric features; scene T3 is a corridor. Although there are not many environmental structures and map noises with unclear geometric features, the observation features are very similar in the global map. The location is very easy to introduce observational ambiguity.

Because the laser rangefinder used in this article does not observe omnidirectionally for different scenarios, 4 sets of simulations are carried out based on four different initial orientations of "UP," "DOWN," "LEFT," and "RIGHT"; contain 20 comparison simulations; one comparison is composed of two simulations based on passive and active global positioning algorithms. These two simulations based on different algorithms are used for comparison, and their initial conditions, such as the initial pose of the real robot and the initial particle distribution., are completely the same; in addition, in order to collect statistical data, the initial conditions of the 20 different comparisons in each group are independent of each other and randomly generated.

According to the defined particle convergence state, during the convergence process, the particle generally converges to the state a first, and secondly, the particle may converge to the state A or B. Of course, during the convergence process, there is also a certain probability that it will not go through the transition state a, but will directly converge to the state A or B. As mentioned above, state A indicates correct convergence, and state B indicates an incorrect convergence result. In the simulation, statistical methods are used to analyze the results. Figure 3 shows the average number of convergence steps in different scenarios.

For state B, the number of convergence failures is recorded and compared, as shown in Table 3.

It can be seen from Figure 3 that no matter in which scenario, the average number of steps the algorithm proposed in this paper converges to states a and A is more efficient than the passive algorithm. Scenario T2, especially T3, brings a lot of ambiguity to the robot observation. For passive algorithms, it is easy to fail to converge in these scenarios. For example, in T3, a total of 80 simulations failed 49 times, and in the application proposed in this article algorithm, the number of failures is reduced to 28. The above results show that the algorithm proposed in this paper effectively accelerates the convergence speed of global positioning due to the influence of known map uncertainty on global positioning and does not specifically extract a clear environment during the application of positioning capabilities to determine robot movements and features to ensure the practical application ability and real-time performance of the algorithm. At the same time, this also shows that the algorithm proposed in this paper has strong robustness for

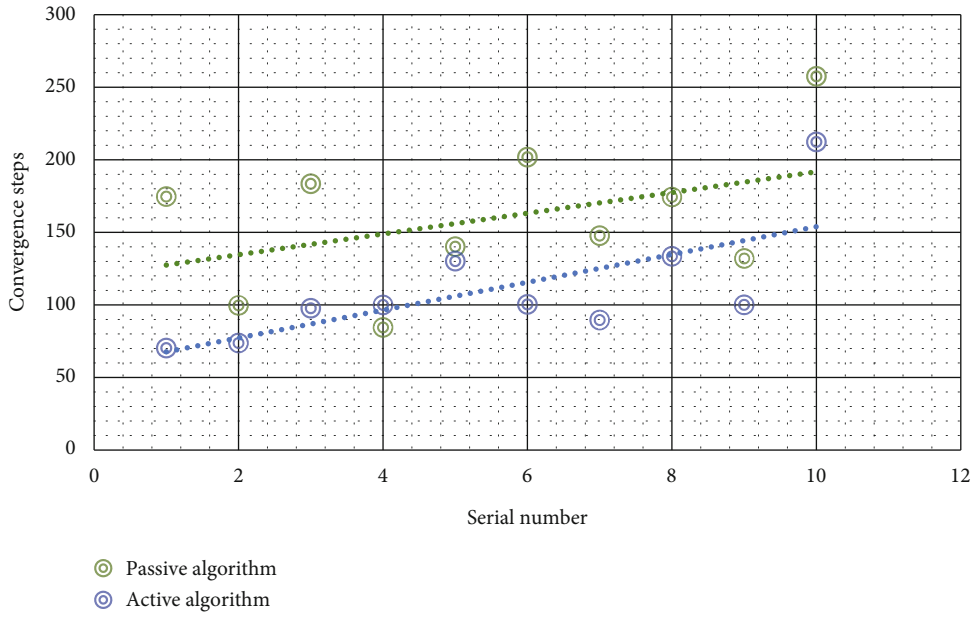

Figure 5: T2 area simulation serial number.

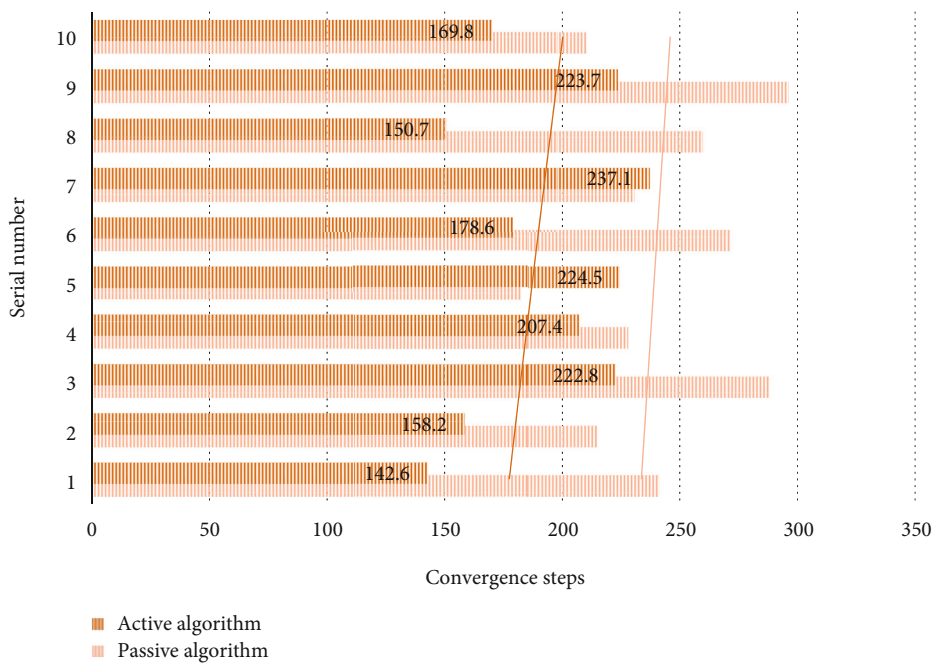

Figure 6: T3 area simulation serial number.

different scenes with fuzzy geometric features and different map noise levels.

The data of each simulation sequence number in scenario T1 is shown in Figure 4:

The data of each simulation sequence number in scenario T2 is shown in Figure 5:

The data of each simulation serial number in scene T3 is shown in Figure 6:

Figures 4–6 compare the number of steps taken by different algorithms to converge to the state through statistical graphs. These data are randomly selected from all the simulations that successfully converged. Figures 4–6 are data in different scenarios. It can be seen that in most cases, the algorithm proposed in this paper converges faster than the passive algorithm. The data clearly shows the advantages that the global positioning algorithm brings to the global positioning algorithm taking into account the uncertainty of the known map (included in the positioning capability estimation): the convergence of the global positioning is accelerated speed and enhances the robustness of the algorithm.

5. Conclusions

The robot itself is a non-linear object with strong coupling and contains many uncertainties. When the final operating robot is in contact with the external environment, the working environment will also significantly affect the performance of the control. In the real-time positioning and walking route of mobile robots, in addition to the measurement errors or performance limitations of its own sensors, the construction noise of known maps, the actual environment lacking clear geometric features, dynamic obstacles, data fusion, and real-time algorithmic factors, both will bring uncertainty to the positioning of mobile robots. This article is to analyze the impact of some or all of the abovementioned uncertain factors on the positioning and walking route of the mobile robot and improve the positioning algorithm. Through simulation and experimental results, it is verified in the actual environment. Algorithm compared with the passive general positioning algorithm, the algorithm in this paper speeds up the convergence of general positioning in the experiment. At the same time, by comparing with the experimental results of the existing active global positioning algorithm, it can be seen that the active global positioning algorithm based on the positioning ability proposed in this paper has a great advantage in computational efficiency; especially for the active global positioning whose core idea is similar to this paper as far as the algorithm is concerned, it can be seen that the improvement effect is more obvious. However, due to the limitations of time and technology, this paper does not conduct a more in-depth discussion of robot positioning, and we will further discuss this in the follow-up.

Data Availability

Data sharing was not applicable to this article as no datasets were generated or analyzed during the current study.

Conflicts of Interest

The authors declare that there is no conflict of interest with any financial organizations regarding the material reported in this manuscript.

References

[1] A. Rezaee, "Determining PID controller coefficients for the moving motor of a welder robot using fuzzy logic," *Automatic Control & Computer ences*, vol. 51, no. 2, pp. 124–132, 2017.

[2] S. J. Gwon, H. T. Kim, and C. W. Ahn, "Designing the moving pattern of cleaning robot based on grammatical evolution with conditional probability table," *KIISE Transactions on Computing Practices*, vol. 22, no. 4, pp. 184–188, 2016.

[3] R. Kawai and T. Arakawa, "Trial development of nursing care robot moving by intuitive hand motion," *International Journal of Innovative Computing Information and Control*, vol. 15, no. 6, pp. 2109–2118, 2019.

[4] X. Li and R. Fung, "Optimal K-unit cycle scheduling of two-cluster tools with residency constraints and general robot moving times," *Journal of Scheduling*, vol. 19, no. 2, pp. 165–176, 2016.

[5] M. Nakajima, K. Tanaka, and F. Matsuno, "Motion control of a snake robot moving between two non-parallel planes," *Advanced Robotics: The International Journal of the Robotics Society of Japan*, vol. 32, no. 10, pp. 559–573, 2018.

[6] J. Kim and J. Chung, "Dynamic analysis of an axially moving robot manipulator supported by bearings," *Journal of Mechanical Science and Technology*, vol. 31, no. 7, pp. 3143–3155, 2017.

[7] T. Yamamoto, M. Konyo, K. Tadakuma, and S. Tadokoro, "A flexible in-pipe robot capable of moving in open spaces via a pneumatic rotary mechanism," *Ifac Papersonline*, vol. 50, no. 1, pp. 1050–1055, 2017.

[8] C. H. Chang, S. C. Wang, and C. C. Wang, "Exploiting moving objects: multi-robot simultaneous localization and tracking," *IEEE transactions on automation science and engineering: a publication of the IEEE Robotics and Automation Society*, vol. 13, no. 2, pp. 810–827, 2016.

[9] J. H. Cho, E. H. Jung, J. Y. Kim, M. H. Park, and Y. T. Kim, "A study on improved navigation algorithm of logistics transportation robot for freight moving on the rack," *Journal of Korean institute of intelligent systems*, vol. 28, no. 5, pp. 436–442, 2018.

[10] C. Liu, "Safe robot navigation among moving and steady obstacles [bookshelf]," *IEEE Control Systems*, vol. 37, no. 1, pp. 123–125, 2017.

[11] K. S. Yoon, M. S. Lee, and Y. W. Sung, "A study on an omnidirectional mobile robot for moving a double-parked car," *Transactions of the Korean Institute of Electrical Engineers*, vol. 67, no. 3, pp. 440–447, 2018.

[12] M. Roozegar and M. J. Mahjoob, "Modelling and control of a non-holonomic pendulum-driven spherical robot moving on an inclined plane: simulation and experimental results," *Iet Control Theory & Applications*, vol. 11, no. 4, pp. 541–549, 2017.

[13] M. Sharifnia and A. Akbarzadeh, "Dynamics and vibration of a 3-PSP parallel robot with flexible moving platform," *Journal of Vibration and Control*, vol. 22, no. 4, pp. 1095–1116, 2016.

[14] Z. L. Ma, P. Q. Zhang, and R. J. Lü, "Mass center adjustment method of quadruped robot moving on slopes," *Beijing Ligong Daxue Xuebao/Transaction of Beijing Institute of Technology*, vol. 38, no. 5, pp. 481–486, 2018.

[15] T. Weingartshofer, M. Schwegel, C. Hartl-Nesic, T. Glück, and A. Kugi, "Collaborative synchronization of a 7-Axis robot," *IFAC-Papers OnLine*, vol. 52, no. 15, pp. 507–512, 2019.

[16] S. Zhao, Z. Zhang, D. Xiao, and K. Xiao, "A turning model of agricultural robot based on acceleration sensor," *IFAC-Papers OnLine*, vol. 49, no. 16, pp. 445–450, 2016.

[17] A. Rutkin, "Robot guard powerless to stop food thieves," *New Scientist*, vol. 231, no. 3090, pp. 24–24, 2016.

[18] E. I. Barakova, P. Bajracharya, M. Willemsen, T. Lourens, and B. Huskens, "Long-term LEGO therapy with humanoid robot for children with ASD," *Expert Systems the Journal of Knowledge Engineering*, vol. 32, no. 6, pp. 698–709, 2015.

[19] B. Gao, Z. Zhu, J. Zhao, and L. Jiang, "Inverse kinematics and workspace analysis of a 3 DOF flexible parallel humanoid neck robot," *Journal of Intelligent & Robotic Systems*, vol. 87, no. 2, pp. 211–229, 2017.

[20] J. Kim, "Path plan strategy of an underwater robot to approach a moving emitter while maximising sound intensity measurements," *IET Radar Sonar & Navigation*, vol. 13, no. 5, pp. 795–801, 2019.

[21] J. M. Kim, J. K. Son, and S. J. Wan, "Development of robot's vision control scheme using the data moving method for the tracking of moving target," *Journal of the Korean Society for Precision Engineering*, vol. 35, no. 7, pp. 669–679, 2018.

[22] S. K. Han, S. Y. Chung, and M. J. Hwang, "A study on motion acceleration-deceleration time to suppress residual vibration of robot," *The Journal of Korea Robotics Society*, vol. 12, no. 3, pp. 279–286, 2017.

[23] S. Saeedi, M. Trentini, M. Seto, and H. Li, "Multiple-robot simultaneous localization and mapping: a review," *Journal of Field Robotics*, vol. 33, no. 1, pp. 3–46, 2016.

[24] S. Kazemi and H. Kharrati, "Visual processing and classification of items on moving conveyor with pick and place robot using PLC," *Intelligent Industrial Systems*, vol. 3, no. 1, pp. 15–21, 2017.

[25] A. A. Mohammed, I. Aris, M. K. Hassan, and N. A. Kamsani, "New algorithm for autonomous dynamic path planning in real-time intelligent robot car," *Journal of Computational and Theoretical Nanoscience*, vol. 14, no. 11, pp. 5499–5507, 2017.

[26] M. Stommel and W. Xu, "Learnability of the moving surface profiles of a soft robotic sorting table," *IEEE Transactions on Automation Science & Engineering*, vol. 13, no. 4, pp. 1581–1587, 2016.

[27] B. Shin, Y. Kim, J. Paik, and K. M. Lee, "Miniaturized twin-legged robot with an electromagnetic oscillatory actuator," *Journal of Bionic Engineering*, vol. 15, no. 1, pp. 106–113, 2018.

[28] X. Wang, "Design and kinematics analysis of transformable wheel-legged robot," *Journal of Computational and Theoretical Nanoscience*, vol. 13, no. 11, pp. 8158–8164, 2016.

[29] R. E. Sánchez-Alonso, J. J. González-Barbosa, E. Castillo-Castañeda, and M. A. García-Murillo, "Análisis Cinemático de un Novedoso Robot Paralelo Reconfigurable," *Revista Iberoamericana de Automática e Informática Industrial RIAI*, vol. 13, no. 2, pp. 247–257, 2016.

[30] X. Dai, L. Jiang, and Z. Yan, "Cooperative exploration based on supervisory control of multi-robot systems," *Applied Intelligence*, vol. 45, no. 1, pp. 18–29, 2016.

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Research Article

Big Data Mining and Analysis of Agricultural Products Based on e-Commerce Platform

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Solve the problem of agricultural product big data mining based on e-commerce platform, meet the needs of e-commerce development to agricultural products, meet the diversified needs of e-commerce platforms, and improve people's living standards and convenience. According to 1000 online questionnaires, 866 people believe that e-commerce can bring them convenience, and 134 people believe that the convenience is insufficient. Even agricultural products, as a traditional primary industry, have begun to be "involved" in the sales mode of e-commerce platforms. In the face of the increasingly huge online consumer demand market, the agricultural product economy has redisplayed a strong market vitality. Of course, the huge market base also makes the e-commerce model of agricultural products pay attention to big data mining and analysis. This paper focuses on how to carry out big data mining and analysis of agricultural products more efficiently from the technical level. Therefore, the agricultural product user data mining technology of e-commerce platform based on Hadoop is proposed. Through the intervention of association rule analysis and algorithm, the improvement of relevant algorithms and agricultural products user behavior analysis system under e-commerce platform based on Hadoop is proposed. The results show that the system can realize the analysis of commodity association degree under various agricultural products user behavior modes and can better help the e-commerce platform of agricultural products realize precision marketing.

1. Introduction

In recent years, with the development of urban and agricultural policies in our country, the entire agricultural sector in our country has developed rapidly. According to data from iiMedia research as of the end of October 2021, China's total agricultural output value has grown for the tenth consecutive year since 2010. By the end of 2020, China's total manufacturing output value will reach 10.7 trillion yuan. At the same time, with the deepening of the Internet, the Internet has had a great impact on all walks of life, network marketing plays a very powerful role, bringing great business opportunities for many enterprises, the Internet enables enterprise managers to realize the cross-regional input of management information, and realize the global management, and agricultural products have been pushed into the development channel of online shopping [1]. Major e-commerce platforms have launched a series of agricultural products. At the same time, in-depth research in the field of e-commerce, the integration of e-commerce organizations in various fields of agricultural products, even if entrepreneurs see the future development direction, even if they have good strategic ideas, they may eventually achieve their strategic goals due to the organizational inertia, and because the organizational ability cannot keep up and become an important participant in the development of e-commerce. Of course, the process of agricultural product e-commerce is similar to the operation of other products. It needs to subdivide the customer group and mine the user information of agricultural products e-commerce platform with the help of big data analysis. Therefore, how to correctly use big data technology and deepen the extraction, analysis, and

utilization of big data in agricultural information is an important link in the development of agricultural e-commerce. Therefore, this paper takes the agricultural product e-commerce platform as an example and proposes the user data mining of the e-commerce platform based on Hadoop, hoping to develop more research and benefits for agricultural e-commerce data mining and provide more technical support and benefits for the development of agricultural e-commerce data mining. Products in this field [2] in the Hadoop ecosystem are shown in Figure 1.

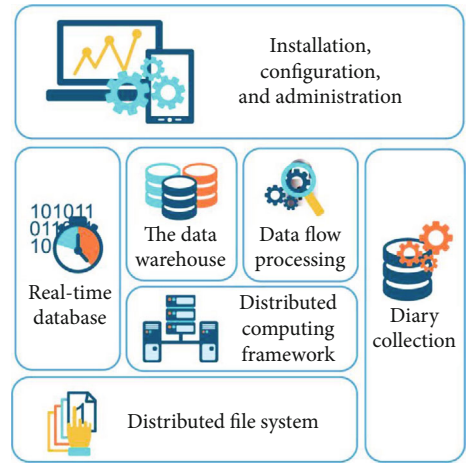

Figure 1: Hadoop ecosystem components.

2. Literature Review

Izzati and others said that at present, in the field of e-commerce, data generated by users in the shopping process can be used as a tool for data analysis, and the association rule algorithm in data mining technology is often used [3]. Li and Huang pointed out that the commodities that meet the association rules can be analyzed through the association rule algorithm, and on this basis, the relevant commodity information that users may be interested in can be pushed uniformly on the e-commerce platform. It is analyzed from two aspects: users and e-commerce platform [4]. Zuo believes that the wide application of data mining algorithms maximizes the benefits of both [5]. Lv and Li also proposed a new way for users to push related advertisements when browsing goods on e-commerce platforms [6]. Janiijevi et al. proposed in the work of text data mining that first collect the scattered or fragmented data generated by users and convert it into structured data and then analyze it in combination with users' behavior, so as to realize the functions of finding common friends and launching related advertisements [7]. In finance and trade-related fields, data mining algorithms gradually play an important role. Chen believes that experts in the financial field can analyze customers' capital status and consumption ability by analyzing customers' deposits, loans, and daily consumption bills, so that they can recommend corresponding financial products for customers [8].

Zhao's research on big data mining, its mining technology, and methods is mostly reflected in the research on clustering methods, feature selection methods, and granular computing, such as using text semantic processing, clustering, and other mining methods and technologies to process social network big data [9]. Zhou et al. verify the effectiveness of the proposed method through specific cases. For high-dimensional data mining, a new feature selection method is proposed [10]. At the same time, existing processes and procedures are compared and evaluated to further determine the performance of the given framework.

In China, some researchers believe that data mining is the process of finding useful information from various incomplete data using different techniques such as archives and professional knowledge. Based on the challenges faced by big data mining, granular computing is regarded as a kind of the new big data mining method clearly explained some existing problems; based on K-means and FP, the Spark platform was developed as a method to extract large amounts of thermal energy data for parallel computing. Once analyzed, this method can improve the efficiency of large-scale thermal energy data mining; use the Canopy algorithm to improve K-shell, and develop new algorithms in parallel on the Hadoop platform; apply for a case of traffic data collection equipment based on big data mining technology, and define the scheme through the case. A computational model based on the output of big data mining technology is developed to analyze various time series and data analysis methods of big data. Predictive models are based on big data environments and can effectively make accurate predictions.

3. Method

3.1. Hadoop Cluster and Related Technologies

3.1.1. Hadoop Platform. When using Hadoop cluster for development, users can conduct independent research and development on the completed underlying platform without in-depth research and analysis of the underlying architecture. At the same time, users can perform the task of data analysis by changing the corresponding parameters in Hadoop cluster. All these provide convenience for R&D work and save a lot of time [11]. When configuring files, several copies of data backups are usually kept, which effectively prevents data loss. Please note that the command you typed is what you want before executing the backup command. Performing a backup command may take quite a very short period of time. In the process of data processing and analysis, if the data block fails and cannot continue, the work of the corresponding data block is transferred to other nodes, which will not directly lead to data loss or job failure. Although the Hadoop platform is widely used and has many of the above advantages, Hadoop itself cannot directly perform computing processing, and it needs the help of other components in its ecosystem [12].

3.1.2. Distributed File System HDFS. The architecture of HDFS consists of the master node namenode and several

Datanode nodes. The work of the master node includes monitoring the metadata in the HDFS directory and the status of the Datanode to see if there will be problems.

3.1.3. Distributed Database HBase. HBase is a distributed storage system based on HDFS. HBase is different from MySQL, which is a common database. MySQL often makes relevant queries through index. HBase can complete millisecond fast query through line key or realize multidimensional query by combining line key with cell value. Therefore, the design of row keys in HBase Table is particularly important. Reasonable row keys cannot only improve the query speed of HBase but also ensure the query efficiency when the rows and columns of HBase Table change [13]. The architecture is shown in Figure 2.

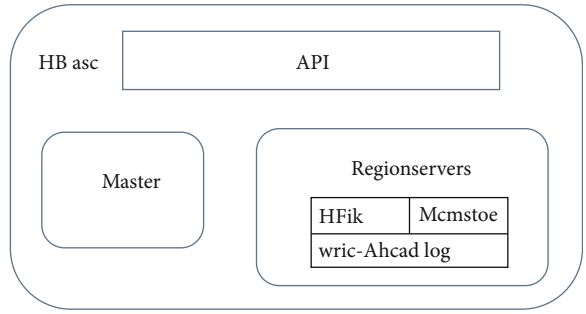

Figure 2: Architecture of HBase.

3.2. Association Rule Analysis Method. The association strategy algorithm usually needs to be analyzed in combination with the scene in the process of data analysis and is driven by data. As we all know, events are created by users, and at the same time, events generate a lot of information. Therefore, there is a relationship between the above three, as shown in Figure 3.

The main idea of the ensemble rule algorithm is to find the true relationship between products through seemingly unrelated purchases. For set L, it is a collection of multiple transaction items. That is $\{L1, L2, L3, \cdots, Ln\}$. For sets X and Y composed of multiple transaction items in set L, they must belong to a subset of set L. The degree of correlation between X and Y is determined by the relationship between X and y. When it comes to the association rule algorithm, we must mention two professional terms, namely, support and confidence. In the above set X, the number of times an item is called the number of supports for those items. The formula is shown in

$$\text{Support\_Count}(X). \tag{1}$$

Suppose T is used to represent the total number of occurrences of all kinds. At this time, the support of item set X is shown in

$$S(X) = \frac{\text{Support\_Count}(X)}{|T|}. \tag{2}$$

If two or more transactions occur at the same time, for example, the number of times X and Y occur at the same time is called the absolute support of $X \Rightarrow Y$. The method of calculating the absolute support is shown in

$$S(X \Rightarrow Y) = \frac{\text{Support\_Count}(X \Rightarrow Y)}{|T|}. \tag{3}$$

The rule of confidence is to calculate the probability of $X \Rightarrow Y$ support number on the premise that X exists, as shown in

$$\text{Con}(X \Rightarrow Y) = \frac{\text{Support\_Count}(X \Rightarrow Y)}{\text{Support\_Count}(X)}. \tag{4}$$

3.3. Big Data Processing and Mining

3.3.1. Big Data Processing. Big data has rich resource types and various application processing methods, but the basic process of information processing is roughly similar, including four stages: data collection, processing and integration, analysis, and data interpretation. The functions are as follows: obtain the required data from the data source, process the data of different models in a unique way, assemble the models into different files, and then process and analyze the data from the necessary analysis processes and tools. Finally, use visual aids to get user recognition results [14].

3.3.2. Big Data Mining. Data mining methods are generally used to describe the characteristics of the target data set, or summarize and summarize the current information to further predict the future situation. According to the different functions, they are divided into descriptive and predictive types, as shown in Figure 4.

3.3.3. Cluster Analysis. Population analysis is an unsupervised study and an important activity of data analysis. Its idea is to aggregate the features of unlabeled samples by similarity. Cluster analysis is a kind of unsupervised learning, which only requires data without marking the results. It can make a large number of observations into several classes according to a certain rule. The observation values within each class are similar, and the difference between each class is large. In order to achieve the automatic division of sample categories, that is, the process of dividing data objects into subsets through static classification method. The data with similar properties are divided into a subset, so that each subset is a cluster, and the data in the cluster has some similar attributes, and the data attributes between clusters have great feature differences [15]. Cluster analysis methods rely only on the distance of the data. The application of clustering analysis in the field of e-commerce is mainly the clustering of users. From the research of this paper, it is the clustering of agricultural products users on the e-commerce platform,

Figure 3: Relationship diagram of users, events, and data.

finding out users with common characteristics, and then adopting targeted marketing strategies.

3.3.4. Data Feature Analysis. Take the agricultural apple as an example. The apple sales stores on the e-commerce platform usually sell 5 kg apples as a piece, so the apple sales price data obtained is the total price of 5 kg apples. When drawing the frequency histogram, the total price data of 5 kg is used. Draw statistical histogram in order to more intuitively describe the data characteristics and distribution form, so as to find the function curve in line with the data change. Because the apple price data is positive, combined with the distribution form of the drawn histogram, it is obvious that it does not conform to the normal distribution, but through the corresponding data transformation, it is found that the logarithm of its random variable conforms to the normal distribution [16], as shown in Figure 5.

In lognormal distribution, let X be a continuous random variable with a positive value, as shown in

$$\ln X \sim N\left(\mu, \sigma^2\right). \tag{5}$$

Then, the probability density of X is shown in

$$f(x, \mu, \sigma) = \begin{cases} \dfrac{1}{\sqrt{2\prod}\sigma x} \exp\left[-\dfrac{1}{2\sigma^2}(\ln x - \mu)^2\right], & x > 0, \\ 0, & x \le 0. \end{cases} \tag{6}$$

Then, it is said that the random variable x obeys the lognormal distribution and is recorded as $\ln X \sim N(\mu, \sigma^2)$.

Let x obey lognormal distribution, and its density function is shown in

$$p(x) = \frac{1}{\sigma x\sqrt{2\prod}} e^{(\ln x - \mu)^2/2\sigma^2}. \tag{7}$$

The mathematical expectation and variance are shown in

$$E(X) = e^{\left(\mu+\sigma^2\right)/2}, \tag{8}$$

$$D(X) = \left(e^{\sigma^2} - 1\right)e^{2\mu+\sigma^2}. \tag{9}$$

In formula (9), the abscissa represents the apple sales price, the ordinate represents the probability density, and the red curve represents the lognormal distribution curve of price fitting. It can be seen from the formula that the lognormal distribution can approximately describe the distribution and trend characteristics of the data. Through further calculation, the parameter values of the fitted distribution curve are obtained: the value of log likelihood function is -4163.35, the mean value is 53.9495, and the variance is 1082.58 [17].

The graphic analysis of apple sales cannot only more intuitively see the changes of apple sales but also provide data analysis basis for the realization of mining task. Data analysis, as an important basis and means for finding problems, adjusting strategies and optimizing directions in the current enterprise operation, has gradually been paid attention to in various industry departments. Assignment is always more important than classification, and classification has positive effects in many fields. An environmental distribution is defined as follows: if the difference in difference x follows a probability, its potential density is given by

$$f(x) = \frac{1}{\sqrt{2\prod}\sigma} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right). \tag{10}$$

Then, x is called a canonical random deviation, and the division obeyed by a canonical random variable is called a canonical distribution.

3.4. Apriori Algorithm. The strategy algorithm of the institute includes a variety of algorithms, such as Apriori algorithm and FP growth algorithm. Association rules are a big data mining task, initially motivated by the shopping basket analysis (Market Basket Analysis) problem. With the advent of the prior algorithm, the algorithm has been widely used in the data mining industry due to its high efficiency in corporate policy analysis [18].

Table 1 shows the purchase records of agricultural product users in the e-commerce platform database. Here, we specify that nonempty itemsets with a support number of no less than 2 are frequent itemsets. The minimum support number is not fixed. For practical problems, the minimum support number can be changed flexibly. Start with choosing a minimum right edge; after each step, always choose the least right edge of the unselected edge, and make it to not form a circle with the selected edge. Let the four records in Table 1 be all the records of the database, and it is easy to find that transactions T1-T4 are $\{A, B, C\}$, $\{A, D, E\}$, $\{A, E\}$, and $\{A, B, D, E\}$. Then, the number and size of the database are 4, and the number of transactions is 4.

(1) Scan the transaction data of the e-commerce platform, and count the support of each product in all the data, including the number of products purchased, product price, and product type. If you buy a lot of things, there are a greater number of supports of the commodity in the process of calculating the number of supports

Calculate the transaction candidate set through step (1) to obtain the support number of each item set [19]. The number of supported sets is shown in Table 2.

(2) After completing the above steps, according to the minimum support 2, the collection components that do not meet the conditions are eliminated, and only the specified items are enabled. As an initial hold

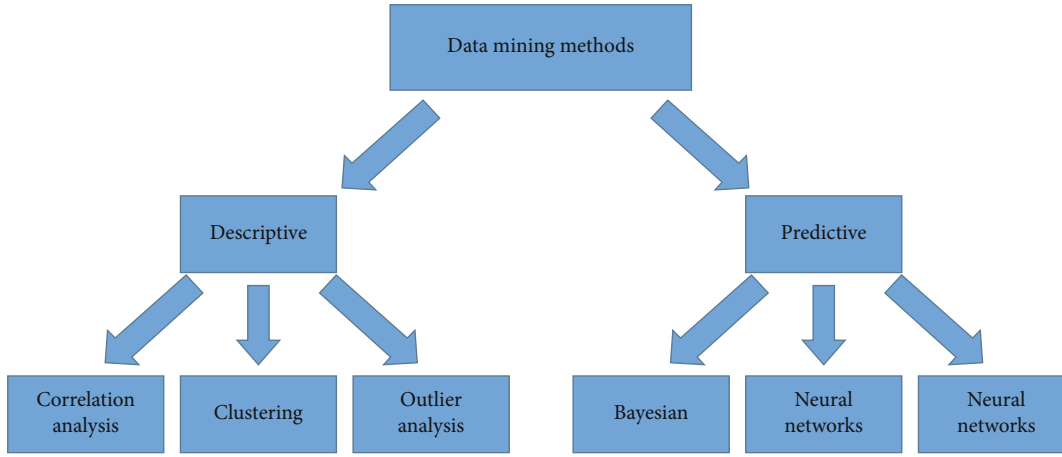

Figure 4: Data mining method.

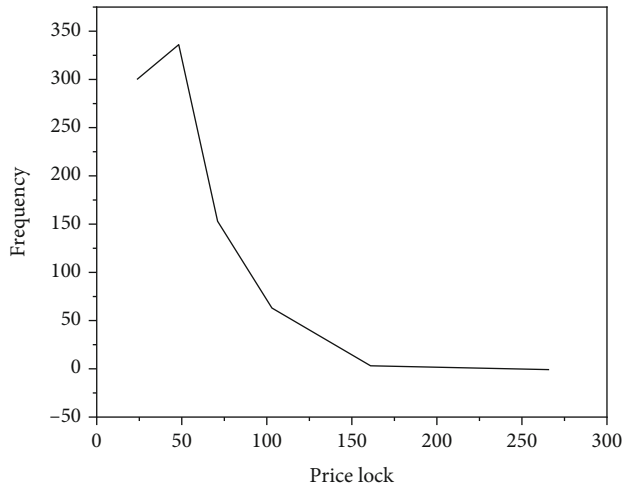

Figure 5: Apple sales price chart (broken line).

Table 1: User purchase record.

Affair	Project
T1	A, B, C
T2	A, D, E
T3	A, E
T4	A, B, D, E

Table 2: Number of items supported by each itemset.

Itemset	Support number
$\{A\}$	4
$\{B\}$	2
$\{C\}$	1
$\{D\}$	2
$\{E\}$	3

minimum support, normally 1 item, set ok, as shown in Table 3

(3) According to the result obtained in step (2), connect the above five itemsets in pairs, and calculate the support number of the itemset formed by the combination of the two after the connection, as shown in Table 4

(4) The connected 2-itemsets are obtained from the above steps, and the qualified itemsets are retained according to the minimum threshold, as shown in Table 5

(5) Connect according to the frequent 2-itemsets obtained in step (4). According to the characteristics of frequent 2-itemsets, its nonempty subsets must also be frequent. Therefore, after connecting the frequent 2-itemsets, you can judge whether they are frequent itemsets according to the first two items. If the conditions of frequent itemsets are not met, prune them. It is not difficult to find the candidate 3-itemset, as shown in Table 6

(6) The candidate 3-itemsets are obtained from the above steps, and the qualified itemsets are retained according to the minimum threshold, as shown in Table 7

After multiple scanning and discrimination, when the two itemsets are related, the Apriori algorithm calculates that $\{AB\}$, $\{AD\}$, $\{AE\}$, and $\{DE\}$ have a high degree of correlation. Finally, when the three itemsets are related, it can be seen that the itemsets $\{A, D, E\}$ are highly related.

Table 3: Frequent 1-itemsets.

Itemset	Support number
$\{A\}$	4
$\{B\}$	2
$\{D\}$	2
$\{E\}$	3

Table 4: Connected 2-itemsets.

Itemset	Support number
$\{A, B\}$	2
$\{A, C\}$	1
$\{A, D\}$	2
$\{A, E\}$	2
$\{B, C\}$	1
$\{B, D\}$	1
$\{B, E\}$	1
$\{C, D\}$	0
$\{C, E\}$	0
$\{D, E\}$	2

Table 5: Frequent 2-itemsets.

Itemset	Support number
$\{A, B\}$	2
$\{A, D\}$	2
$\{A, E\}$	2
$\{D, E\}$	2

Table 6: Candidate 3-itemset.

Itemset	Support number
$\{A, B, D\}$	1
$\{A, B, E\}$	1
$\{A, D, E\}$	2

Table 7: Frequent 3-itemsets.

Itemset	Support number
$\{A, D, E\}$	2

The purpose of association analysis is to find interesting associations or interrelationships between the sets of items from a large number of data, and the most classical Apriori algorithm has a great influence in the field of association rule analysis. Through the support number, we can determine whether there is an association relationship between itemsets; that is, for the purchase data of all users, how many goods they buy have an association relationship [20]. However, if we want to determine the strength of the correlation degree, we need to calculate it in combination with the confidence degree, as shown in

$$\text{Confidence}(X \Rightarrow Y) = P\left(\frac{X}{Y}\right) = \frac{\text{Support\_Count}(Y \Rightarrow X)}{\text{Support\_Count}(X)}. \tag{11}$$

The degree of association is judged by setting the value of confidence. For example, if the confidence is 50%, then less than 50% is a weak correlation; otherwise, greater than or equal to 50% is a strong correlation. In this way, we can get the itemset with high degree of correlation that meets the conditions [21]. Although the Apriori algorithm can accurately find the itemsets with strong correlation, the Apriori algorithm also has some disadvantages that cannot be ignored: in the process of Apriori algorithm mining, it is necessary to scan all the contents of the database for several times. Every time a frequent itemset is found, the database needs to be completely scanned. Moreover, the candidate item set generated in this way is also very large. When the database structure is relatively simple, the Apriori algorithm can work better, but when the database is relatively large, the I/O times of Apriori algorithm will be very high. Therefore, the Apriori algorithm needs to be improved [22].

4. Results and Analysis

Combining the MapReduce framework in Hadoop ecology with the improved Apriori algorithm, the traditional single computer operation mode is transformed into parallel operation and then processed [23]. The improved algorithm is divided into two stages.

In the first stage of the algorithm, the specific process is as follows:

(1) Input transaction database s, divide the data set in database s into N data blocks, and allocate these n data blocks to each computer node

(2) Convert each data block node into a data structure $< T, k >$ key value pair that meets the requirements of MapReduce, where T is the transaction name in the dataset and k is the transaction item corresponding to each transaction

(3) Mapper function will be executed to scan the data blocks in each computer node according to the corresponding key value and output the key value pairs of $<k, v>$, where k is the transaction item corresponding to each transaction and v is the number of transaction items supported)

(4) Integrate the key value pairs generated in step (3) through the combine function, and take the integrated key value pairs as the input of the reducer

Table 8: Running time of improved Apriori algorithm under two operating environments (*s*).

Minimum support	Improved Apriori algorithm for stand-alone version	Hadoop cluster improved Apriori algorithm
0.2	76	41
0.4	55	33
0.6	38	26
0.8	29	22

Table 9: Running time of improved Apriori algorithm under two operating environments (*s*).

Dataset size	Improved Apriori algorithm for stand-alone version	Hadoop cluster improved Apriori algorithm
67544	22	24
88424	36	26
102256	48	29

function. Then merge the local candidate 1-itemset, that is, add the key value pairs with the same K in the key value pair set to obtain the global candidate 1-itemset. Then, a two-dimensional array is constructed with row values as transaction sets and columns as transaction item sets, and the column values that do not meet the minimum support number are deleted. Reduce the size of the two-dimensional array and the number of transaction items in the transaction database s, so as to reduce the I/O times when scanning the database during iteration, so as to save time [24].

(5) Step (4) is completed. The nonempty transaction itemset Q1 that meets the conditions is the frequent 1-itemset

In the second stage of the algorithm, the implementation steps are as follows:

(1) Max_l and Min_l are determined from the frequent 1-itemset Q1 obtained by the optimization in the first stage, in which the maximum value of the length of the highest frequent set is Max_l = N and the minimum value is Min_l = 1

(2) Based on the idea of halving, the length L of the frequent itemset set to be iterated in the next MapReduce stage is obtained according to

$$L = \frac{\text{Min\_l} + \text{Max\_l}}{2} \tag{12}$$

(3) After iterating the set length L in the next stage obtained in (2), take out the combination of frequent itemsets with length L in the frequent 1-itemset with set length N. The number of "connected" sets obtained in this way is C_N^L

(4) The process of the mapper and reducer in the second stage is the same as that in the first stage, except that the value of K in the key value pair $<k, v>$ is changed from 1 to L; that is, the process of Mapper and Reducer for one transaction item is changed to l transaction items. After scanning transaction database S, frequent L-itemsets are obtained

Aiming at the problems of repeated scanning and large I/O overhead in the iterative operation of traditional Apriori algorithm, a feasible improvement strategy is proposed. Firstly, by constructing a two-dimensional transaction array, the initial input data set is simplified, and the items that are certainly not frequent item sets are removed to reduce the time of scanning the transaction database; then, the strategy of half thought is used to solve the leapfrog frequent itemset, which no longer uses the traditional step-by-step iterative solution, and reduces the number of iterations; Finally, the two improved methods are combined and deployed on Hadoop platform. Using MapReduce framework on Hadoop platform can greatly improve the processing efficiency. Resource Manager is a global resource manager with two components: scheduler (Scheduler)+Application Manager (Application Manager). Then, the specific implementation process and some pseudocodes of the algorithm are described. Through the analysis of the algorithm, the results obtained are consistent with those obtained by the traditional Apriori algorithm, which can prove the correctness of the algorithm [25].

(1) Experiment 1: first, 98566 data are selected in the agricultural product data behavior of the e-commerce platform and set 4 groups of minimum support degrees, which are 0.2, 0.4, 0.6, and 0.8, respectively. The Apriori algorithm is improved on the stand-alone version, and the Apriori algorithm is improved on the Hadoop cluster version for collaborative purposes. In the case of unified data processing, the running time of the improved Apriori algorithm in the two processes is compared [26]. The unit is seconds, and the result is a number. The experimental results are shown in Table 8

According to the data of the experimental results obtained in Table 8, the running time of the improved Apriori algorithm of the stand-alone version and the improved Apriori algorithm of the Hadoop cluster version.

In (1), the performance of the two algorithms in different operating environments is compared by setting different

minimum support degrees. Now, the minimum support is set to 0.5. Just change the file size, and use the default behavior set to select 67544, 88424, and 102256 files in the file. Compare the running time of the improved stand-alone version of Apriori algorithm and the improved Hadoop cluster version of Apriori algorithm in different files [27]. The experimental results are shown in Table 9.

The experimental data obtained from Table 9 shows that the runtime is used to improve the standalone version of the Apriori algorithm and the improved Hadoop cluster version of the Apriori algorithm. As the first set of experimental results of Operation 1, the upgrade completion of the Apriori algorithm of the Hadoop cluster version is greater than that of the stand-alone version of the Apriori algorithm, and the time required for parallelization may be negligible. Combined with the results of the above two experiments, it has been proved that the algorithm improvement effect in the Hadoop cluster is better, and the performance of the algorithm will be better when the amount of data collection is also large.

(2) Experiment 2: when the file size is fixed, the file selection size is 102256, and the minimum support is 0.2-0.8. Experimental comparisons were made by continuously changing the size of the minimum support. The purpose is to identify whether there is an improvement in the performance of the improved Apriori algorithm in a Hadoop cluster

The results of Study 2 show that with the minimum support, the number of iterations of the product solution is gradually reduced, and the performance of the two algorithms is almost the same, but the execution time is the same as that of Apriori. Algorithms are improved, even worse than the improved Apriori algorithm based on compressed matrices. These test teams showed that the improved Apriori algorithm performed better, its application to the big data analysis of agricultural products on the e-commerce platform will be more efficient, and the results will be more accurate.

5. Conclusion

The experiment shows that the agricultural product data mining technology based on Hadoop e-commerce platform is feasible, which can solve the problem of big data mining of agricultural products, meet the needs of e-commerce, and solve the drawbacks of e-commerce at the same time. Agricultural products have improved people's lives and the convenience of shopping. In today's era of big data, the cost of big data starts in the terabyte. Users find products they like or are interested in on a multitude of e-commerce platforms, like looking for a needle in a haystack. These processes will also cost users a lot of time and energy; at the same time, for Internet e-commerce platforms such as Taobao and JD, if the platform cannot correctly identify user data, it will have a negative impact on the fierce competition of e-commerce, resulting in unsuccessful e-commerce business. Therefore, how to accurately and timely identify the user behavior of e-commerce platform is a research hotspot. For the agricultural products of the e-commerce platform, the main function of the data is to store the internal information such as the sales volume, price, and opening time of the products for sale through the e-commerce platform, through data analysis, agricultural product recommendation, agricultural product inventory site optimization, price analysis, etc. Finally, push value analysis to e-commerce business management to provide intelligent support services for e-commerce enterprises to achieve profitability, quality management, and business success.

Based on e-commerce platform, Hadoop-based data mining technologies are identified, including interfaces such as Hadoop cluster, HDFS data system, MapReduce, and HBase. It also discusses the process of identifying organizations and the processes involved in data mining, usually including the Apriori algorithm and FP to develop algorithms.

The Apriori algorithm always suffers from low performance when dealing with big data, and the improvement strategy has prepared for its benefits. First, the product setting consists of a two-dimensional array, and the rows of the two-dimensional array that do not meet the minimum support are removed to make the product more efficient. Then, using the concept of halving to create live objects, the number of iterations in the work process can be reduced to reduce the running time of the algorithm; finally, two optimization strategies are integrated on the Hadoop platform. Example procedures used for the development of the programs and algorithms are described in detail. The improvement of Apriori algorithm based on Hadoop platform is determined by experiments, and the time spent by the improved algorithm is compared by managing different models. In the experiment, the user behavior data provided by Alibaba Cloud was selected, and the Hadoop platform was designed and tested. Firstly, the improvement of the single-machine version of Apriori algorithm and the algorithm improvement of Hadoop cluster version are compared and analyzed through experiments. Then, the development of the existing Apriori algorithm, the integration of the integration-based Apriori algorithm, and the compression matrix-based Apriori algorithm is carried out on the Hadoop platform. a comparative analysis; finally, a separate collaborative development algorithm is separated, and an experimental comparative analysis of collaborative improvements such as product improvement ideas, iterative improvement ideas, and optimization strategies is carried out. The test results show that the algorithm has a shorter lifespan and a more obvious algorithm improvement; a large number of agricultural products data mining that can be applied to the e-commerce platform can improve the sales volume of agricultural products on the e-commerce platform and the operating environment of the e-commerce platform of agricultural products.

Data Availability

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

Conflicts of Interest

The author declares no conflicts of interest.

Acknowledgments

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References

[1] N. Wardhani, W. Izaak, and M. Yohanes, "Analysis of ocr's factor and sales promotion on e-commerce," *Journal of Economics Business and Government Challenges*, vol. 3, no. 2, pp. 127–132, 2021.

[2] N. Maslak, L. Zhang, and X. Lu, "Analysis of agricultural trade in China based on the theory of factor endowment," *Agricultural and Resource Economics*, vol. 6, no. 1, pp. 50–61, 2020.

[3] R. R. Izzati, N. S. Muntiah, and N. Hidayah, "An analysis of factor that influence the interests in behaviors of using accounting information systems based on e-commerce," *Jurnal AKSI (Akuntansi dan Sistem Informasi)*, vol. 5, no. 1, pp. 1–5, 2020.

[4] X. Li and D. Huang, "Research on value integration mode of agricultural e-commerce industry chain based on internet of things and blockchain technology," *Wireless Communications and Mobile Computing*, vol. 2020, Article ID 8889148, 11 pages, 2020.

[5] J. Zuo, "Analysis of e-commerce characteristics based on edge algorithm and cox model," *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 6628068, 13 pages, 2021.

[6] X. Lv and M. Li, "Application and research of the intelligent management system based on internet of things technology in the era of big data," *Mobile Information Systems*, vol. 2021, Article ID 6515792, 6 pages, 2021.

[7] S. Janiijevi, O. Petrovi, and M. Stefanovi, "Sales prediction on e-commerce platform, by using data mining model," *Serbian Journal of Engineering Management*, vol. 5, no. 2, pp. 60–76, 2020.

[8] S. Chen, "Analysis of customization strategy for e-commerce operation based on big data," *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 6626480, 11 pages, 2021.

[9] Z. Zhao and H. Wang, "The analysis of internet commercial judicial based on big data alliance and mining service process model," *Complexity*, vol. 2021, Article ID 2897823, 17 pages, 2021.

[10] N. Zhou, Z. Zhang, and J. Li, "Analysis on course scores of learners of online teaching platforms based on data mining," *Ingénierie des Systèmes D Information*, vol. 25, no. 5, pp. 609–617, 2020.

[11] Y. J. Wan and Z. C. Yu, "Exploring the development of e-commerce for fresh agricultural products under the background of e-commerce law," *The Journal of Internet Electronic Commerce Resarch*, vol. 20, no. 6, pp. 135–163, 2020.

[12] S. Liu and W. Zhang, "Application of the fuzzy neural network algorithm in the exploration of the agricultural products e-commerce path," *Intelligent Automation and Soft Computing*, vol. 26, no. 3, pp. 569–575, 2020.

[13] R. R. Ramírez, A. Chamorro, and L. Moreno, "Organic and online attributes for buying and selling agricultural products in the e-marketplace in Spain," *Electronic Commerce Research and Applications*, vol. 42, no. 1, article 100992, 2020.

[14] S. Teng, "Route planning method for cross-border e-commerce logistics of agricultural products based on recurrent neural network," *Soft Computing*, vol. 25, no. 18, pp. 12107–12116, 2021.

[15] C. Y. Lin, "An empirical study on decision factors affecting fresh e-commerce purchasing geographical indications agricultural products," *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*, vol. 71, pp. 541–551, 2020.

[16] Y. Huo, "Agricultural product E-commerce recommendation system based on neural factorization machine in smart cities," *Internet Technology Letters*, vol. 4, no. 1, 2021.

[17] J. Wang and Y. Tao, "Reverse integration and optimisation of agricultural products e-commerce omnichannel supply chain under internet technology," *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*, vol. 71, pp. 604–612, 2021.

[18] X. Liu, "Empirical study on b2c e-commerce logistics network optimisation of agricultural products," *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*, vol. 71, no. 5, pp. 346–362, 2021.

[19] D. Lyu, L. Zhou, and X. Ma, "Income-increasing effect of e-commerce of agricultural products based on IT absorptive theory," *Wireless Networks*, vol. 28, no. 5, pp. 2337–2344, 2022.

[20] F. Zhang and Y. Zhang, "A big data mining and blockchain-enabled security approach for agricultural based on internet of things," *Wireless Communications and Mobile Computing*, vol. 2020, Article ID 6612972, 8 pages, 2020.

[21] Z. Rao and J. Yuan, "Data mining and statistics issues of precision and intelligent agriculture based on big data analysis," *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*, vol. 71, no. 9, pp. 870–883, 2021.

[22] R. Yu, C. Wu, B. Yan, B. Yu, and N. Chen, "Analysis of the impact of big data on e-commerce in cloud computing environment," *Complexity*, vol. 2021, Article ID 5613599, 12 pages, 2021.

[23] S. Zhang and H. Mao, "Optimization analysis of tennis players' physical fitness index based on data mining and mobile computing," *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 9838477, 11 pages, 2021.

[24] B. Yan, C. Wu, R. Yu, B. Yu, and Y. Yu, "Big data-based e-commerce transaction information collection method," *Complexity*, vol. 2021, Article ID 8665621, 11 pages, 2021.

[25] D. S. Schwering, W. I. Sonntag, and S. Kühl, "Agricultural E-commerce: attitude segmentation of farmers," *Computers and Electronics in Agriculture*, vol. 197, article 106942, 2022.

[26] S. Liang, "Research on the method and application of mapreduce in mobile track big data mining," *Recent Advances in Electrical & Electronic Engineering (Formerly Recent Patents on Electrical & Electronic Engineering)*, vol. 14, no. 1, pp. 20–28, 2021.

[27] S. S. Alrumiah and M. Hadwan, "Implementing big data analytics in e-commerce: vendor and customer view," *IEEE Access*, vol. 9, pp. 37281–37286, 2021.

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Research Article

A Hybrid Approach for Identification of Deficiencies in Enterprise Internal Control

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Enterprise management and internal control are used to prevent and control risks and promote enterprises to achieve development strategy. This paper adopts comprehensive multidisciplinary research method to study the basic theory of prediction of major defects in enterprise internal control. Firstly, this paper proposes the prediction index system and sample selection standard of internal control major defects. Totally, 630 listed company and 12 indicators are collected and then use the random forest classification method based on principal component analysis. The parameters of random forest are optimized by genetic algorithm. Finally, the prediction model of major internal control defects of listed companies is established. The experimental results show that the average score of PCA-RF model in TPR value reaches 85%, which is nearly 20% higher than the 65% of RF model, proving that the PCA and GA can significantly improve the classification accuracy of ST Company and has important practical significance. Therefore, the proposed method system can reasonably solve the prediction problem of major defects in internal control.

1. Introduction

An important internal mechanism in business management is the internal control that corrects mistakes, prevents fraud, and ensures the organization's ability to develop functions. Internal control has existed since ancient times. In the era of increasingly complex industrial organizational structure and more serious financial fraud, the importance of internal control is becoming more and more prominent.

The goal of internal control is to prevent and control risks and promote enterprises to achieve development strategy. Internal controls are always flawed because companies cannot predict all future risks and are constrained by management perceptions and cost-effectiveness principles. According to the signal transmission theory, internal control defects, especially major defects, are important signals to judge the existence of business risks of enterprises. Disclosing major defects of internal control will produce negative effects [1], so enterprises have insufficient endogenous motivation to disclose defect information. Under the requirement of national compulsory disclosure, the public internal control information gradually becomes the game product between technical operation and regulatory rules. Many concealment and insufficient disclosure phenomena occur frequently, such as the events of the long-life biological vaccine, the failure of Zhangzidao scallop, and the financial fraud of Yabet. As a result, the principal-agent mechanism, orderly flow of property rights, and effective allocation of resources in the social and economic system cannot run smoothly. The prediction of major defects in internal control is a process of identifying and warning possible major defects by using appropriate methods according to the financial or nonfinancial data and other relevant information disclosed by enterprises. It aims to reduce the information asymmetry between enterprises and shareholders, creditors, investors, and government regulatory departments and reduce transaction costs paid by stakeholders to collect true information or falsify disclosed information. Predictive research provides a feedforward control method based on cybernetics. By integrating the characteristic information of data mining and referring to the path of "taking expectation as the standard-measuring reality-comparing reality and expectation-

determining deviation-analyzing the cause of deviation," major defects of internal control are actively identified to guide future actions.

The research on internal control defect prediction is mainly carried out from three aspects: defect identification, defect influencing factors, and prediction methods. The identification results of internal control defects answer the question of whether there are defects in enterprises and which are major defects and can reflect the implementation effect of internal control construction of enterprises. However, China's internal control standards have not yet made a clear description of how to divide the defects of different levels, nor for financial reporting and nonfinancial reporting internal control to make a reasonable distinction, policy, and practice level generally exist lack of norms, vague concept, and insufficient attention. Scholars generally believe that enterprises with financial fraud and significant financial restatement have major defects in internal control. However, with the change of external operating environment and the reconstruction of internal organizational structure, factors affecting the existence of internal control defects range from accounting and auditing to organizational structure and business operations. It is further expanding in the macrodirection such as marketization level, legal environment, and government regulation, and nonfinancial factors are playing an increasingly significant role [2, 3]. Therefore, both financial and nonfinancial factors should be considered comprehensively in the construction of prediction models. In terms of prediction methods, the prediction accuracy achieved by logistic regression and discriminant analysis in existing studies is about 70%~80% [4], and the prediction performance still has great room for improvement. With the rapid introduction of artificial intelligence technology into public view, the major defect prediction method has been transformed from statistical measurement to machine learning. Prediction models based on machine learning, such as support vector machine, BP neural network, and integration algorithm, have stronger ability to learn empirical knowledge from data than traditional econometric models and can extract useful information from a large number of nonlinear, high-dimensional, and high-noise data to obtain better prediction effect. Some existing studies have shown that artificial intelligence algorithm can effectively analyze and predict the financial situation and other field [5, 6], management ability of enterprises [7], and risk management [8].

Scholars establish indicators to monitor internal control in terms of effectiveness, audit efficiency, and timeliness [9]. Some scholars have analyzed the decisive factors of major internal control defects [10] or tried to establish a model to distinguish major internal control defects by testing and discriminant methods [11]. Compared with traditional statistical methods such as univariate and multivariable discrimination and regression, neural network does not need to preset standardized function formulas and give hypotheses of statistical distribution characteristics of variables in the model, and it can be used for identification and prediction of variables and models changing over time [12]. At present, in addition to the aforementioned application of neural network in enterprise internal control, many scholars have used neural network methods to explore financial crisis, enterprise bankruptcy, financial market trend prediction [13–15], and bank performance evaluation [16]. However, the NN-based model is easy to overfit. Based on the above analysis, this paper tries to answer the following questions: how to establish a suitable index system for predicting major internal control defects of listed enterprises in China; by comparing different machine learning algorithms, the prediction model based on ensemble algorithm is better than the existing research. Which factors have a greater impact on the forecast results? The possible contributions of this paper are as follows: first, starting from the key elements of internal control and combining empirical evidence, the predictive index system is constructed from the four dimensions of internal governance mechanism, external environmental risk, financial status, supervision, and information communication. Second, machine learning algorithm is used to build prediction models, and the best prediction effect is found by comparing six models including logistic regression, support vector machine, decision tree, BP neural network, random forest, and XGBoost. Most existing literatures are based on linear regression method, with strong explanatory ability but weak prediction ability. This paper demonstrates the advantages of machine learning, especially integrated learning, in prediction performance, and tests the practicality of prediction index system. Third, further explore the improvement space of prediction model through feature contribution analysis.

The main contributions in this paper is as followings: (1) this paper constructed a prediction index system including four aspects, including the company's internal governance, risk, financial situation, and supervision. In order to quantitatively study the enterprise's internal control and management ability, this paper successfully constructed a new data set. (2) This paper successfully applied the machine learning algorithm to the traditional enterprise management field and verified the effectiveness and prediction effect of the algorithm. (3) The model in this paper can not only predict enterprise management risk but also find several important indicators that influence enterprise management risk.

2. Model Structure

RF is an ensemble model which was proposed by Breiman (2001) first. RF mainly employ the concept of bagging model and simple decision trees, to promote the generalization performance, RF use a bootstrap sampling algorithm and a CARTs algorithm to generate multiple unrelated decision trees [17]. Figure 1 indicates a structure of the RF algorithm.

The proposed model in this article is mainly divided into four parts: data processing, feature extraction, recognition, and evaluation. The structure of the proposed algorithm in this paper for prediction of deficiencies in enterprise internal control system is introduced in Figure 2. In Figure 2, China Stock Market & Accounting Research Database (CSMAR) is based on the academic research needs of Shenzhen CSMAR Data Technology Co., Ltd. Based on professional standards of authoritative databases such as CRSP, COMPUSTAT, TAQ, and THOMSON and combined with China's actual

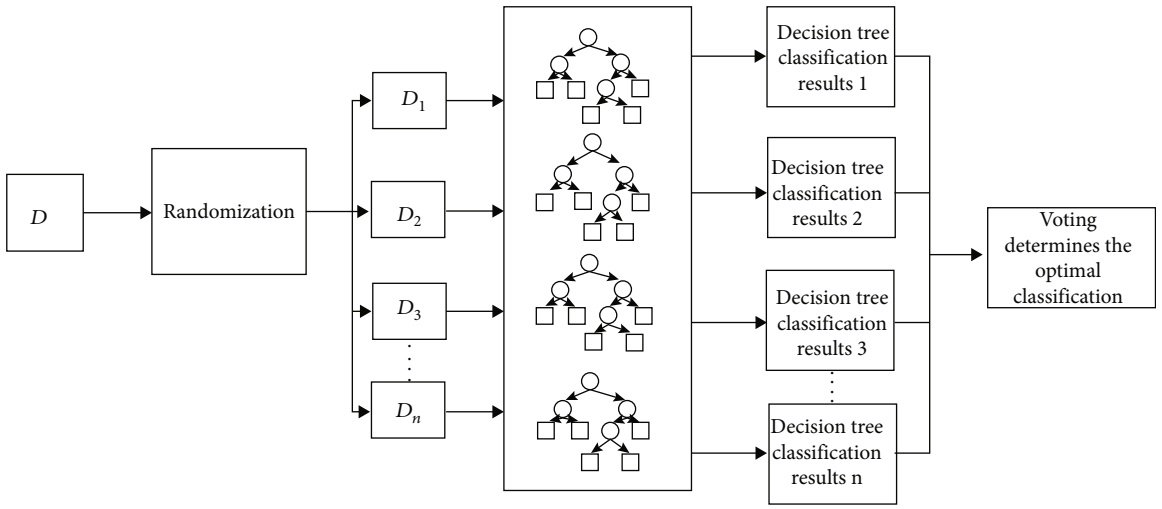

Figure 1: The structure of the RF algorithm.

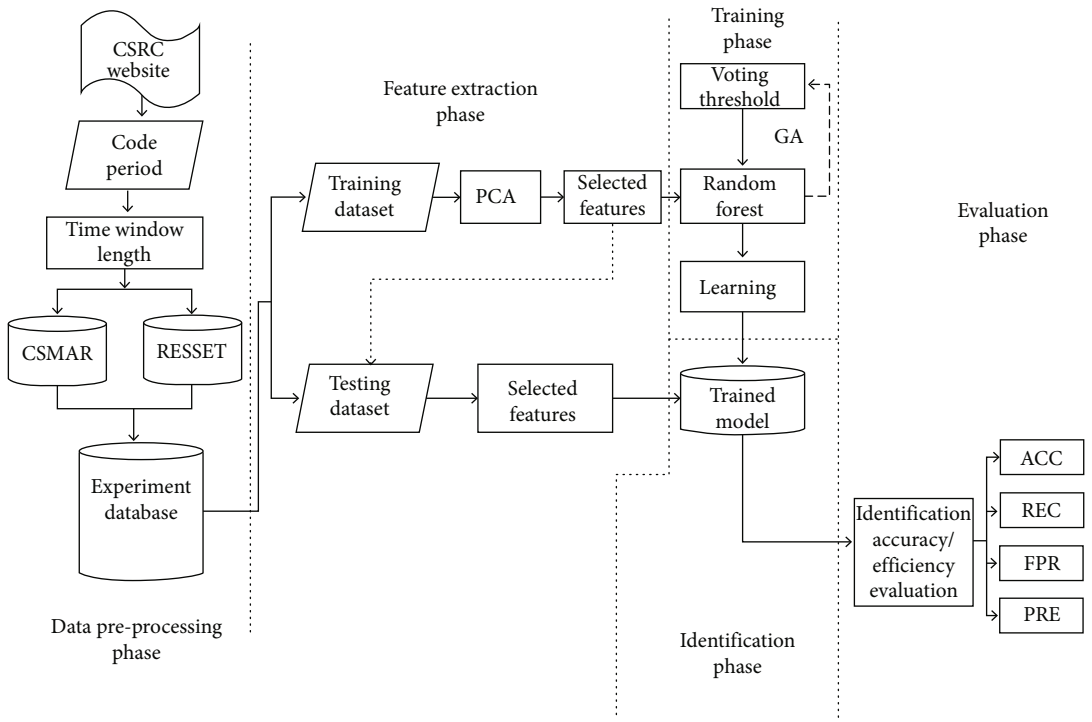

Figure 2: The structure of the PCA-RF algorithm for prediction of deficiencies in enterprise internal control system.

national conditions, the research-based accurate database in the economic and financial field is developed [18]; RESSET database is a professional data platform for model testing, investment research, and more [19].

In this paper, we also use some classical machine learning algorithms as benchmark models to verify the effectiveness of our proposed model.

3. The Theoretical Analysis

3.1. Identification and Determination of Internal Control Defects. Institutional theory holds that it is necessary to use rights and obligation arrangement or authority to limit the boundary of enterprises' pursuit of their goals and coordinate imperfect conflicts. The identification of internal control defects comes from the widely recognized "internal control-integration framework" and "enterprise risk management-integration framework" issued by COSO, which defines control defects as perceived, potential, or actual defects that will adversely affect the ability of enterprises to achieve goals. According to the degree of impact, the defects are classified into major defects, important defects, and general defects.

Based on the consideration of limited resources and costeffectiveness, internal control defects should be judged not only by the existence of defects or deficiencies in the

control system but also by the extent to which such defects or deficiencies hinder the development of enterprises. Therefore, it is more urgent to identify major defects from the possibility and degree of deviation from the target. However, creditors, investors, and government regulatory departments mainly learn major defect information through the internal control evaluation report, internal control audit report, and financial report publicly disclosed by enterprises and passively receive the identification results.

In general, when judging whether an enterprise has major internal control defects, in addition to referring to the signs of major defects, reliable and objective identification results should be actively sought from other public channels, which is conducive to the subsequent model construction. The CSRC published since 2001, for example, the announcement of administrative punishment and markets in the disclosure of the listed company financial statement fraud, major guarantees, or significant related party transactions disclosure not according to stipulations or intentional omission, executives illegal behavior such as securities trading can be a conclusive that internal control is weak performance and sign complementary with other major defects.

3.2. Factors Affecting Internal Control Defects. Reference to the "internal control-integrated framework," "the listed company's internal control guidelines," "enterprise internal control basic norms," and form a complete set of guidelines, "publicly issued securities company information disclosure and reporting Rules No. 21-general provisions of the annual internal control evaluation report," and other documents issued marked the basic formation of China's internal control standard system. Enterprises on the basis of internal environment, risk assessment, control activities, information and communication, and internal supervision of the five elements build their own internal control system, covering the development strategy, corporate governance, organizational structure, corporate culture, social responsibility, financial activities, and many other factors, but the tedious internal control system is still unable to prevent fraud, corruption, and major risks, even leads to more defects in practice. Therefore, the construction of the prediction index system of major internal control defects should be based on the basic national conditions and enterprise needs, combined with existing empirical studies, and give priority to solving the urgent practical problems existing in internal control, rather than endlessly expanding the connotation and boundary of internal control and incorporating all relevant influencing factors.

Based on the above analysis and from the key elements of internal control, exploring the causes of defects along the wave source can guide the construction process of the prediction index system, in which the control environment is the basis, the control activities are the means of implementation, and the supervision is the dynamic feedback of the control activities, which is completed through information transmission and communication. Control environment is a general term for various factors that influence the establishment, strengthening or weakening of specific policies, procedures, and their efficiency. Internal control of any enterprise exists in a certain control environment, a good control environment can essentially enhance the execution effect of internal control. Control activities run through the entire organization, throughout all levels, business units, processes, and technical environment; the most basic control activity is transaction control. Financial performance to some extent reflects the closed-loop flow of important transactions, and the existence of defects can be detected from abnormal changes in financial data. The supervision process can timely evaluate the effectiveness of internal control and improve the defects found, which is the dynamic feedback of control activities, while information and communication can ensure that the feedback can be effectively communicated within the enterprise and between the enterprise and the external. This paper constructs the prediction index system of internal control major defects from three aspects: control environment, control activities, supervision, and information communication. Based on the importance of control environment, it is further divided into internal governance mechanism and external environmental risks.

3.3. Prediction Model Based on Machine Learning. Machine learning has been widely used in financial fraud identification, credit risk assessment, financial distress, and financial fraud identification, etc., providing a lot of help for making management decisions [20–23]. The prediction method of internal control defects has also been transformed from statistical learning to machine learning. Before the application of machine learning methods, relevant studies generally use econometric models to conduct causal analysis on variables, and these two methods have different trade-offs in model interpretability and prediction ability: econometric model focuses on explaining phenomena and finding the laws behind phenomena, requires to clarify the reasons for good model fitting and the interaction between variables, and pursues relatively simple function form and easily explained model estimation results. Machine learning is not limited to interpretability, it can learn more empirical knowledge from data, discover useful information in a large number of nonlinear, high-dimensional, and high-noise data, and flexibly select function forms to fit data, so it has strong predictive ability.

Among the mainstream machine learning algorithms, logistic regression has better fitting effect on linear relationship and is suitable for data with strong linear relationship between features and variables. Support vector machine (SVM) is a small sample learning method that adheres to mathematical principles. Based on kernel method, input data is mapped to a high-order vector space to solve classification problems, which requires high sample balance. The decision tree consists of a series of tree structures organized by "divide and conquer." The data are divided into different subsets according to different characteristics, and the information gain or Gini coefficient is used as the evaluation criteria. BP neural network is a kind of multilayer feedforward network trained according to the error back propagation algorithm, which constantly adjusts the weights and thresholds of the whole network through back propagation.

However, there are many parameters, it is difficult to train, and the output results are difficult to explain. Random forest is a forest composed of many unrelated decision trees in a random way, and the purity of data set divided by a feature is measured by information gain or Gini index, to determine the partition feature. XGBoost uses a greedy algorithm to enumerate all possible partitioning cases of features and then determines the optimal feature set based on which the final predicted value is the sum of predicted values of each base learner. It is worth noting that no algorithm can perfectly solve all problems, and all kinds of machine learning algorithms have their own good data sets, and the prediction model needs to be optimized through continuous practice.

4. Research Design

4.1. Data Sources and Sample Selection. Since 2007, listed companies in China have been required to disclose self-assessment reports of internal control, and the submission of internal control guidelines was voluntary disclosure at the initial stage. However, the proportion of disclosure increased year by year to 46% in 2011, and the proportion of disclosure is not high, and the disclosure of major defects of internal control is even less. In 2012, the internal control of listed companies in China entered the stage of comprehensive compulsory disclosure, and the proportion of disclosure in Shanghai Stock Exchange increased to 75.32%. In the initial stage of internal control information disclosure in China, there are mandatory disclosure and voluntary disclosure, and their disclosure motives are different, so they cannot be compared with each other. To sum up, this paper selects Chinese A-share listed companies (excluding the financial industry, companies subject to ST and companies with incomplete data) during the period of comprehensive compulsory disclosure from 2012 to 2020 as the sample basis. According to the selection criteria of major defect samples, 630 companies with 818 records of major defect samples are finally obtained. A total of 18,901 records were identified as significant defects in the control sample for eight years.

4.2. Definition of Variables

4.2.1. Dimension of Internal Governance Mechanism. Referring to relevant research results, internal governance mechanism can be measured by equity balance degree, institutional shareholding ratio, board size, proportion of independent directors, management power, and executive compensation. Specific indicators are listed as follows:

(1) Degree of equity balance (Tang and Xu [24])

The ratio of the sum of the shareholding of the second to tenth largest shareholders to the shareholding of the first largest shareholder.

(2) Institutional shareholding (Hermanson and Ye [25])

The ratio of the number of shares held by institutional investors to the total shares of listed companies.

(3) Board size (Hoitash and Bedard [2])

The natural log of the total number of board members.

(4) Proportion of independent directors (Krishnan [26])

Ratio of the number of independent directors to the total number of directors.

(5) Management power(Hermanson and Ye [25])

For general manager, the value is 1; for general manager and director, it is 2; for general manager and vice chairman, it is 3; for general manager and chairman, it is 4.

4.2.2. Dimension of External Environmental Risk. This paper selects the following indicators to measure:

(1) Degree of internationalization (Hammersley and Bedard [2])

Take 1 if you have overseas income; otherwise, take 0

(2) Listing years (Fethi and Pasiouras [16], Skaife et al. [27], Ge and Mcvay [28])

4.2.3. Dimension of Financial Status. This paper selects the following indicators to measure (Doyle et al. [29], Ge and Mcvay [28], Rice and Weber [30]):

(1) Z-score

Altman bankruptcy risk prediction model

(2) ROA

$$\frac{\text{Net profit}}{[(\text{ending balance of assets} + \text{beginning balance of assets})/2]} \quad (1)$$

(3) ROE

$$\frac{\text{Net profit}}{[(\text{ending value of net assets} + \text{initial value of net assets period})/2]} \quad (2)$$

4.2.4. Supervision and Information Communication. This paper selects the following indicators to measure:

(1) Changes in audit fees (Hoag and Hollingsworth [31])

$$\frac{(\text{Audit fee of current period} - \text{audit fee of previous period})}{\text{audit fee of previous period}} \quad (3)$$

(2) Whether the "top ten" (Chen et al. [32])

If it is one of the top ten audit institutions evaluated by CICPA, the value is 1; otherwise, the value is 0.

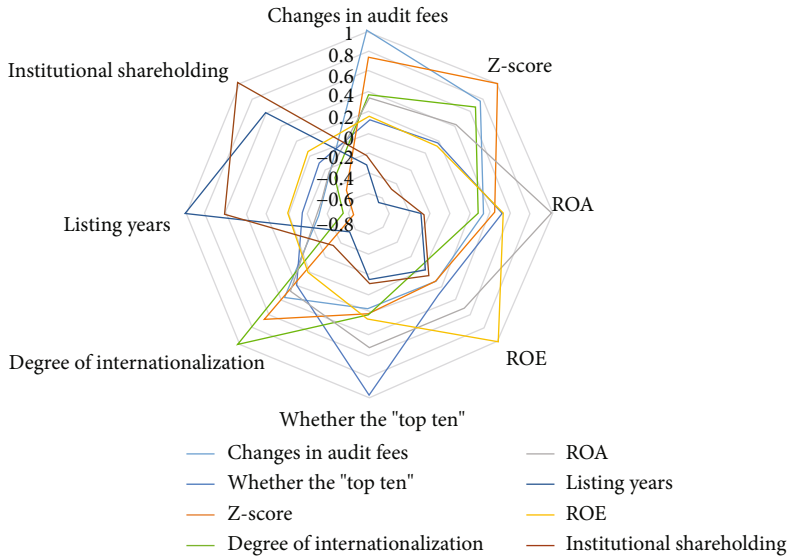

Figure 3: Correlation analysis of the indicators.

5. Model Process

5.1. Feature Engineering. Figure 3 is the correlation analysis diagram of an indicator, which shows the correlation between indicators of continuous value selected by us. We use this radar diagram to show it.

Figure 4 shows the classification results for internal control defects. In Figure 4, companies with internal control deficiencies are shown in red, and companies with no internal control deficiencies are shown in blue. The double-significance test can only test whether the differentiation of different indicators is significant between two groups of samples, but cannot solve the problem of multicollinearity between data, which often makes the model less accurate or even completely distorted. To address this problem, Principal component analysis (PCA) is adopted in this paper for feature reduction based on the double significance test. PCA is a linear combination transformation of the initial indicators to obtain uncorrelated principal components and achieves the purpose of variable screening and dimensionality reduction while retaining most of the original information.

For each dynamic data set obtained, principal component analysis was conducted based on double significance test. The 80% cumulative variance contribution rate was used as the screening criterion for the target principal components. Table 1 shows that we have obtained three main principal components after processing by principal component analysis algorithm (these three principal components contribute 86% of information content in total). After dimensionality reduction of principal component analysis, the final input index dimension of our model has changed from the original 12 indicators to the present 3 indicators.

5.2. Model Evaluation. The prediction results were divided into true positive, false positive, true negative, and false negative according to the combination of the true category and the prediction category, which were represented by the confusion matrix, as shown in Table 2.

In the verification process, after the input test data, the model will generate the prediction probability of a certain

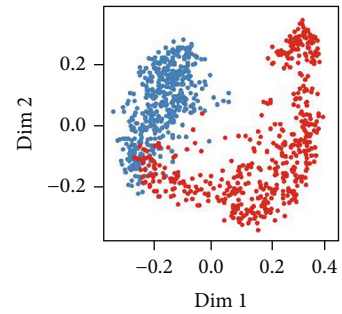

Figure 4: The classification results for internal control defects.

Table 1: Principal component rotation matrix.

Indicator	PC1	PC3	PC12
Degree of equity balance	0.048	0.009	0.023
Institutional shareholding	0.002	0.611	0.04
Board size	0.03	0.048	0.137
Proportion of independent directors	0.125	0.061	0.083
Management power	0.015	0.059	0.286
Degree of internationalization	0.12	0.004	0.056
Listing years	0.037	0.07	0.061
(1) *Z*-score	0.031	0.088	0.044
(2) ROA	0.426	0.054	0.124
(3) ROE	0.065	0.255	0.212
Changes in audit fees	0.004	0.261	0.053
Whether the “top ten”	0.061	0.097	0.056

Table 2: Confusion matrix.

The actual situation	Predicted results	
	No significant defects are predicted	No significant defects are predicted
Positive example (significant defect)	Real-positive example	False counterexample
Counterexamples (no significant defects)	False-positive example	True counterexample

Table 3: Result of the proposed method and benchmark method.

	Accuracy	FR rate	Precision	DR	$f1$
RF	88.92%	11.12%	88.96%	88.96%	88.96%
gbdt	85.77%	11.12%	88.84%	82.39%	85.51%
PCA-RF	87.86%	10.00%	85.45%	90.00%	87.67%
nn	84.18%	16.67%	85.24%	81.95%	83.57%
knn	85.50%	16.59%	87.25%	84.64%	85.93%
Bayes	85.81%	10.00%	81.30%	79.00%	85.45%
Logistic	85.40%	17.29%	88.72%	81.67%	85.06%
Tree	85.72%	17.07%	88.86%	82.55%	85.60%
Ctree	83.55%	19.90%	87.65%	79.25%	83.26%

label (such as the probability of an enterprise is predicted to have major defects), the test samples in descending order of the probability value, and the classification process is to find the threshold and "truncate" for two categories, greater than a threshold for one class, otherwise another class. If the threshold is large, truncate at the backward position, and if the threshold is small, the forward position can be used to check the positive examples. The ROC curve (receive-operating characteristic curve) and the AUC value (area under ROC curve) are the best measures of the model generalization performance from the above perspective. The abscissa FPR (false-positive rate) of the ROC curve represents the case of majority class error, and the ordinate TPR (true-positive rate) represents the model's ability of the model to capture minority classes, which can measure how the model misjudge majority classes when it tries to capture minority classes. The area enclosed by the ROC curve is the AUC value. The larger the AUC value is, the closer the ROC curve is to the upper left corner, and the better the prediction effect is.

In addition, the TPR and TNR are introduced to evaluate the predictive classification ability of the model for minority and majority samples, respectively. The AUC value is a general performance indicator of the classifier, which refers to the area under the ROC curve and the axis, and its value is not affected by the distribution of positive and negative samples in the data set. The F-value is a combination of recall and precision which are positively correlated with F-value. The G value is a combination of the TPR and TNR values, and the G value will get larger only when both TPR and TNR values are high. Both the F and G values take into account the classification of minority samples, so they can be used as evaluation criteria for the unbalanced financial warning model. Each indicator can be derived from the confusion matrix, and the specific formulas are shown in Equations (4)–(9), respectively.

$$\mathrm{ACC} = \frac{\mathrm{TP} + \mathrm{TN}}{\mathrm{TP} + \mathrm{FN} + \mathrm{TN} + \mathrm{FP}}, \tag{4}$$

$$\mathrm{TPR(Recall)} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}, \tag{5}$$

$$\mathrm{TNR} = \frac{\mathrm{TN}}{\mathrm{TN} + \mathrm{FP}}, \tag{6}$$

$$\mathrm{Precision} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}}, \tag{7}$$

$$F = \frac{2 \times (\mathrm{Recall} \times \mathrm{Precision})}{\mathrm{Recall} + \mathrm{Precision}}, \tag{8}$$

$$G = \sqrt{\mathrm{TPR} \times \mathrm{TNR}} = \sqrt{\frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}} \times \frac{\mathrm{TN}}{\mathrm{TN} + \mathrm{FP}}}. \tag{9}$$

6. Analysis

The performance of prediction models with different algorithms in each data set is shown in Table 3, which preliminarily indicates the availability of the prediction index system. In comparison, the prediction effect of RF and PCA-RF ensemble models on data sets with different time spans is stronger than that of the other 7 individual learners, and the PCA-RF model is slightly better than the random forest model, and the prediction result is more robust, indicating that compared with the individual learners, the integration model represented by PCA-RF has better predictive performance and application value in predicting major defects of internal control in enterprises. One of the fundamental tenets of machine learning is that no algorithm can

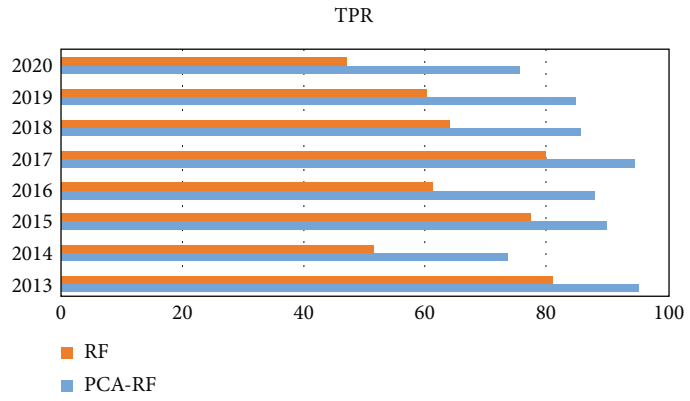

Figure 5: Result of TPR.

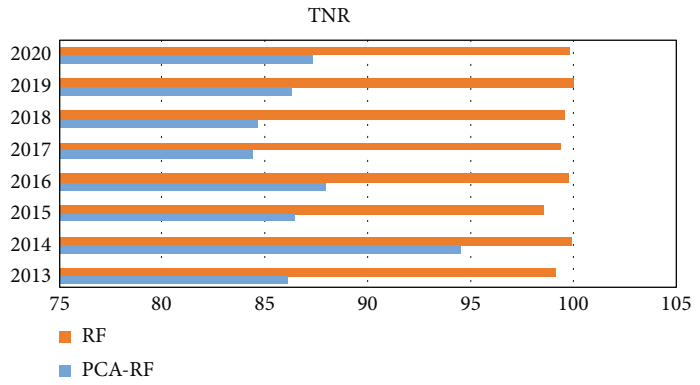

Figure 6: Result of TNR.

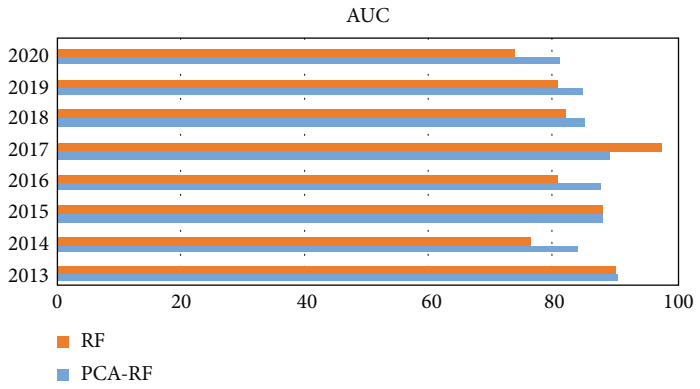

Figure 7: Result of AUC.

solve every problem perfectly, and every algorithm has a problem area in which it excels. The above results preliminarily indicate that the prediction index system of major internal control defects suitable for listed enterprises in China is established in this paper, and through comparison, the prediction effect of integrated model based on PCA-RF algorithm is the best.

6.1. Model Comparison Analysis. In order to verify whether the PCA-RF model can deal with the data imbalance in dynamic prediction, the RF model is used as a comparative model. In addition, since the RF is a strong classifier, a relatively stable test result can be obtained with the number of cycles $U = 20$. In each cycle, the optimal parameters of the RF models are obtained by the GA. After that, 50 iterations are performed to avoid the randomness interference on the model accuracy. The classification performance of the two models in each year is shown in Figures 5–10.

It can be seen that the average score of PCA-RF model in TPR value reaches 85%, which is nearly 20% higher than the 65% of RF model, proving that the former can significantly improve the classification accuracy of ST Company (a few

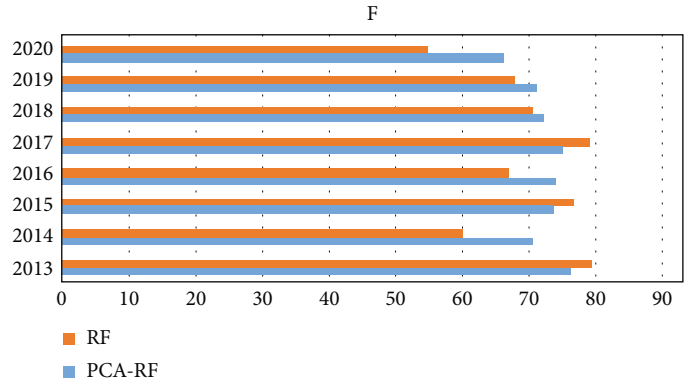

Figure 8: Result of *F*.

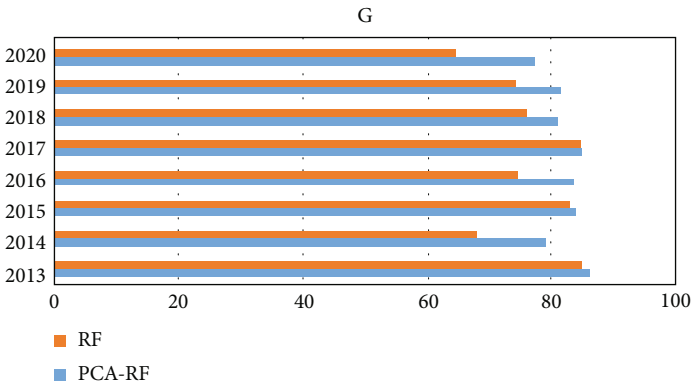

Figure 9: Result of *G*.

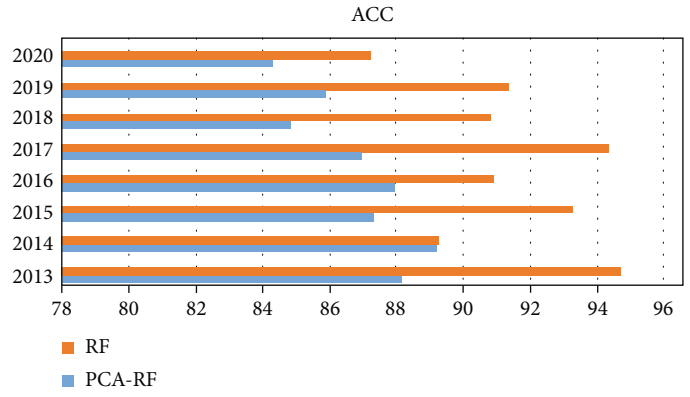

Figure 10: Result of ACC.

types of samples) and has important practical significance. In addition, the performance of PCA-RF model is superior to RF model in AUC and *G* value. Although the improvement in *F* value is limited, it can still maintain relatively stable, which proves the excellent comprehensive performance of the former.

7. Conclusion

This paper adopts comprehensive multidisciplinary research method to study the basic theory of prediction of major defects in enterprise internal control. Firstly, this paper proposes the prediction index system and sample selection standard of internal control major defects. Totally, 630 listed company and 12 indicators are collected and then use the random forest classification method based on principal component analysis. The parameters of random forest are optimized by genetic algorithm. Finally, the prediction model of major internal control defects of listed companies is established. The prediction model of major defects in internal control is designed to identify enterprises with major defects in internal control, so that they can get early warning hints

in decision-making of management, investment, evaluation, and supervision and correct and improve the defects pertinently. Furthermore, from the perspective of the prediction index system, it is beneficial to identify the root causes of internal control defects, formulate solutions in time, and prevent the expansion of losses by looking for the unreasonable internal governance mechanism, serious external environmental risks, and abnormal financial conditions that may exist in enterprises. The main conclusions of this paper are as follows: (1) it is feasible to establish the prediction index system of major internal control defects. In this paper, the prediction index system of major defects of internal control is established from the four dimensions of internal governance mechanism, external environmental risk, financial status, supervision, and information communication, and 12 prediction features are screened out after feature engineering processing. The AUC values of prediction models based on different time spans and different algorithms are basically above 0.8. (2) PCA-RF model is slightly better than random forest model. Due to different algorithm principles, RF model can learn more feature information and have a wider range of feature selection.

Abbreviations

PCA: Principal component analysis
SVM: Support vector machine
ANN: Artificial neural network
KNN: *K* nearest neighbors
DT: Decision tree
NB: Naive Bayesian
CARTs: Classification and regression trees
RF: Random forest
REC: Recall
FPR: False-positive rate
PRE: Precision
ACC: Accuracy.

Data Availability

Data that can be provided by the corresponding author has no reserves.

Conflicts of Interest

The author declares that there is no conflict of interest in this work.

References

[1] J. S. Hammersley, L. A. Myers, and J. Zhou, "The failure to remediate previously disclosed material weaknesses in internal controls," *Auditing: A Journal of Practice and Theory*, vol. 31, no. 2, pp. 73–111, 2012.

[2] U. Hoitash and H. Bedard, "Corporate governance and internal control over financial reporting: a comparison of regulatory regimes," *Accounting Review*, vol. 84, no. 3, pp. 839–867, 2009.

[3] K. Johnstone, L. Chan, and K. H. Rupley, "Changes in corporate governance associated with the revelation of internal control material weaknesses and their subsequent remediation," *Contemporary Accounting Research*, vol. 28, no. 1, pp. 331–383, 2011.

[4] M. Franklin, *Sarbanes Oxley Section 404: Can Material Weakness be Predicted and Modeled? An Examination of the Variables of the ZETA Model in Prediction of Material Weakness*, Dissertations & Theses-Gradworks, 2007.

[5] G. C. Florea, "Financial statements forecast," *International conference Knowledge-Based Organization*, vol. 26, no. 2, pp. 19–22, 2020.

[6] L. Li, H. Li, G. Kou et al., "Dynamic camouflage characteristics of a thermal infrared film inspired by honeycomb structure," *Journal of Bionic Engineering*, vol. 19, no. 2, pp. 458–470, 2022.

[7] J. Yu, "Qualitative simulation algorithm for resource scheduling in enterprise management cloud mode," *Complexity*, vol. 2021, Article ID 6676908, 12 pages, 2021.

[8] S. Deng, C. Wang, M. Wang, and Z. Sun, "A gradient boosting decision tree approach for insider trading identification: an empirical model evaluation of China stock market," *Applied Soft Computing*, vol. 83, article 105652, 2019.

[9] A. Masli, G. F. Peters, V. J. Richardson, and J. M. Sanchez, "Examining the potential benefits of internal control monitoring technology," *The Accounting Review*, vol. 85, no. 3, pp. 1001–1034, 2010.

[10] J. Doyle, W. Ge, and S. McVay, "Determinants of weaknesses in internal control over financial reporting," *Journal of Accounting and Economics*, vol. 44, no. 1-2, pp. 193–223, 2007.

[11] J. B. Kim, B. Y. Song, and L. Zhang, "Internal control weakness and bank loan contracting: evidence from SOX section 404 disclosures," *The Accounting Review*, vol. 86, no. 4, pp. 1157–1188, 2011.

[12] K. C. Chung, S. S. Tan, and D. K. Holdsworth, "Insolvency prediction model using multivariate discriminant analysis and artificial neural network for the finance industry in New Zealand," *International Journal of Business and Management*, vol. 39, no. 1, pp. 19–28, 2008.

[13] F. Abid and A. Zouari, "Financial distress prediction using neural networks," in *Proceedings of the MS'2000 International Conference on Modeling and Simulation*, pp. 399–406, Spain, 2000.

[14] M. Perez, "Artificial neural networks and bankruptcy forecasting: a state of the art," *Neural Computing and Applications*, vol. 15, no. 2, pp. 154–163, 2006.

[15] F. J. López-Iturriaga, Ó. López-de-Foronda, and I. Pastor-Sanz, *Predicting Bankruptcy Using Neural Networks in the Current Financial Crisis: A Study of U.S. Commercial Banks*, Working Paper, University of Burgos, 2010.

[16] M. D. Fethi and F. Pasiouras, "Assessing bank efficiency and performance with operational research and artificial intelligence techniques: a survey," *European Journal of Operational Research*, vol. 204, no. 2, pp. 189–198, 2010.

[17] S. Deng, C. Wang, Z. Fu, and M. Wang, "An intelligent system for insider trading identification in Chinese security market," *Computational Economics*, vol. 57, no. 2, pp. 593–616, 2021.

[18] Resset databaseMay 2022, http://www.resset.cn/databases.

[19] China Stock Market & Accounting Research DatabaseMay 2022, https://www.gtarsc.com/.

[20] S. Y. Kim and A. Upneja, "Predicting restaurant financial distress using decision tree and AdaBoosted decision tree models," *Economic Modelling*, vol. 36, pp. 354–362, 2014.

[21] C. C. Lin, A. A. Chiu, S. Y. Huang, and D. C. Yen, "Detecting the financial statement fraud: the analysis of the differences between data mining techniques and experts' judgments," *Knowledge-Based Systems*, vol. 89, pp. 459–470, 2015.

[22] N. Sanaz and S. Mehdi, "Cost-sensitive payment card fraud detection based on dynamic random forest and k-nearest neighbors," *Expert Systems with Applications*, vol. 110, pp. 381–392, 2018.

[23] S. M. Askari and M. A. Hussain, "IFDTC4.5: intuitionistic fuzzy logic based decision tree for E-transactional fraud detection," *Journal of Information Security and Applications*, vol. 52, article 102469, 2020.

[24] A. P. Tang and L. Xu, *Institutional Ownership, Internal Control Material Weakness and Firm Performance*, vol. 49, no. 2, 2007Social Science Electronic Publishing, 2007.

[25] D. R. Hermanson and Z. Ye, "Why do some accelerated filers with SOX section 404 material weaknesses provide early warning under section 302?," *Auditing: A Journal of Practice & Theory*, vol. 28, no. 2, pp. 247–271, 2009.

[26] J. Krishnan, "Audit committee quality and internal control: an empirical analysis," *Accounting Review*, vol. 80, no. 2, pp. 649–675, 2005.

[27] H. A. Skaife, D. W. Collins, and W. R. Kinney, "The discovery and reporting of internal control deficiencies prior to sox-mandated audits," *Journal of accounting and economics*, vol. 44, no. 1-2, pp. 166–192, 2007.

[28] W. Ge and S. E. Mcvay, "The disclosure of material weaknesses in internal control after the Sarbanes-Oxley act," *Accounting Horizons*, vol. 19, no. 3, pp. 137–158, 2005.

[29] J. T. Doyle, W. Ge, and S. Mcvay, "Accruals quality and internal control over financial reporting," *Accounting Review*, vol. 82, no. 5, pp. 1141–1170, 2007.

[30] S. C. Rice and D. P. Weber, "How effective is internal control reporting under SOX 404? Determinants of the (non-)disclosure of existing material weaknesses," *Journal of Accounting Research*, vol. 50, no. 3, pp. 811–843, 2012.

[31] M. L. Hoag and C. W. Hollingsworth, "An intertemporal analysis of audit fees and section 404 material weaknesses," *Auditing A Journal of Practice & Theory*, vol. 30, no. 2, pp. 173–200, 2011.

[32] Y. Chen, F. A. Gul, C. Truong, and M. Veeraraghavan, *Audit Quality and Internal Control Weakness: Evidence from SOX 404 Disclosures*, Electronic Publishing, 2012.

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Research Article

Optimization Design of Multi-UAV Communication Network Based on Reinforcement Learning

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In recent years, due to the application of high-definition video codec technology, high-precision satellite navigation technology, mobile base station positioning technology, and broadband technology, the performance of UAVs has been greatly improved. In the military field, drones have become an important weapon alongside missiles on the battlefield. In the future, military drones will perform strategic missions such as battlefield reconnaissance and long-range destruction. Outside the military field, DJI's Zenmuse series drones are used for filming, MG series drones are used for pesticide spraying, and Beijing Zhonghangzhi unmanned helicopters are used for geological surveys, precise inspection of power lines, and maritime law enforcement. With the continuous improvement of technical specifications, UAV communication technology requires further research and development. This paper has conducted research experiments on the optimization of multi-UAV communication network based on reinforcement learning. The experimental data show that it is marked as the AoI value corresponding to the completion of a certain self-task. It can be seen that the final AoI of the communication trajectory of reinforcement learning is 115, and the AoI greedy strategy finally obtains AoI of 140 seconds, achieving about 18% of the total AoI reduce, which effectively improve the performance of the system. From the above data, the research of reinforcement learning method has great benefits for the development of UAV communication.

1. Introduction

In the 100 years since the first drone was invented in 1917, the drone industry has grown rapidly, from a single flight to a multibillion dollar output. With the continuous development of military high-tech, unmanned aerial vehicles (UAVs) have emerged in modern warfare due to their low cost, easy maintenance, reduced casualties, and the ability to perform tasks in a variety of complex and harsh environments and gradually attracted the attention of the world's military powers. In future wars, there will be less and less direct human participation and more confrontation between unmanned military equipment. In order to adapt to the situation of informatized warfare and quickly collect and process real-time and accurate intelligence information, UAVs have been widely used in modern combat command for reconnaissance, surveillance, and other tasks, especially the reconnaissance of enemy areas and important targets. In the networked environment, the mode of warfare has undergone tremendous changes. As an important part of the Internet era, "sharing" also plays an important role in networked warfare. In a networked environment, the "distance" between troops is approximately zero, and information resources and services can be easily shared. Under the traditional platform-centric combat mode, in order to obtain the information they need, each unit needs to configure corresponding equipment, such as unmanned aerial vehicles and ground stations. Under the condition of underdeveloped intelligence sharing, various combat units often have the problem of duplication of resource allocation and

duplication of information collection. For the UAV troops, the repeated deployment of a large number of UAVs will also lead to problems in airspace security, electromagnetics, and communication management, which will greatly limit the effective use of UAV system resources.

With the rapid development of UAV technology, higher requirements are put forward for the simultaneous use of multiple types and numbers of UAVs in the same war. Under the traditional use of UAVs, the managers and users are the same unit. The result is that the tasks between different units cannot be efficiently coordinated and unified, and the information obtained cannot be shared in time, which is extremely unfavorable for joint operations and high-level commanders' war decisions. In addition, under the complex informationized battlefield conditions in the future, due to the different coverages of battlefield communication links, different mission requirements, and different mission capabilities of various UAVs, a single type of UAV system obviously cannot meet the needs of the battlefield. By establishing a generalized monitoring and control network, the UAVs, ground stations, decision-making systems, and control systems scattered in the battlefield environment are connected into an organic whole. Through this network, personnel at all levels can timely understand the battlefield situation, share intelligence information, and achieve seamless command, control, and communication, which is obviously beneficial to improving efficiency.

After the optimization of multi-UAV communication network based on reinforcement learning in this paper, the data shows that the AoI of the communication trajectory of reinforcement learning is 118 and 157 when the number of ground nodes is 6 and 10, respectively; the AoI of the greedy algorithm is 139 and 199, respectively; that is, the AoI that can be obtained by the reinforcement learning algorithm is smaller, and with the increase of the number of ground nodes, its advantages are more obvious. From the above data, it can be seen that the multi-UAV communication network optimization research experiment of reinforcement learning is of great significance for promoting the development of the current multi-UAV communication network.

2. Related Work

This paper studies some technologies of multi-UAV communication network, which can be fully applied to the research in this field. The main research goal of Amorim et al. is to obtain the path loss index and shadow model of wireless channels between airborne UAVs and cellular networks [1]. Fawaz et al. improve the performance of existing relay-assisted FSO systems by relaxing these two highly restrictive assumptions by integrating UAVs as buffer-assisted mobile relays into traditional relay-assisted FSO systems [2]. Mamaghani and Hong studied the problem of maximizing the average secrecy rate for UAV wireless communication systems, where UAVs are used to transmit confidential information to ground destinations in the presence of ground passive eavesdroppers [3]. Wang et al. studied the average packet error probability and effective throughput of control links in UAV communication, where a ground central station sends control signals to UAVs that require ultra-reliable low-latency communication [4]. Liu et al. designed a recurrent neural network based on long short-term memory for UAV position prediction [5]. These methods provide some references for our research, but due to the short time and small sample size of the relevant research, they have not been recognized by the public.

Based on reinforcement learning, we have reviewed the following related materials to optimize the research on multi-UAV communication networks. Gershman and Daw review the major advances in the psychology and neuroscience of reinforcement learning over the past two decades through comprehensive experimental studies on simple learning and decision-making tasks [6]. Li et al. tried to introduce qualitative rules into reinforcement learning and represented these rules through a cloud inference model [7]. Peng et al. showed that reinforcement learning methods can be adapted to learn robust control policies capable of imitating a wide range of example motion clips [8]. Sallab et al. proposed a framework for autonomous driving using deep reinforcement learning, gave a brief introduction to deep reinforcement learning, and then described the proposed framework [9]. Ying et al. proposed a new deep reinforcement learning method, an advanced reinforcement learning algorithm that uses a deep Q-network to approximate the Q-valued action function [10]. He et al. proposed a new deep reinforcement learning method, and the simulation results under different system parameters showed its effectiveness [11]. These methods provide sufficient literature support for our study of multi-UAV communication network optimization with reinforcement learning.

3. Overview of Reinforcement Learning and UAV Communication

The characteristics of UAV battery power supply make power consumption a factor that has to be considered in the UAV support network. Therefore, this paper takes the development of UAVs to a higher level by studying reinforcement learning to optimize the UAV communication network.

3.1. Overview of Reinforcement Learning. Reinforcement learning is an important machine learning method that has been at the forefront of intelligent control and artificial intelligence research in recent years [12]. Among various learning methods, reinforcement learning has the ability to adapt to complex systems and self-training. It approaches optimal control policies through trial-and-error learning that interacts with the environment, a learning mechanism that has been successfully applied to nonlinear control, artificial intelligence for solving complex problems, robot control, optimization, and planning.

Reinforcement learning (RL) first appeared in the 1950s as learning by trial and error in a dynamic environment. The agent method does not calculate the task performance of the agent but guides the agent through rewards and

punishments, which is now becoming an important branch of machine learning and artificial intelligence [13].

There are two strategies to solve the problem of reinforcement learning: first, searching the action space to find actions that work better in the environment, this approach has been used for example in genetic algorithms and genetic programming; second, using statistical methods and dynamic programming techniques to assess the utility of actions in the state of the world. RL is based on autonomous learning by exploring an unknown environment, whereby an agent acquires knowledge about the environment to optimize the course of action.

Reinforcement learning is a machine learning method that learns by interacting with the environment and taking feedback from the environment as input. The basic idea is to learn by trial and error, matching environmental states and actions, and the agent (learner or decider) interacts with the environment over time and assumes that the cumulative reward is maximized. In reinforcement learning, cues are provided by the environment with the purpose of providing some sort of evaluation of how good or bad the chosen action is, rather than telling the agent how to choose the right action. Since the external environment provides very little information for the agent, it must rely on the experience of interacting with the environment to learn independently. Therefore, the agent uses the evaluation signals from the external environment to optimize its decision and find the best behavior policy.

Reinforcement learning is a method that focuses more on learning through interaction and decision-making than other machine learning methods. In reinforcement learning, the agent must figure out, through trial and error, which activity brings the greatest immediate reward. The action not only affects the immediate reward but is also important for all subsequent rewards. With the deepening of research, reinforcement learning can be divided into the following branches: logic-based reinforcement learning, hierarchical learning, multiagent learning, POMDP learning, etc. [14]. The agent environment structure diagram is shown in Figure 1.

Reinforcement learning problems can be viewed as a framework for learning directly from interactions and goal achievement. Learners and decision-makers are called agents, and all other elements except agents are called environments. These interactions are continuous, the agent chooses actions, the environment reacts to these actions and generates new situations for the agent, and the environment returns reward values. Through the above process, the agent learns how to optimize its behavioral policy in the environment in order to maximize the cumulative reward over time.

In addition to the two components of the environment and the learning agent, a reinforcement learning system also needs four other main subelements: the strategy, the reward function (or cost function), the value function, and the optional environment model. The strategy is to define the learning mode or the action behavior mode displayed by the learning agent in a given time. The reward function, defining the goal of a reinforcement learning problem, is

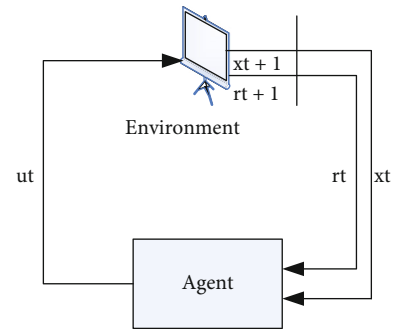

Figure 1: Agent environment structure diagram.

its main task. The value function refers to the accumulation of the expected rewards of the learning agent from the current state to the final state. The environment model (optional), before the learning agent actually has not experienced the future action, takes the possible future situation into account through the model and then makes planning decisions for future action selection [15]. The schematic diagram of the relationship between the four core parts of reinforcement learning is shown in Figure 2:

Early reinforcement learning systems were a trial-and-error learning method that was almost the opposite of planning decision-making methods. However, adding the planning method of the model and state space to the reinforcement learning makes the reinforcement learning closely related to the dynamic programming method, so that the reinforcement learning method gradually becomes clear. It can be seen that the main goal of reinforcement learning is to obtain the best strategy through continuous improvement of the strategy to achieve the final goal. The development route of reinforcement learning is shown in Figure 3.

Early reinforcement learning algorithms learned through trial-and-error learning to achieve their goals. With the development of reinforcement learning, dynamic programming and optimal control algorithms and time difference (TD) learning algorithms appear in turn. These three main lines eventually constitute the main framework of modern reinforcement learning algorithms. From a modeling perspective, reinforcement learning falls into two categories: model-based learning algorithms and model-free methods. The former extracts empirical knowledge from the environment to establish a learning model and then determines the optimal strategy according to the model; the latter selects strategies through direct interaction with the environment. Commonly used model-free learning algorithms are as follows: AHC, temporal difference (TD), and Q-learning. The model-free method has the characteristics of iterative calculation, and its calculation amount is small, and because it cannot make full use of the prior knowledge, it is not as good as the model method in terms of convergence speed. The following mainly introduces several typical RL methods [16].

Dynamic programming methods use a value function to search for good policies and are suitable for solving large problems. If the environment is a finite Markov set, and

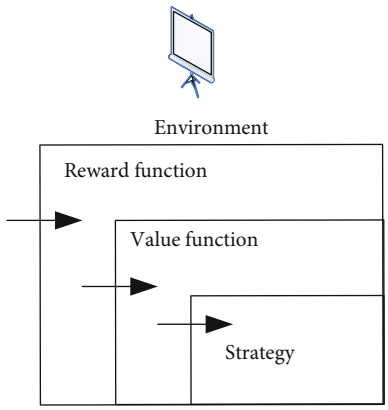

Figure 2: Schematic diagram of the relationship between the four core parts of reinforcement learning.

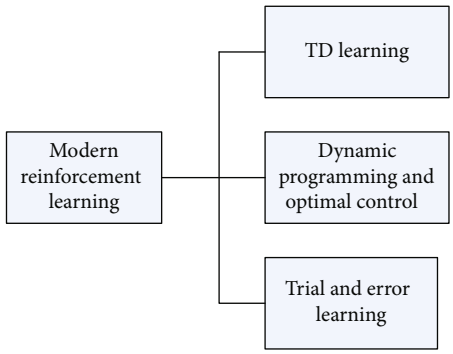

Figure 3: The development route of reinforcement learning.

for each policy, information about the dynamic environment is fully known, then the value function is given by

$$V^*(s) = \max_b \left\{ r_s(b) + \gamma \sum_{b \in B} P_{ss'}[b] V^{\pi^*}\left(s'\right) \right\}. \quad (1)$$

The dynamic programming algorithm requires an immediate reward value r and a state transition function P. In other words, this problem can only be solved if the environment model is known.

Monte Carlo is a model-free algorithm that iteratively learns by computing state, action, and value functions. The algorithm differs from traditional Q-learning in that it is based on a multistage reward averaging mechanism. Therefore, the algorithm converges too slowly and is less used in modern artificial intelligence. Its iterative formula is as follows:

$$V(s_t) = V(s_{t+1}) + \alpha[R_t - V(s_t)]. \quad (2)$$

Unlike dynamic programming, this algorithm does not require modeling of the environment or limited information about the environment, but it also has a slower convergence rate because it features learning average rewards.

The TD learning algorithm is one of the most important algorithms in the reinforcement learning method. It is a combination of the above two methods. The iterative formula of the TD (0) algorithm is

$$V(s_{t+1}) = V(s_t) + \alpha(r_{t+1} + \gamma V(s_{t+1}) - V(s_t)). \quad (3)$$

The TD algorithm was proposed in 1998, and it was proved that the TD algorithm must converge when the learning rate satisfies certain conditions. However, the convergence rate of the TD algorithm is slow because the agent only changes the value function estimates of neighboring states in each iteration [17]. The effective method is that when the agent obtains the instantaneous reward value, it can take any step backwards, which is the so-called multistep TD learning algorithm. The convergence rate of the TD (μ) learning algorithm is significantly improved by the following iterative formula:

$$V(s_t) = V(s_t) + \alpha(r_{t+1} + \gamma V(s_{t+1}) - V(s_t))e(s). \quad (4)$$

Among them, $e(s)$ is defined as the qualification trace of state s, which can be calculated in the following ways:

$$e(s) = \begin{cases} \gamma\mu e(s) + 1, \text{if } s = s_t, \\ \gamma\mu e(s), \text{otherwise}. \end{cases} \quad (5)$$

The Q-learning algorithm is a model-independent reinforcement learning algorithm proposed in 1989. Its essence is an off-policy TD learning algorithm. Different from the TD algorithm, the state is used in the Q-learning update iteration, and the reward value $Q(s, a)$ of the action pair is used as the estimation function, instead of the reward value $V(s)$ of the state in the TD as the estimation function. The iterative form of the Q-learning algorithm is as follows:

$$Q(s_t, a_t) = Q(s_t, a_t) + \alpha_t \left(r_{t+1} + \gamma \max_a Q(s_{t+1}, a_{t+1}) - Q(s_t, a_t) \right). \quad (6)$$

Among them, a_t is the learning rate of the agent at time t, and γ is the discount factor. Under the nondeterministic Mahalanobis decision process, the learning rate of Q-learning also satisfies the following two conditions:

$$\sum_{l=1}^{\infty} \alpha_l = \infty, \quad (7)$$

$$\sum_{l=1}^{\infty} \alpha_l^2 < \infty. \quad (8)$$

When $1 \longrightarrow \infty$, Qk (s, a) will receive $Q^*(s, a)$ with probability 1.

The Sarsa learning algorithm is proposed as an improved network form of the Q-learning algorithm, which still uses Q -value iteration. The iterative calculation formula for the

value function of the Markov decision process in the Sarsa learning algorithm is

$$Q(s_t, a_t) = Q(s_t, a_t) + \alpha(r_{t+1} + \gamma Q(s_{t+1}, a_{t+1}) - Q(s_t, a_t)). \tag{9}$$

The main difference between Sarsa algorithm and Q algorithm is that the Q algorithm uses the maximum operator of the next action value function to adjust the action value function estimate of the current step, while the Sarsa algorithm only uses the actual trajectory data in the Mahalanobis decision process to adjust the action value function estimation [18].

The Markov decision chain is regarded as a basic multistep prediction model, which is the mathematical basis for reinforcement learning research. For the Markov decision chain, setting the state space as S, then

$$P_{ij}^{y} = P\{M_y = j | M_0 = i\}, \forall i, j \in S, y \in Y. \tag{10}$$

It is called the y-step transition probability of the Markov decision chain starting from state i and transferring to j after y-steps. Letting P be a matrix composed of all elements, there are

$$P^{(y)} = \left(P_{ij}^{y}\right). \tag{11}$$

The above formula is the y-step transition probability matrix of the Markov decision chain, and the one-step transition probability matrix is P.

Reinforcement learning methods first mathematically model a class of stochastic problems with discrete states and discrete time. In practice, the Markov decision model is the most commonly used [19].

The discrete-time finite Markov decision process can be expressed as

$$\forall i, j \in S, a \in A, y \geq 0, \tag{12}$$

$$P\left(M_{y+1} = j \middle| M_y = i, A_y = a, M_{y-1}, A_{y-1}, \cdots, M_0, A_0\right), \tag{13}$$

$$P\left(M_{y+1} = j \middle| M_y = i, A_y = a\right) = P(i, a, j). \tag{14}$$

J is the objective function of decision optimization. The state transition probability P satisfies

$$\sum_{j \in S} P(i, s, j) = 1. \tag{15}$$

There are two main types of decision optimization objective function J of the Markov decision process. That is, the discounted total return target and the average expected return target, respectively, were shown in the following two equations:

$$J_d = E\left(\sum_{t=0}^{\infty} r_t\right), 0 < \gamma < 1, \tag{16}$$

$$J_a = \limsup_{Y \longrightarrow \infty} \frac{1}{Y} E\left(\sum_{t=0}^{Y-1} r_t\right). \tag{17}$$

These two decision optimization objective functions have been widely studied and applied in the field of dynamic programming, and a lot of research has also been done in reinforcement learning theory and algorithms, mainly for the total return discount objective function.

3.2. Overview of UAV Communication. The unmanned aerial vehicle (UAV) is a powered, radio-controlled, or autonomously programmed aircraft operated by an unmanned pilot. The first drones were developed by the British in the 1970s and were primarily used as target drones in the initial stages; after entering the 1960s, the research on drones focused on reconnaissance; since then, the development of drones has entered the era of demand traction; since the 1980s, the miniaturization of UAVs has become another main direction for the development of UAVs. Many small UAVs have been used in civilian applications due to their advantages of light weight, good concealment, and low price [20, 21].

Currently, the development and use of UAVs is on the rise worldwide, mainly due to modern military and civilian needs and technological developments. The use of military UAVs has expanded from traditional aerial surveillance, battlefield monitoring, and battlefield assessment to combat, ground attack, missile interception, and even air combat. UAVs not only support manned combat aircraft but also replace manned aircraft in many situations. Currently, UAV research focuses on high-altitude and unmanned combat aircraft.

In terms of military use, UAVs such as the Global Hawk and Predator in the United States and Heron and Hunter in Israel are all UAVs with relatively successful research and development and excellent parameter performance. UAVs for military purposes can be divided into the following: target drones, mainly to identify the flight status and attack process of various aircraft; unmanned reconnaissance aircraft, used to monitor the battlefield and provide various intelligence information for combat troops; decoy drones are mainly used to induce the enemy to turn on the radar to obtain radio wave information and attract enemy firepower; signal jamming drones are used for electromagnetic interference and electronic detection of the enemy; and unmanned combat drones are a combination of fighter jets and drones. They can usually carry small precision weapons and can attack and intercept missiles to achieve combat purposes. UAVs are mainly used for civilian use in forest fire fighting, communication relay, pesticide spraying, aerial photography of competitions, and meteorological detection.

Compared with manned aircraft, UAV has the following characteristics and advantages: simple structure, no traditional cockpit, and UAV is much smaller than manned aircraft; this safety feature is great, and there will be no accidents; the performance is good, and the pilot factor does not need to be considered when developing the UAV; concealment, compared to manned aircraft, the size and mirror

surface of drones are much smaller, coupled with unique and complex designs and concealment materials, making them much more stealthy and survivable; the cost is low, the cost of UAV is only one-tenth or even a few percent of manned aircraft; and it is convenient and flexible to take off and land and has a short fuselage [22, 23].

In order to maximize the role of a single UAV, expand the application field of UAVs and make UAVs safer and more reliable when performing various tasks such as aerial surveillance, reconnaissance, and combat, and a multi-UAV system is proposed. Several research activities related to UAVs have been carried out in many fields. In the field of joint control of multiple UAVs, the main aspects being studied are the command and control of multiple UAVs, trajectory planning, and multimission [24].

Due to the characteristics of strong network dynamics and individual control autonomy, the multi-UAV system requires the multi-UAV network to have automatic networking and adapt to the rapid changes of network topology. Mobile ad hoc network (MANET) becomes the network technology for multi-UAV systems. The "UAV Roadmap" and "UAV System Integration Roadmap" issued by the US military put forward the important role of UAVs in the future global information network and pointed out that UAV self-organizing network will be the main content of multi-UAV network research in the future. Based on the above research and analysis, it can be concluded that the usefulness of the information transmitted between multiple UAVs is highly dependent on the communication performance; so, communication plays a key role in UAV dynamics.

Due to its fast flight speed, cooperative autonomy, limited energy, and irregular topology changes, the multi-UAV system also puts forward higher requirements for the network technology it adopts. The characteristics of the multi-UAV network can be summarized as follows: without a central node, in order to increase the robustness of the UAV system, the overall structure of the multi-UAV network should be equivalent to a peer-to-peer network; self-organizing, multi-UAV systems should have the characteristics of rapid deployment and rapid combat; when some drones in the network fail and cannot continue to perform tasks, the network topology needs to be rebuilt to maintain normal network communication; so, the network needs to be self-healing; dynamically changing network topology, the external environment of the UAV is complex during the execution of the mission, and its movement track is generally executed according to the preset route; good QOS and high security, due to the characteristics of wireless communication and the influence of the unknown environment in which the drone performs the task, the data transmission between the drones needs to have high security.

Mobile autonomous network (MANET) is not a new technology, it has been used for more than 40 years, and the idea and concept of MANET was first proposed in the United States in 1968.

The protocol of MANET network consists of physical layer, link layer, network layer, and application layer. The operating environment of the MANET network is very different from that of the wired network; so, the technology chosen for the network is also very different, especially in the lower three layers of the network: the physical layer, the link layer, and the network layer. The corresponding relationship between the MANET protocol stack model and the OSI model is shown in Figure 4.

The physical layer is responsible for modulation, coding, transmission, and reception of wireless data. The communication layer is divided into a medium access layer (MAC) and a logical link control layer (LLC), which are responsible for regulating access to shared wireless channels and control of logical links. The network layer is a key feature of the metropolitan area network technology, which distinguishes it from other networks by its basic features. The network layer provides transport protocols, mobile communication algorithms, and dynamic single-path and multipath routing algorithms for the metropolitan area network. Network layer routing protocols usually meet the following requirements: distributed operation, loop-free routing, demand-driven routing, high security, and support for one-way communication.

UAV MANET has three typical applications: battlefield coverage, battlefield reinforcement, and extended applications. Battlefield coverage refers to deploying multiple UAVs to form a metropolitan area network in order to expand the reconnaissance capabilities of UAVs to achieve coverage of the entire battlefield; battlefield reinforcements are mainly used for long-range target reconnaissance. The distance from the base station to the target exceeds the communication range of a single UAV; so, multiple UAVs must be deployed to transmit target reconnaissance signals; the extended application diagram of the UAV MANET network is shown in Figure 5.

The UAV network is connected to the global information network through relay satellites or ground UAV control stations and can be used as a channel to receive and transmit information required for cyber warfare by transmitting reconnaissance signals and forwarding control instructions to the ground combat network.

4. Multi-UAV Communication

4.1. Multi-UAV for Reinforcement Learning. This section simulates the multi-UAV communication trajectory and analyzes the results to verify its effectiveness. The TensorFlow framework is used to build a reinforcement learning network, in which both the actor and critic networks are two-layer fully connected networks, and the rectified linear unit (ReLU) and the sigmoid function are used as activation functions.

Since there is no work to solve the joint problem of continuous communication and linking of multiple UAVs, the communication trajectory obtained by the strategy proposed in this section is compared with the communication trajectory obtained by the basic greedy strategy to verify its feasibility and effectiveness. The purpose of the compared greedy algorithm is to minimize the AoI, and each time the ground node with the smallest AoI is selected for service, the

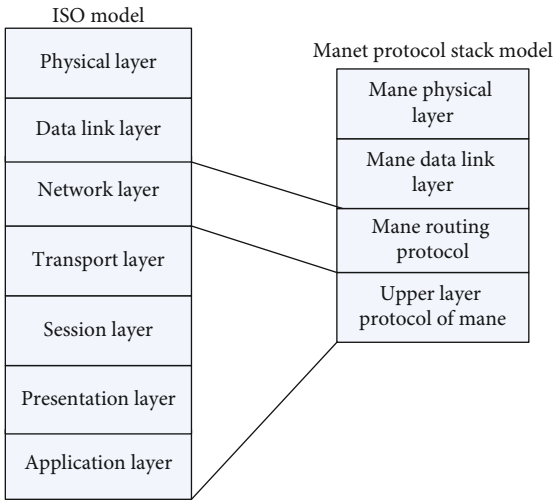

Figure 4: Correspondence between MANET protocol stack model and OSI model.

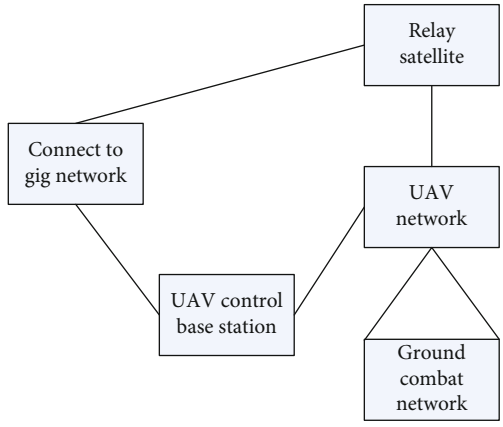

Figure 5: Schematic diagram of extended application of UAV MANET network.

communication trajectory is to fly to the selected node until the information transmission is completed.

In the simulation reinforcement learning communication strategy, when the task starts at $k = 0$, all nodes update the data once, then the ground nodes are updated twice when $k = 20$, the ground nodes are updated for the third time when $k = 40$, and the remaining nodes will not be updated again during the flight cycle. Since the flight time is required to reach the transmission range of the ground node, the communication trajectory obtained by this strategy has a trade-off between the flight time and the AoI. Jointly planning the trajectory of the drones working together and the drone link sequence make the AoI minimize.

The performance of the planned communication trajectory is analyzed. First, the simulation analysis of the time-dependent change process of the target performance AoI value during the task execution process is carried out. The comparison of the evolution process of AoI over time under different strategies is shown in Figure 6.

As can be seen from Figure 6, which is marked as the corresponding AoI value when a certain self-task is completed, it can be seen that the AoI finally reached by the communication trajectory of reinforcement learning is 115. The total AoI obtained by the AoI greedy strategy is 140 seconds, which reduces the total AoI by about 18% and effectively improves the performance of the system. This is because, compared with the greedy strategy, the communication trajectory through reinforcement learning can more reasonably plan the communication trajectory according to the information generation law of the century.

In order to further verify the performance of the proposed communication trajectory planning strategy, based on Monte Carlo simulation, the results obtained by 50 simulations were averaged, and the final Aol was further compared under different numbers of ground nodes. Assuming that the total amount of tasks remains unchanged, the total task amount is equally divided into different numbers of ground nodes to compare the final Aol value of the communication trajectory under the proposed reinforcement learning algorithm and the communication trajectory obtained by the Aol greedy algorithm. The final AoI comparison of different ground nodes is shown in Figure 7.

As can be seen from Figure 7, when the number of ground nodes is 6 and 10 for the communication trajectory of reinforcement learning, the AoI is 118 and 157, respectively; the greedy algorithm is 139 and 199; that is, the AoI that can be obtained by the reinforcement learning algorithm is smaller, and as the number of ground nodes increases, its advantages are more obvious. Therefore, in a more complicated situation with the increase of ground nodes, the strategy of simply selecting the nodes to be served according to the greedy strategy to determine the communication trajectory is not suitable. It is necessary to consider the collaborative work between UAVs as much as the reinforcement learning strategy and obtain better communication trajectories and link strategies through multiple offline learning.

4.2. Multi-UAV Route Planning. In this section, the communication route planning method based on the reinforcement learning algorithm is simulated and optimized. Two groups of simulation results are given before and after optimization. The parameters of the two groups of simulation experiments are different in the number of flight steps of the UAV, and other basic parameters are the same.

In simulation experiment 1, the initial speed direction of each UAV is the vertical boundary line pointing into the mission area. Assuming that the flying distance of the UAV after a fixed time interval is one step, when the number of flight steps in this experiment is 30 steps, the coverage rate of the six UAVs within 30 steps of flight changes as shown in Figure 8.

It can be seen from Figure 8 that with the increase of flight steps, the coverage of the mission area increases rapidly, the coverage of the task area is 0.76, 0.85, 0.97, 0.98, 0.98, 0.99, and 1, respectively, and the complete monitoring coverage of the task area is completed around the 15th step. It can be seen from the above simulation results that the

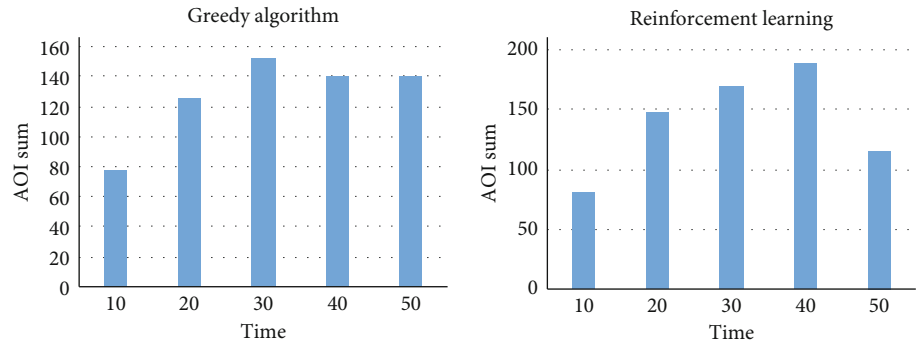

Figure 6: Comparison of the evolution of AoI over time under different strategies.

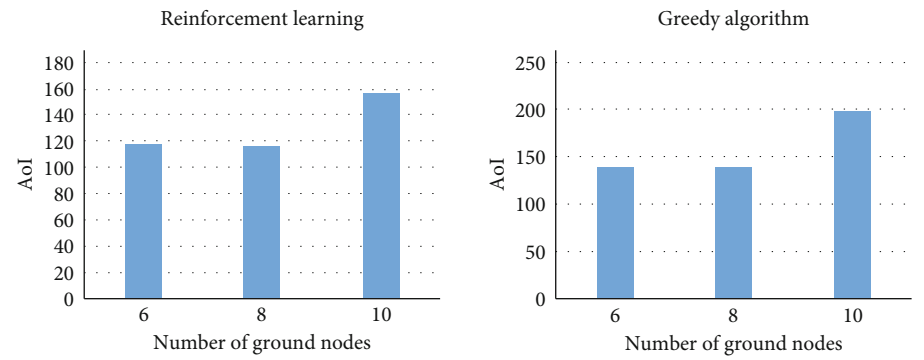

Figure 7: Final AoI comparison of different ground nodes.

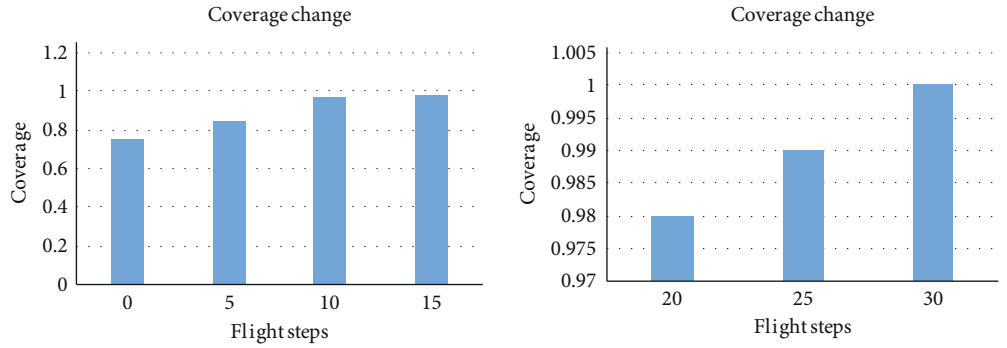

Figure 8: Coverage variation of 6 drones within 30 steps of flight.

route of multiple UAVs planned based on the reinforcement learning algorithm makes the percentage of surveillance coverage area of the UAV swarm sustainably maintained above 98% after convergence. It is proved that the flight of multiple UAVs along the route planned by this method can realize the maximum continuous monitoring of the designated target area by the UAV swarm.

In simulation experiment 2, the starting coordinates and initial speed directions of each UAV are the same as those in experiment 1, and the number of flight steps in this experiment is 300 steps. The coverage changes of 6 UAVs within 300 steps of flight are shown in Table 1.

It can be seen from Table 1 that the coverage rate of the six drones reached 0.970, 0.969, 0.970, 0.971, 0.972, and 0.973 at the lowest and 0.995, 0.996, 0.997, 0.998, 0.999, and 1 at the highest; when the drones fly longer and the number of flight steps is longer, the surveillance coverage of the target area by the drone group will fluctuate greatly. The onboard radar has an average coverage of the mission area of 98.1%; so, this will be improved on below.

Based on the above two simulation results, optimization analysis is carried out to demonstrate the effectiveness of the improved reinforcement learning method. The following two simulation experiments are introduced: the first

Table 1: Coverage change of 6 UAVs within 300 steps of flight.

Steps	50	100	150	200	250	300
1	0.977	0.970	0.990	0.973	0.968	0.995
2	0.978	0.971	0.991	0.974	0.969	0.996
3	0.979	0.972	0.992	0.975	0.970	0.997
4	0.980	0.973	0.993	0.976	0.971	0.998
5	0.981	0.974	0.994	0.978	0.972	0.999
6	0.982	0.975	0.995	0.979	0.973	1

Table 2: The optimized coverage of 6 UAVs within 300 steps of flight.

Steps	50	100	150	200	250	300
1	0.974	0.984	0.985	0.995	0.993	0.988
2	0.975	0.985	0.986	0.996	0.994	0.989
3	0.976	0.986	0.987	0.997	0.995	0.990
4	0.977	0.987	0.988	0.998	0.996	0.991
5	0.978	0.988	0.989	0.999	0.997	0.992
6	0.979	0.989	0.990	1	0.998	0.993

Table 3: Coverage of 6 UAVs within 300 steps of the flight with the reinforcement learning multistep method.

Steps	50	100	150	200	250	300
1	0.995	0.990	0.993	0.994	0.992	0.991
2	0.996	0.991	0.994	0.995	0.993	0.992
3	0.997	0.992	0.995	0.996	0.994	0.993
4	0.998	0.993	0.996	0.997	0.995	0.994
5	0.999	0.994	0.997	0.998	0.996	0.995
6	1	0.995	0.998	0.999	0.997	0.996

simulation experiment is mainly to compare with the method before optimization to test the effectiveness of the improved method; the second experiment is mainly to test whether the reinforcement learning method is still effective under different simulation parameters.

In simulation experiment one, because the main purpose is to compare with the experimental results before the improvement, the same basic parameters as the experiment before the improvement are used. The coverage changes of the six UAVs optimized by the reinforcement learning method within 300 steps of flight are shown in Table 2.

It can be seen from Table 2 that the optimized 6 UAVs fly within 300 steps, and the average coverage rate of all UAV airborne radars to the mission area during the entire flight process is 98.9%, which is higher than that before optimization. The coverage changes of the 6 UAVs in the reinforcement learning multistep method within 300 steps are shown in Table 3.

From Table 3, it can be concluded that the 6-plus UAV of the reinforcement learning multistep method has an average coverage rate of 99.5% of the mission area during the entire flight process within 300 steps.

Combining all the experimental data in this section, we can know that the two improved methods used later will improve the surveillance coverage of the target area by the UAV swarm, and the multistep method of reinforcement learning has the best effect.

5. Conclusions

UAVs play an important role in intelligence and surveillance missions, electronic countermeasures, firepower, airborne early warning, target designation and communications, and important auxiliary information systems due to their flexibility and versatility, as well as the advantage of not having to worry about loss. At the same time, due to the information and intelligence requirements for high-speed communication, personal communication, and military covert/counter-secret communication, the demand for UAVs has greatly increased in recent years, and the demand for UAVs even exceeds the actual capabilities of existing systems. In the field of resource utilization and optimization, the field of optimizing UAV training has attracted extensive attention from international researchers. Therefore, it is very

important to study the use of reinforcement learning to optimize the UAV communication network, achieve higher throughput under the premise of ensuring communication quality, and avoid channel congestion and mutual interference in the UAV communication system. This paper puts forward practical suggestions for the development of multi-UAV communication through the research on the multi-UAV communication network of reinforcement learning, which has important theoretical and practical significance.

Data Availability

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflicts of Interest

The author declares no potential competing interests in this paper.

Authors' Contributions

And all authors have seen the manuscript and approved to submit to your journal.

References

[1] R. Amorim, H. Nguyen, P. Mogensen, I. Z. Kovacs, J. Wigard, and T. B. Sorensen, "Radio channel modeling for UAV communication over cellular networks," *IEEE Wireless Communications Letters*, vol. 6, no. 4, pp. 514–517, 2017.

[2] W. Fawaz, C. Abou-Rjeily, and C. Assi, "UAV-aided cooperation for FSO communication systems," *IEEE Communications Magazine*, vol. 56, no. 1, pp. 70–75, 2018.

[3] M. T. Mamaghani and Y. Hong, "Joint trajectory and power allocation design for secure artificial noise aided UAV communications," *IEEE Transactions on Vehicular Technology*, vol. 70, no. 3, pp. 2850–2855, 2021.

[4] K. Wang, C. Pan, H. Ren, W. Xu, L. Zhang, and A. Nallanathan, "Packet error probability and effective throughput for ultra-reliable and low-latency UAV communications," *IEEE Transactions on Communications*, vol. 69, no. 1, pp. 73–84, 2021.

[5] C. Liu, W. Yuan, Z. Wei, X. Liu, and D. W. K. Ng, "Location-aware predictive beamforming for UAV communications: a deep learning approach," *IEEE Wireless Communications Letters*, vol. 10, no. 3, pp. 668–672, 2021.

[6] S. J. Gershman and N. D. Daw, "Reinforcement learning and episodic memory in humans and animals: an integrative framework," *Annual Review of Psychology*, vol. 68, no. 1, pp. 101–128, 2017.

[7] C. Li, L. Cao, and X. Chen, "Cloud reasoning model-based exploration for deep reinforcement learning," *Dianzi Yu Xinxi Xuebao/journal of Electronics & Information Technology*, vol. 40, no. 1, pp. 244–248, 2018.

[8] X. B. Peng, P. Abbeel, S. Levine, and M. van de Panne, "DeepMimic," *ACM Transactions on Graphics*, vol. 37, no. 4, p. 1, 2018.

[9] A. Sallab, M. Abdou, E. Perot, and S. Yogamani, "Deep reinforcement learning framework for autonomous driving," *Electronic Imaging*, vol. 29, no. 19, pp. 70–76, 2017.

[10] H. Ying, Z. Zheng, and F. R. Yu, "Deep-reinforcement-learning-based optimization for cache-enabled opportunistic interference alignment wireless networks," *IEEE Transactions on Vehicular Technology*, vol. 66, no. 11, pp. 10433–10445, 2017.

[11] Y. He, N. Zhao, and H. Yin, "Integrated networking, caching, and computing for connected vehicles: a deep reinforcement learning approach," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 1, pp. 44–55, 2018.

[12] G. Li, N. Cao, P. Zhu et al., "Towards smart transportation system," *Journal of Organizational and End User Computing*, vol. 33, no. 3, pp. 35–49, 2021.

[13] Y. He, F. R. Yu, N. Zhao, V. C. M. Leung, and H. Yin, "Software-defined networks with mobile edge computing and caching for smart cities: a big data deep reinforcement learning approach," *IEEE Communications Magazine*, vol. 55, no. 12, pp. 31–37, 2017.

[14] M. Mahmud, M. S. Kaiser, A. Hussain, and S. Vassanelli, "Applications of deep learning and reinforcement learning to biological data," *IEEE Transactions on Neural Networks*, vol. 29, no. 6, pp. 2063–2079, 2018.

[15] M. Cutler, T. J. Walsh, and J. P. How, "Real-world reinforcement learning via multifidelity simulators," *IEEE Transactions on Robotics*, vol. 31, no. 3, pp. 655–671, 2015.

[16] L. Lei, Z. Wang, and H. Zhang, "Adaptive fault-tolerant tracking control for MIMO discrete-time systems via reinforcement learning algorithm with less learning parameters," *IEEE Transactions on Automation Science and Engineering*, vol. 14, no. 1, pp. 299–313, 2017.

[17] J. Hwangbo, I. Sa, R. Siegwart, and M. Hutter, "Control of a quadrotor with reinforcement learning," *IEEE Robotics & Automation Letters*, vol. 2, no. 4, pp. 2096–2103, 2017.

[18] T. Liu, X. Hu, S. E. Li, and D. Cao, "Reinforcement learning optimized look-ahead energy management of a parallel hybrid electric vehicle," *IEEE/ASME Transactions on Mechatronics*, vol. 22, no. 4, pp. 1497–1507, 2017.

[19] S. S. Mousavi, M. Schukat, and E. Howley, "Traffic light control using deep policy-gradient and value-function-based reinforcement learning," *IET Intelligent Transport Systems*, vol. 11, no. 7, pp. 417–423, 2017.

[20] R. P. Selvam, "Earthworm optimization with deep transfer learning enabled aerial image classification model in IoT enabled UAV networks," *Fusion: Practice and Applications*, vol. 7, no. 1, pp. 41–52, 2022.

[21] M. R. Brust, G. Danoy, D. H. Stolfi, and P. Bouvry, "Swarm-based counter UAV defense system," *Discov Internet Things*, vol. 1, no. 1, p. 2, 2021.

[22] Y. Khosiawan, Y. Park, I. Moon, J. M. Nilakantan, and I. Nielsen, "Task scheduling system for UAV operations in indoor environment," *Neural Computing and Applications*, vol. 31, no. 9, pp. 5431–5459, 2019.

[23] K. Hossain, C. Mantel, and S. O. Forchhammer, "No-reference prediction of quality metrics for H.264-compressed infrared sequences for unmanned aerial vehicle applications," *Journal of Electronic Imaging*, vol. 28, no. 4, article 043012, 2019.

[24] E. Anderlini, D. Forehand, P. Stansell, Q. Xiao, and M. Abusara, "Control of a point absorber using reinforcement learning," *IEEE Transactions on Sustainable Energy*, vol. 7, no. 4, pp. 1681–1690, 2016.

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Research Article

Joint Event Relation Identification Based on Multiscale Convolutional Neural Network and Sharing Strategy

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At present, most of the event relation identification work mainly focuses on the sequential temporal and explicit causal relation between events. These methods usually ignore the role of synchronous temporal and implicit causal relation in sentences, which makes the semantic understanding of the model deviate from the text. In this paper, we propose a joint event relation identification model. The model uses bidirectional GRU and multiscale convolutional neural network to obtain the context semantic features and multiscale local semantic features of text, respectively. Then, these two kinds of features are fused to fully obtain the semantics of the text itself. In addition, we build encoders and decoders of event temporal and causal relation, respectively, to obtain the event temporal and causal semantic features from text. In this process, considering the correlation between event timing and causality, we use three different parameter sharing strategies to realize the interaction between event temporal and causal semantic features. The experimental results on the legal field dataset we constructed show that our model has made significant improvements compared with the baseline model. Through experimental analysis, our method can effectively improve the identification performance of synchronous temporal and implicit causality relation.

1. Introduction

Event relation identification [1] in text is an important research topic in the field of information extraction and natural language processing, especially in some specific fields, such as the judicial field. Mastering the causal and temporal relation between events can provide support for the analysis of the cause and development of the case. Among the possible relation types between events, this paper focuses on the joint identification of temporal and causal relation.

For the causal relation of events, it mainly depends on the explicit causal indicators in the text, such as "cause," "so," "therefore," and "because." By constructing the causal rule base [2] and using the model to learn the causal relation features in the text, the causal relation between events can be identified. In example 1 shown in Figure 1, due to the causal indicator "cause," the model can easily identify the "cause-effect" relation between event A and event B. However, in the face of some implicit causal relation, that is, when there are no explicit causal indicators in the text, the semantic features of causality are obscure, and it is difficult for the model to learn the causal features. In example 2 shown in Figure 1, there are no indicators in the text that can directly express cause and effect, so it is difficult to obtain the "cause-effect" relation between event A and event B.

For the temporal relation of events, the event chain is constructed according to the shortest dependent path [3] between events or the sequence of events in the text, and then, the event chain [4] is optimized to distinguish the temporal relation. In example 3 shown in Figure 2, by analyzing the sequence of events in the text, it is clear that there is a "before" relation between event A and event B and a "before" relation between

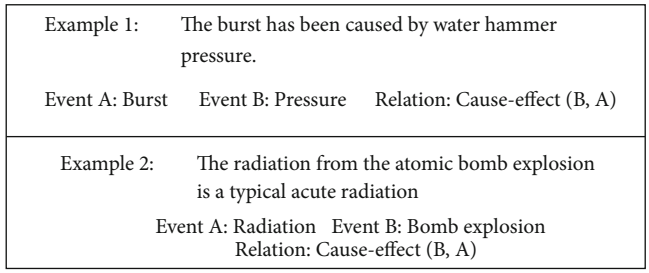

Figure 1: Examples of causal indicators.

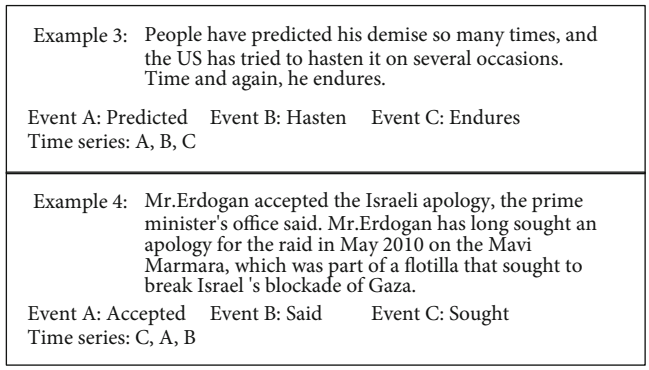

Figure 2: Example of causal event chain.

event B and event C. However, there are some differences between the sequence of events in the text and the sequence of their occurrence. When the difference is large, it is difficult to optimize the event chain, resulting in the difficulty of identifying the sequence of events. In example 4 shown in Figure 2, the sequence of events in the text is "A, B, C," but temporal relation between them is "C, before, A," "A, before, B." Due to the great difference between the initial event chain and the real results, the mainstream methods are difficult to completely optimize the initial event chain.

In this paper, we propose a joint event relation identification model of timing and causality. Our contributions include the following:

(i) The fusion of context and multiscale local semantic features is used to fully mine the semantic information contained in the text, so as to provide semantic support for causal and temporal relation feature mining

(ii) Temporal and causal relation encoders and decoders are constructed, respectively, to amplify the causal and temporal features of events in the text semantic information, and the correlation learning of timing and causality is realized by using the shared parameter strategy

(iii) We experiment on the constructed legal domain dataset, and the experimental results show that the performance of our proposed model is better than that of the baseline model

2. Related Work

At present, the research of event relation identification mainly focuses on event causal and temporal relation identification. Among them, event causality identification mainly excavates the causality between ordered event pairs, and event timing identification mainly distinguishes the sequential timing and synchronous timing between events.

2.1. Event Causality Identification. For the study of event causality, the method based on template matching was mainly used in the early stage. Kaplan and Berry-Rogghe [5] used manual weaving rules to establish domain knowledge base and used knowledge reasoning technology to identify the causal relation between events. By combining with cue phrase and pattern matching, Khoo and Kornfilt [6] extracted causal language pattern rules for English corpus in the field of medicine and achieved good results in event causal recognition. Bethard et al. [7, 8] annotated the event timing and causality at the same time and used the manually annotated timing relation to assist the causality classifier to extract the causality between events. Mostafazade et al. [9] proposed an event semantic annotation model CaTeRS, which provides an annotation tool for the joint identification of event timing relation and causality. Mirza and Tonelli [10] combined the prediction results of event causality to make auxiliary judgment on the time sequence relation, so as to realize the correlation between event timing and causality. Using the constraints and linguistic rules between time series and causality, Ning et al. [11] transformed the joint identification task of event time series and causality into an integer linear programming problem and used deep learning technology to solve the problems existing in causality identification.

Riccomagno and Smith [12] proposed the chain event graph model, which is a discrete Bayesian network model and provides a flexible and highly scalable framework. The model can be used to express and analyze the meaning of causal hypothesis and strengthen the causal reasoning ability of the model through the interactive calculation of causal correlation generated in the basic network. Acharya and Lee [13] proposed an incremental causality network model to assist in inferring causality by learning time priority. The model infers causality by using an incremental Bayesian network called incremental hill climbing Monte Carlo. In addition, the authors also propose a two-layer causal network, which can realize the causal analysis of event flow without prior knowledge.

2.2. Event Timing Relation Identification. The early research on the temporal relation of events paid more attention to the various semantic features contained in the text itself. Marcu and Echihabi [14] paired words in order and took it as a feature of temporal relation to realize the discovery of temporal relation. With the establishment and development of TimeML (Time Markup Language) tagging system and the emergence of time series corpora such as TimeBank, more and more researchers began to extract event temporal relations from high-quality time series corpora such as

TimeBank. Mani et al. [15] used event attributes to construct feature vectors based on TimeBank labeled corpus, including event type, posture, shape, polarity, and tense, and used maximum entropy classifier to identify temporal relations. On the basis of Chambers et al. [16], Mani et al. [17] further combined semantic features such as part of speech and syntactic tree structure and extracted lexical and morphological features from WordNet, so as to greatly expand the feature space, which is conducive to the classifier to fully learn the temporal features between events.

In recent years, the global optimization method based on graph model has been widely used in many tasks, such as event identification and event timing relation identification. Chambers and Jurafsky [18] used integer linear programming method to improve the experimental performance on English temporal relation corpus. Li et al. [19] mined multiple document-level constraints derived from Chinese event semantics and used the integer linear programming method to globally optimize the classifier results, which significantly improves the recognition performance of event timing relation in Chinese text. Xu et al. [4] proposed an event timeline framework based on joint reasoning; that is, the events in the article form a complete event chain according to the order of their occurrence, then used the integer linear programming model to optimize the event chain, and add the event homonymy information to the model, which further improves the recognition ability of the model to the temporal relation.

The existing event causality identification methods mainly focus on explicit causality. However, due to the lack of explicit causality indicators in some texts, the model cannot accurately obtain the causal semantic features between events and identify the implicit causality in the text. For the identification of event timing relation, the existing research mainly constructs the event chain through the dependent path between events or the sequence of events in the text and then optimizes the event chain through global reasoning, integer linear programming, and other methods, so as to distinguish the event sequence and synchronous timing. However, the sequence of events in some texts is quite different from that in the text. When the generated event chain is different from the beginning and end nodes of the real time chain and the intermediate nodes are also misplaced, the existing methods can only optimize some nodes of the event chain. It is difficult to optimize the nodes with a large span, such as the beginning and end nodes, resulting in the model that cannot accurately distinguish the sequence of events and synchronous timing relation in the text.

3. Model

We propose a joint event relation identification model based on multiscale CNNs and sharing strategy. The overall architecture is shown in Figure 3. Firstly, the initial semantic representation of the text is obtained by BERT [20]. The context semantic features and multiscale local semantic features of the text are obtained through Bi-GRU [21] and multiscale convolution neural network [22], respectively. The multiscale CNN obtains the local semantic features of the text with different granularity by setting different convolution kernel sizes. Then, the context semantic features and multiscale local semantic features are fused to fully obtain the rich semantic information in the text. Based on the fused semantic information, encoders and decoders of event causality and temporal relation are constructed, respectively, to amplify the causal and temporal features implied in the semantic features of the text itself, and three different shared parameter strategies are used to realize the correlation between causal and temporal features, so that temporal and causal relations can provide additional semantic information for each other's accurate identification. Finally, the event relation classifier is used to recognize the event causality and temporal relation.

3.1. Context and Multiscale Local Semantic Feature. For text context semantic feature acquisition, we use Bi-GRU to extract text features and obtain text context semantic features through forward and backward GRU networks, respectively. The specific calculation method of GRU network semantic status update is as follows:

$$\begin{aligned} z_t &= \sigma(W_z \bullet [h_{t-1}, x_t]), \\ r_t &= \sigma(W_r \bullet [h_{t-1}, x_t]), \\ \widetilde{h_t} &= \tanh\left(W \bullet [r_t * h_{t-1}, x_t]\right), \\ h_t &= (1 - z_t) * h_{t-1} + z_t * \widetilde{h_t}, \end{aligned} \tag{1}$$

where h_{t-1} is the contextual semantic information of the $t-1$ word in the text, x_t is the initial semantic representation of the tth word in the text, h_t is the contextual semantic information of the tth word in the text, and σ is the activation function. z_t is the update door, r_t is the reset door, and W_z and W_r is the weight calculated by the two gates, respectively. For the update gate, when its value is larger, it means that the more text context semantic information is retained at present, and the less text context semantic information is retained in the previous sequence step. For the reset gate, the smaller its value is, the more context semantic information of the previous sequence step will be discarded, and the more semantic features of the current input word will be retained.

The text initial embedding is used as the input of Bi-GRU. The Bi-GRU network is composed of two GRU in different directions, which learn the contextual semantic features of the text from the front and back, respectively:

$$\begin{aligned} \overrightarrow{h_n} &= \overrightarrow{\mathrm{GRU}}\left(\overrightarrow{h_{n-1}}, x_n, \theta_{\mathrm{GRU}}\right), \\ \overleftarrow{h_n} &= \overleftarrow{\mathrm{GRU}}\left(\overleftarrow{h_{n-1}}, x_n, \theta_{\mathrm{GRU}}\right), \\ h_n &= \overrightarrow{h_n} \bigoplus \overleftarrow{h_n}, \end{aligned} \tag{2}$$

where $\overrightarrow{h_n}$ and $\overleftarrow{h_n}$, respectively, represent the hidden layer semantic representation of forward and backward GRU when the sequence step size is n; θ_{GRU} is the network

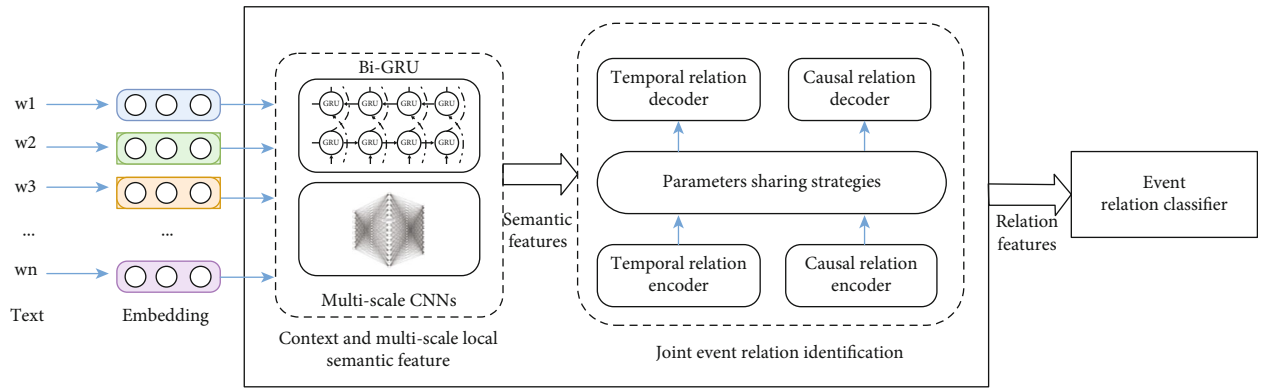

Figure 3: The overall architecture of the proposed joint event relation identification model.

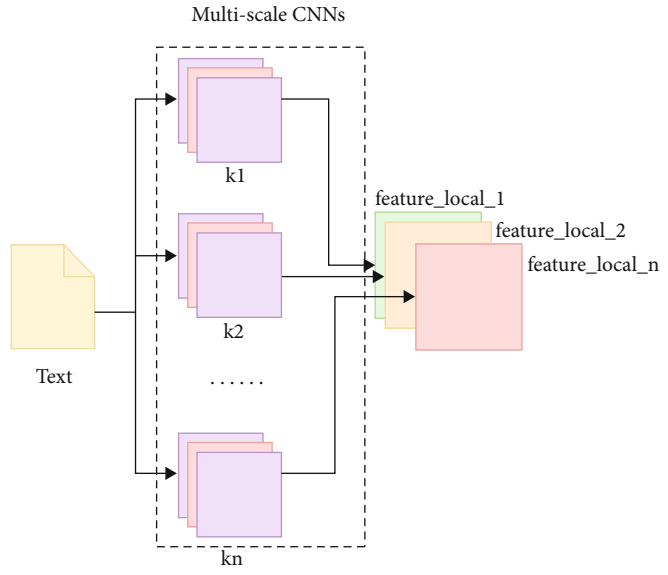

Figure 4: The feature learning mechanism of multiscale CNNs.

Table 1: Experimental results.

Model	Precision	Recall	F1
CNN-GRU-CRF	0.521	0.438	0.476
Attention-LSTM	0.493	0.469	0.481
Joint identification method	0.628	0.542	0.582
Encoder sharing	0.631	0.549	0.587
Decoder sharing	0.649	0.548	0.594
Both sharing	0.675	0.581	0.624

parameter of GRU; and x_n represents the initial semantic representation of the nth word in the text.

In order to fully mine the local semantic features of different granularity in the text, this section constructs a multiscale convolution neural network and sets different convolution kernel sizes. The feature learning mechanism of multiscale convolution neural network is shown in Figure 4. Given the text, the embedded initial semantic representation of the text is obtained through the BERT model and used as the input of multiscale convolutional neural network. Firstly, the convolution kernel set K of multiscale convolution neural network is defined, as shown in equation (3) below, where k_i represents the number of convolution kernels and n represents the number of convolution kernels.

$$K = \{k_1, k_2, k_3, \cdots, k_n\}. \tag{3}$$

The initial semantic representation of the text is input into the convolution kernel k_i to carry out convolution operation to obtain the local feature of words in the text, as shown in the following equation:

$$\text{Feature}_{\text{local\_}i} = \sigma\left(W_i \text{embedding}_{t:t+j-1} + b_i\right) \tag{4}$$

where $\text{embedding}_{t:t+j-1}$ is the embedded representation of the input word vector and j is the convolution kernel k_i window size; W_i and b_i is the weight and bias of convolution layer corresponding to different convolution kernel sizes in

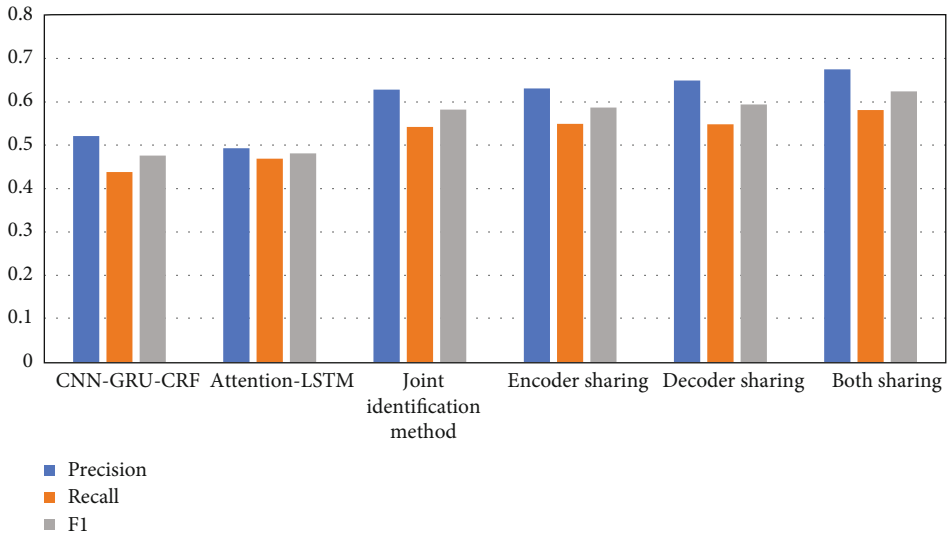

Figure 5: Comparison of experimental results.

Table 2: Ablation experimental results.

Model	Precision	Recall	F1
MCNN	0.428	0.394	0.410
GRU	0.399	0.384	0.391
MCNN-GRU	0.575	0.519	0.546
MCNN-GRU-sharing	0.642	0.573	0.606

multiscale convolution neural network, which is a learnable parameter; and $\sigma(\cdot)$ is the activation function.

Using equation (4) above, make all convolution kernels in the convolution kernel set act on the initial semantic representation of the text, and the local semantic features of words in the text with different granularity can be obtained, as shown in the following equation:

$$\text{Feature}_{\text{local}} = \left\{ \text{feature}_{\text{local}_1}, \text{feature}_{\text{local}_2}, \cdots, \text{feature}_{\text{local}_n} \right\}. \tag{5}$$

Because different convolution kernels can form local semantic features of text with different granularity, if these local semantic features are directly spliced, the dimension of local semantic features of words will be too high. Therefore, this section through the local semantic $\text{Feature}_{\text{local}}$ performs the maximum pooling operation to reduce the dimension of the text while retaining the local semantic features of different granularity, as shown in the following equation:

$$\max_{\text{local}} = \text{maxpooling}(\text{feature}_{\text{local}}). \tag{6}$$

The local features with different granularity of word vectors in the text are maximally pooled, and the output dimension is fixed through the full connection layer, and finally, the multiscale local semantic feature representation of the central word vector is obtained, as shown in the following equation:

$$F_{\text{local}} = \left\{ \max_{\text{local}_1}, \max_{\text{local}_2}, \cdots, \max_{\text{local}_n} \right\}. \tag{7}$$

Repeat the convolution process of the above central word vector, and scan the whole text sequence with the convolution set K to obtain the multiscale local semantic features of the text, as shown in the following equation:

$$\text{Feature}_{\text{local}} = \left\{ F_{\text{local}_1}, F_{\text{local}_2}, F_{\text{local}_3}, \cdots, F_{\text{local}_n} \right\}. \tag{8}$$

3.2. Relation Coding and Decoding. We build encoders and decoders of event causality and temporal relation, respectively. The event relation encoder is used to learn the semantic feature representation of event timing and causality in the text, and the event relation decoder is used to correspond the learned semantic feature representation of event relation with event relation coding.

3.2.1. Event Relation Encoder. We use Bi-LSTM [23] as the temporal and causal semantic feature encoder. This is because LSTM is mainly used to learn long-term dependency problems, which can well model and represent the dependency in the text, and because LSTM introduces memory unit, it can automatically update and selectively forget the dependency features in the text.

Fuse the context and multiscale local semantic features obtained in Section 3.1, and input them into the Bi-LSTM network to obtain the temporal or causal features in the text. The specific calculation method is as follows:

$$\begin{aligned} \overrightarrow{\text{rel\_}h_n} &= \overrightarrow{\text{LSTM}}\left(\overrightarrow{\text{rel\_}h_{n-1}}, [h_n ; F_{\text{local}}], \theta_{\text{LSTM}}\right), \\ \overleftarrow{\text{rel\_}h_n} &= \overleftarrow{\text{LSTM}}\left(\overleftarrow{\text{rel\_}h_{n-1}}, [h_n ; F_{\text{local}}], \theta_{\text{LSTM}}\right), \\ \text{rel\_}h_n &= \overrightarrow{\text{rel\_}h_n} \oplus \overleftarrow{\text{rel}_{h_n}}, \end{aligned} \tag{9}$$

where $\overrightarrow{\text{rel\_}h_n}$ and $\overleftarrow{\text{rel\_}h_n}$, respectively, represent the hidden layer representation of event relation semantics in the text of forward and backward LSTM at time n, θ_{LSTM} is the network parameter of LSTM, and $[h_n ; F_{\text{local}}]$ indicates the splicing and fusion of context semantic features and multiscale local semantic features of text.

3.2.2. Event Relation Decoder. The decoder is used to apply the learned event relation semantic feature $\text{rel\_}h_n$ converted into the hidden layer representation of event relation, which can be simply expressed by the following equation:

$$\text{rel} = \text{decoder}(\text{rel}_{hn}). \tag{10}$$

We use a full connection layer as the event relation decoder. As shown in equation (11) below, we map the event relation semantic features learned by the encoder to the event relation label representation space, so as to establish association with the event relation label, where W and B are the weight and offset of the full connection layer, respectively, which are learnable parameters, and $\sigma(\cdot)$ is the activation function.

$$\text{rel} = \sigma(W\text{rel}_{hn} + b). \tag{11}$$

3.3. Joint Event Relation Identification. Considering the correlation between timing and causality, there is often time series between events with causality, while there must be no causality between events with synchronous time series. Therefore, we take temporal relation identification and causality identification as two subtasks: $\text{task}_{\text{time}}$ and $\text{task}_{\text{cause}}$. There is no sequence between the two subtasks, but they are carried out at the same time. For the interaction between the two subtasks, we choose three different parameter sharing strategies: (1) sharing the coding layer, (2) shared the decoding layer, and (3) share the encoding layer and decoding layer.

3.3.1. Sharing the Coding Layer. Firstly, the event temporal relation identification task and the causal relation identification task, respectively, use their respective event relation encoders to process the semantic features of the text and obtain their respective event relation semantic features, as shown in equations (12) and (13) below:

$$\text{rel}_{\text{time}} = \text{Encoder}_{\text{time}}([h_n ; F_{\text{local}}]), \tag{12}$$

$$\text{rel}_{\text{cause}} = \text{Encoder}_{\text{cause}}([h_n ; F_{\text{local}}]), \tag{13}$$

where the event relation encoder is the Bi-LSTM encoder introduced in Section 3.2, h_n is context semantic feature, and F_{local} is a multiscale local semantic feature. Then, the two subtasks share their own event relation coding layer states, respectively, and splice them with their own coding layer states to generate joint relation semantic features, as shown in equations (14) and (15) below.

$$\text{rel}'_{\text{time}} = \text{rel}_{\text{time}} \bigoplus \text{rel}_{\text{cause}}, \tag{14}$$

$$\text{rel}'_{\text{cause}} = \text{rel}_{\text{cause}} \bigoplus \text{rel}_{\text{time}}. \tag{15}$$

Finally, the semantic features of event joint relation are decoded by using their respective event relation decoders to obtain the decoded event relation representation.

3.3.2. Shared the Decoding Layer. Similarly, the event temporal relation encoder and causality encoder are used to process the semantic features of the text to obtain their respective event relation semantic features rel_{time} and $\text{rel}_{\text{cause}}$, as shown in equations (12) and (13) above.

When decoding, the event timing relation and causality are decoded by their respective event relation decoders, as shown in equations (16) and (17) below.

$$d_{\text{time}} = \text{Decoder}_{\text{time}}(\text{rel}_{\text{time}}), \tag{16}$$

$$d_{\text{cause}} = \text{Decoder}_{\text{cause}}(\text{rel}_{\text{cause}}). \tag{17}$$

Then, the two subtasks share their own decoding layer states and splice them with their own decoding layer states, as shown in equations (18) and (19) below.

$$d'_{\text{time}} = d_{\text{time}} \bigoplus d_{\text{cause}}, \tag{18}$$

$$d'_{\text{cause}} = d_{\text{cause}} \bigoplus d_{\text{time}}. \tag{19}$$

In the final classification of event relation, the full connection layer is used to predict the event relation of the spliced decoding layer state, as shown in equations (20) and (21) below, where W_{time}, b_{time} and W_{cause}, b_{cause} are the weight and offset of the full connection layer of the two subtasks, respectively, and $\sigma(\cdot)$ is the activation function.

$$d'_{\text{time}} = d_{\text{time}} \bigoplus d_{\text{cause}}, \tag{20}$$

$$d'_{\text{cause}} = d_{\text{cause}} \bigoplus d_{\text{time}}. \tag{21}$$

3.3.3. Share the Encoding Layer and Decoding Layer. After passing through the respective event relation encoders, the semantic feature representation of the respective event relation is obtained. The two subtasks share their respective coding layer states and splice them to generate the semantic representation of joint relation $\text{rel}'_{\text{time}}$ and $\text{rel}'_{\text{cause}}$, as shown in equations (14) and (15) above.

Then, each event relation decoder is used for decoding to obtain the decoded event relation hidden layer representation d_{time} and d_{cause}. Then, the two subtasks share their own decoding layer states and splice them with their own decoding layer states, as shown in equations (18) and (19) above.

Similarly, when classifying the event relation, the full connection layer is used to predict the event relation of the spliced decoding layer state, as shown in equations (20) and (21) above.

4. Experiments

In this part, we give the experimental results of the proposed model. We first describe the constructed dataset. Then, we

introduce the relevant settings of the experiment and the baseline of our comparison. The experimental results show that the proposed model is improved in the joint identification of event timing and causality.

4.1. Dataset. According to the needs of event sequence and causality extraction task and the relation between events which has directionality, it is necessary to mark the head event and tail event of the event relation in the text. We use "< E1 > event_1 < / E1 >" to represent the head event, use "< E2 > event_2 < /E2 >" to represent the tail event, and use "rel" to represent the relation between the head event "event_ 1" and tail event "event_ 2". For event relations, we define the following relation types: before, after, meanwhile, cause-effect, effect–cause, and other.

4.2. Experimental Settings. The hyperparameters of the model we use are set as follows: in the initial vectorization representation stage, set the word vector dimension output by the BERT pretraining language model to 762. In the stage of using Bi-GRU to obtain the semantic features of text context, set the number of layers of Bi-GRU to 2 and its dimension to 512. The multiscale convolution neural network is used to obtain the multiscale local semantic features of the text, and the convolution set K is set as

$$K = \{5,10,15,20\}. \tag{22}$$

In the event timing and causality feature coding stage, set the number of layers of Bi-LSTM to 2 and its dimension to 512. In the event timing and causality feature decoding stage, set the number of network layers of the full connection layer to 1 and its dimension to 256. In the event timing and causality prediction stage, set the number of network layers of the full connection layer to 1, and its dimension is the total number of event relation labels 7. In all parts using activation functions, except that the last step of event relation prediction uses softmax activation function, the rest uses relu activation function. The normal distribution with standard deviation $N(0,0.01)$ is adopted for all parameters in the model to initialize the parameters. The batch size during training is 16. The back propagation algorithm is used for learning, and the Adam optimizer is used for optimization training. LR is set to 0.0001.

4.3. Baseline and Evaluation Metrics. In order to verify the effectiveness of our proposed model, three comparison models are selected for comparison:

CNN-GRU-CRF: Zheng proposed an event causality identification model based on double-layer CNN-GRU-CRF, which regards event causality identification as a sequence annotation task. In this method, CNN and Bi-GRU are used to obtain the local semantic features and contextual features of the text, respectively, and fuse them. Then, CRF is used to obtain the dependency rules between event relation tags, determine the final prediction tag sequence, and complete the identification of event causality.

Attention-LSTM: Zhang proposed an event timing relation recognition model combining self-attention mechanism and neural network. Taking the shortest dependent path sequence of event sentences as the input of the model, first use the nonlinear sublayer (CNN or RNN) to preliminarily semantically encode the input of the model, then use the self-attention network layer to capture the global information in the output of the nonlinear layer, and finally use a softmax layer to classify the event timing relation.

Joint identification method: Zhang proposed a joint identification model of event timing and causality based on neural network. This method takes the dependent path sequence as the input of the model, takes the event timing identification as the main task, and takes the event causality identification as the auxiliary task. The correlation between causality and temporal relation is realized through parameter sharing. Finally, the relation classifier is used to classify timing and causality, respectively.

In addition, since we proposed three different parameter sharing strategies in the joint event relation identification stage, we also carried out experiments on three different parameter sharing strategies.

4.4. Quantitative Results. For the task of event timing and causality identification in the text, the accuracy, recall, and F1 are used to evaluate the performance of the model. Table 1 shows the specific values of the experimental results of the comparison model and the three models based on the parameter sharing strategy. Figure 5 more vividly shows the accuracy, recall, and F1 of the event relation extraction by different models. It can be seen that the model proposed in this paper has been significantly improved. It can be seen from the data in the table that compared with the comparison model, the event relation joint identification model based on multiscale convolution neural network and sharing strategy has improved in various evaluation indexes. By comparing the experimental data of three shared parameter models, it can be found that the performance of the model based on shared coding and decoding layer is relatively better, while the performance of the model only shared coding layer is relatively weak.

By comparing with two single event relation identification models (CNN-GRU-CRF and attention-LSTM model in the table), it is found that the joint event relation identification model based on multiscale convolution neural network and sharing strategy proposed in this paper considers the correlation between event timing and causal relation, integrates event timing characteristics with event causal characteristics, and learns the correlation characteristics, which makes the model perform better in implicit causality identification and sequential, synchronous, and temporal differentiation tasks. Compared with the joint identification model (joint identification method in the table), it is found that although this method also considers the correlation between event timing and causality, it does not well model and represent the semantic features of the text itself in the previous feature construction stage, resulting in the lack of some semantic features of the text, so the performance of this model is relatively poor. Through the experimental results of the three proposed parameter sharing models, it is found that the strategy of sharing coding and decoding

layer comprehensively considers the different semantic information of event relation semantic features in the coding stage and decoding stage and integrates the event relation features, so it can well correlate the event timing relation and causality and play the role of auxiliary prediction.

In addition, in order to highlight the importance of each module in our model, we also conducted ablation experiments. The experimental results are shown in Table 2.

The number of layers and parameter settings of each model in the table are the same as those of the previous experiments. MCNN indicates that only multiscale local semantic features of text are obtained. GRU indicates that only context semantic features are obtained. MCNN-GRU acquires both features. MCNN-GRU-sharing also adds a parameter sharing policy. From the experimental results, it can be seen that compared with the context semantic features, the multiscale local semantic features obtained by MCNN are more important for the identification of event relations. By combining the two semantic features and fully modeling the semantic features of the text, the accuracy of event relation recognition can be further improved. The introduction of sharing strategy can fully consider the correlation characteristics between event timing and causality and play an auxiliary role in prediction.

5. Conclusion

Aiming at the difficulty of identifying the implicit causal relation of events in text and distinguishing the sequential and synchronous temporal relation, this paper proposes a joint event relation identification model based on multiscale convolutional neural network and sharing strategy. The context sequence semantic features and multiscale local semantic features of the text are obtained through Bi-GRU and multiscale CNNs, respectively, and then, the context sequence semantic features and multiscale local semantic features are fused to make full use of the rich semantic information in the text. Then, the coders and decoders of causality and temporal relation are constructed, respectively, to amplify the causality and temporal features implied in the semantic features of the text itself. In addition, we use three different shared parameter strategies to realize the correlation between temporal features and causal features, so that temporal features and causal relations can provide additional semantic features for each other's accurate prediction. We evaluated the proposed method on the constructed dataset. The results show that the performance of this method is better than that of the previous methods in the joint identification of event timing and causality.

Data Availability

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

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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References

[1] Z. Li, Q. Li, X. Zou, and J. Ren, "Causality extraction based on self-attentive BiLSTM-CRF with transferred embeddings," *Neurocomputing*, vol. 423, pp. 207–219, 2021.

[2] S. Zhao, T. Liu, S. Zhao, Y. Chen, and J. Y. Nie, "Event causality extraction based on connectives analysis," *Neurocomputing*, vol. 173, pp. 1943–1950, 2016.

[3] Q. Do, W. Lu, and R. Dan, "Joint inference for event timeline construction," in *Proceedings of the 2012 Joint Conference on Empirical Methods in Natural Language Processing and Computational Natural Language Learning*, pp. 677–687, 2012.

[4] Y. Xu, R. Jia, and L. L. Mou, "Improved relation classification by deep recurrent neural networks with data augmentation," in *Proceedings of COLING 2016, the 26th International Conference on Computational Linguistics: Technical Papers*, pp. 1461–1470, 2016.

[5] R. M. Kaplan and G. Berry-Rogghe, "Knowledge-based acquisition of causal relationships in text," *Knowledge Acquisition*, vol. 3, no. 3, pp. 317–337, 1991.

[6] C. S. G. Khoo and J. Kornfilt, "Automatic extraction of cause-effect information from newspaper text without knowledge-based inferencing," *Literary and Linguistic Computing*, vol. 13, no. 4, pp. 177–186, 1998.

[7] S. Bethard, W. Corvey, and S. Klingenstein, "Building a corpus of temporal-causal structure," in *Proceedings of the 6th International Conference on Language Resources and Evaluation*, pp. 908–915, Marrakech, Morocco: European Language Resources Association, 2008.

[8] S. Bethard and J. H. Martin, "Learning semantic links from a corpus of parallel temporal and causal relations," in *Proceedings of ACL-08: HLT, Short Papers (Companion Volume)*, pp. 177–180, Columbus, Ohio, USA: Association for Computational Linguistics, 2008.

[9] N. Mostafazadeh, A. Grealish, and N. Chambers, "CaTeRS: causal and temporal relation scheme for semantic annotation of event structures," in *Proceedings of the 4th Workshop on Events: Definition, Detection, Coreference, and Representation*, pp. 51–61, San Diego, California: Association for Computational Linguistics, 2016.

[10] P. Mirza and S. Tonelli, "CATENA: causal and temporal relation identification from natural language texts," in *Proceedings of COLING 2016, the 26th International Conference on Computational Linguistics: Technical Papers*, pp. 64–75, Osaka, Japan: Association for Computational Linguistics, 2016.

[11] Q. Ning, Z. Feng, and H. Wu, "Joint reasoning for temporal and causal relations," in *Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics (Long Papers)*, pp. 2278–2288, Melbourne, Australia: Association for Computational Linguistics, 2018.

[12] E. Riccomagno and J. Q. Smith, "The causal manipulation of chain event graphs," 2007, preprint arXiv: 0709.3380.

[13] S. Acharya and B. S. Lee, "Incremental causal network construction over event streams," *Information Sciences*, vol. 261, pp. 32–51, 2014.

[14] D. Marcu and A. Echihabi, "An unsupervised approach to recognizing discourse relations," in *Proceedings of the 40th*

Annual Meeting of the Association for Computational Linguistic, pp. 368–375, Philadephia, Pennsylvania, USA, 2002.

[15] I. Mani, M. Verhagen, B. Wellner et al., "Machine learning of temporal relations," in *Proceedings of the 21st International Conference on Computational Linguistics and 44th Annual Meeting of the ACL*, pp. 753–760, Sydney, Australia, 2006.

[16] N. Chambers, S. Wang, and D. Jurafsky, "Classifying temporal relations between events," in *Proceedings of the ACL 2007 Demo and Poster Sessions*, pp. 173–176, Prague, Czech Republic, 2007.

[17] I. Mani, B. Wellner, and M. Verhagen, "Three approaches to learning TLINKS in time ML," *Computer Science Department*, 2007.

[18] N. Chambers and D. Jurafsky, "Jointly combining implicit constraints improves temporal ordering," in *Proceedings of the 2008 Conference on Empirical Methods in Natural Language Processing*, pp. 698–706, Honolulu, Hawaii, USA, 2008.

[19] P. Li, Q. Zhu, and G. Zhou, "Global inference to Chinese temporal relation extraction," in *Proceedings of COLING 2016, the 26th International Conference on Computational Linguistics: Technical Papers*, pp. 1451–1460, Osaka, Japan, 2016.

[20] K. Cho, B. Van Merriënboer, and C. Gulcehre, "Learning phrase representations using RNN encoder–decoder for statistical machine translation," in *Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing (EMNLP)*, pp. 1724–1734, Doha, Qatar, 2014.

[21] J. Chung, C. Gulcehre, and K. H. Cho, "Empirical evaluation of gated recurrent neural networks on sequence modeling," 2014, preprint arXiv:1412.3555.

[22] Y. Wang, D. Ning, and S. Feng, "A novel capsule network based on wide convolution and multi-scale convolution for fault diagnosis," *Applied Sciences*, vol. 10, no. 10, p. 3659, 2020.

[23] B. A. Pearlmutter, "Learning state space trajectories in recurrent neural networks," *Neural Computation*, vol. 1, no. 2, pp. 263–269, 1989.

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Research Article

Artificial Intelligence Technology to Record the Number of Times the Ball Passes the Net in Tennis Matches

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Tennis competition is one of sports events. The vigorous development of sports can promote people's pursuit of sports spirit and promote social unity and stability. However, in the course of social modernization development, sports events also need to follow closely, and we can no longer rely on traditional tools to support the development of events, which is not conducive to the positive development of sports. Due to the problem that the number of times the ball crosses the net in the traditional tennis game is too backward and the error rate is high, this paper uses artificial intelligence technology to record the number of times the ball crosses the net in tennis games and introduces the Center Net target based on the diagnostic criteria and comprehensive evaluation of tennis nets. Detect and track tennis balls by target recognition, feature extraction, and other methods, and record the times of net passing. However, considering that abnormal behaviors will also occur in the process of tennis passing through the net, the density-based DBSCAN clustering algorithm is used to discriminate and record abnormal behaviors in tennis matches. In order to verify the detection performance of DBSCAN clustering algorithm and Center Net target detection, the video of tennis match was analyzed and compared by drone from the perspective of time and space. By recording the number of times the ball crosses the net during the tennis receiving, connecting and attacking, and stalemate phases, the performance of the two recording times is compared. R^2 are all higher than 0.94, and R values are 0.982 and 0.963, respectively, so the recall rate of DBSCAN clustering algorithm is 0.02 higher, which is better than Center Net target detection. Using artificial intelligence technology to record the number of times the ball crosses the net in tennis games can not only improve the scientificity and accuracy of the record but also promote the development of the sports industry.

1. Introduction

Sports is a product of the human social process. It can not only keep people in a good state of mind and work but also have the functions of promoting health, entertainment, and education. It can meet people's spiritual and cultural needs, promote national unity, and promote economic development. It develops the healthy development of society. Artificial intelligence is one of the types of computer science. Since the birth of artificial intelligence, the theory and technology have become increasingly mature. The technological products brought by artificial intelligence in the future will be the crystallization of human wisdom. And artificial intelligence technology has penetrated into all walks of life and has a positive role in promoting the development of the industry. The continuous development of deep learning and computer vision technology and the continuous upgrading of computer hardware have provided new ways and methods for tennis net counting in tennis matches.

The diagnostic criteria and comprehensive evaluation of tennis net times is an emerging research field in tennis. This paper systematically studies the whole process of tennis net times system construction, diagnosis, and comprehensive evaluation. When diagnosing the times of tennis passing

the net, Center Net target detection and DBSCAN clustering algorithm are used to analyze the game video, respectively, and the times of tennis passing the net are recorded. The target is selected by the method of Center Net target detection, the characteristic analysis of the target is performed, and the target is locked for diagnosis, which is beneficial to improve the accuracy of the record. The DBSCAN clustering algorithm records the number of abnormal tennis passes over the net during the game, which can greatly reduce the dispute time for scoring points during the game and is also conducive to the fairness of the game.

The pros and cons of the tennis net counting algorithm in the game are directly related to the evaluation of the game results. This paper mainly uses the Center Net object detection and the DBSCAN clustering algorithm to identify and count the tennis nets in the tennis match. In the process of counting the tennis nets in the game, the abnormal behavior in the game is analyzed according to the DBSCAN clustering algorithm, and the diagnostic indicators at all levels are used to carry out real-time diagnosis and analysis of the players during the game and after the game, which can relatively meticulously analyze the players' games. In the current state of the game, the second-level tactical diagnostic index evaluation method is used to track and diagnose the players' games, which can not only evaluate the number of times the players pass the net in each tactical link in each game but also evaluate the players' tactical levels in each period. The combination of artificial intelligence technology and sports competitions, tracking the competition according to artificial intelligence, and determining the results of the competition is beneficial to the principle of fairness and openness of the competition.

2. Related Work

With the advancement of science and technology, the sports industry is also approaching modernization. In order to solve the problem that tennis players move slowly and the shadows are missed by normal algorithms, Jie and Fei propose a method combining tennis player detection and improved Gaussian mixture model to remove the shadows of players in tennis games. In order to verify the effectiveness of the proposed method, the effects of the proposed method on shadow removal with the Gaussian mixture model method and the background difference model were compared [1]. Lever et al.'s study analyzed the impact of sleep on competition by combining factors such as written parameters, well-being, anxiety, and competition results on adolescent sleep records during high-performance youth tennis tournaments [2]. Meffert et al. looked at male players' pull length, serve and return behavior, and number of winners and forced and unforced errors to determine the possible impact of possible mental stress in a tiebreak situation, aim to compare player performance at tiebreak point (TBP) and nontiebreaker point (NTBP) [3]. Cui et al. use descriptive statistics that help provide general information on game characteristics and assess player performance. Through classification tree analysis, it was shown that tennis player performance depends on familiarity with the court surface as well as other contextual variables [4]. However, the relevance of intelligent technology research on the number of tennis passes in tennis games is still insufficient.

Artificial intelligence has brought about high-tech changes, which have contributed to the development of society. Zheng et al. studied the human sleep process and classified sleep stages and realized the extraction and classification of EEG features based on K-means clustering algorithm [5]. Chin et al. show great potential to improve system speed without degrading object detector accuracy by experimenting on the ImageNet VID dataset, i.e., the speedup of dynamic domain-specific approximation is up to 7.5 times [6]. Khalifa et al. use the method of detecting multiple objects by background subtraction to sequentially track the features of different surveillance videos. In object detection at each frame, pixel differences are computed against a reference background frame to detect objects that only apply to any ideal static condition [7]. Han et al. delve into a comprehensive review of object detection techniques based on advanced deep learning techniques, including object detection (OD), salient object detection (SOD), and class-specific object detection (COD) [8]. In order to improve the effect of automatic epilepsy detection, Zhan et al. proposed a new classification method based on unsupervised multiview clustering results, which reduces the sample dimension and increases the sample separability [9]. Gallo and Cappozi proposed a web-based data mining method to break through the limitations of human recognition ability, which combines correlation graphs with cluster analysis to rapidly extract patterns from WBM, which are then tied to manufacturing defects [10]. However, the accuracy of the study of tennis net counts still needs to be improved.

3. Tennis Net Recognition Technology in Machine Learning

3.1. Center Net Object Detection. Corner Net determines the target by extracting spatial information from the upper left and lower right corners of the detected object. Only the edge features of the target can be extracted, resulting in false detection. Therefore, in order to avoid the above problems, Center Net target detection is used. For object detection, the mean estimated score is usually complemented by angular nets, and this reduces false detections by the network [11].

In the early tennis technique and tactics research, after the statistical indicators were designed, they were collected on-site. Due to the limitation of human and material resources, there were few statistical indicators, and only some technical links could be collected for diagnosis and analysis [12]. Later, with the popularization and application of computers, Excel was used to compile corresponding tables for on-the-spot/post-game video collection and summary calculation data. Compared with manual work, this collection method was efficient, fast, and easy to operate and had more statistical indicators [13]. In order to evaluate the parameters, it is more convenient and faster to use a computer, but no matter what method of data collection is used, manual participation is required, and the collection

of a large amount of game data is still time-consuming and laborious, and complete intelligent collection has not been achieved.

Using artificial intelligence technology as an important way to strive to achieve intelligent training and competition plays an important role in improving the sports potential of athletes and transforms it into sports performance through competition [14]. Through the Center Net target detection technology, the game skill detection, tactical analysis, and diagnosis in tennis matches are used as the judging criteria. Center Net provides a simpler and more efficient object detection algorithm [15]. The main idea is as follows: the target frame is represented by a single point in the center of the target frame, and other attributes, such as target size, dimension, 3D range, orientation, and object pose, are regressed through image features at the position of the center point [16]. Regression models are both predictions and explanations, and this is reflected in the unordered series of events that the model outputs, but the disadvantage of multiple correlations is in predictive models. The overall structure of Center Net target detection is shown in Figure 1.

The basic network structure of Center Net is similar to that of Corner Net. The algorithm flow of Center Net is as follows: first, input a picture, after 7×7 target detection, reduce the picture size to a quarter of the original size, and extract it according to features [17]. In network extraction features, the difference between Center Net and Corner Net is as follows: Corner Net is an Hourglass Network composed of two hourglass modules, while Center Net is an Hourglass Network composed of an hourglass module. The prediction model is divided into three parts, heatmaps, size, and offsets. Among them, heatmaps is the center point information of the output prediction. Size is the width and height information of the predicted image. Offsets is used to fine-tune the prediction frame.

Winning or losing a tennis match requires several back-and-forth confrontations, a win or loss requires multiple rounds, a win or loss of a game requires multiple serve points and break points, and a win or loss requires at least one point or more [18]. The Center Net algorithm performs target detection on the center point of the tennis ball to obtain the target attribute and transmits the image to the fully curved network to form a heatmap; secondly, the peak point of the heatmap is determined; finally, the target position will be generated [19]. In this paper, the central net algorithm is used to detect the tennis net passing state. The target center point is shown in Figure 2.

In the tennis game picture, the tennis picture is used as input and input to DLA or Hourglass function map512*512*3 downsampling stride = 4, heatmap center offset (x,y), box size (width, height), and3*3Max pooling peak as object center, as shown in Figure 3.

Center Net center point prediction is to calculate the ground resolution point for a certain C class in each target object map during the whole training process, then mark the video image, and use the Gaussian kernel to distribute the key points to the feature map, making it overlap with the target image [20]. The central keypoint computes the regression target size for each target trained by the ensemble. To speed up the computation, a single size prediction is used for each object class, and the edge size is increased at the center point [21]. After inputting the original video, the objective function of the entire training is adjusted by adding relevant absorption, and the formula is as follows:

$$T = \left(\frac{a_1 + a_2}{2}, \frac{b_1 + b_2}{2}\right), \tag{1}$$

$$B_{abc} = \exp\left(-\frac{\left(a - \overset{\Lambda}{T}_b\right)^2 + \left(b - \overset{\Lambda}{T}_b\right)^2}{2\sigma^2 T}\right), \tag{2}$$

$$\overset{\Lambda}{T} = \left(\frac{T}{R}\right), \tag{3}$$

$$T_P = \left(\frac{a_1{}^{(P)} + a_2{}^P}{2}, \frac{b_1{}^{(P)} + b_2{}^P}{2}\right), \tag{4}$$

$$K_T = \left(a_2{}^{(P)} - a_1{}^{(P)}, b_2{}^{(P)} + b_1{}^{(P)}\right), \tag{5}$$

$$L_{\text{size}} = \frac{1}{m}\sum_{x=1}^{m}\left|\overset{\Lambda}{K}_{TP} - K_T\right|, \tag{6}$$

$$L_{\text{det}} = L_k + \lambda_{\text{size}} L_{\text{size}} + \lambda_{\text{off}} L_{\text{off}}, \tag{7}$$

$$\lambda_{\text{size}} = 0.1, \tag{8}$$

$$\lambda_{\text{off}} = 1. \tag{9}$$

The video data is intercepted by the video interception program, and the overall information of the tennis is marked with the annotation tool, as shown in Figure 4.

3.2. DBSCAN Clustering Algorithm. In the information age, huge amounts of data are generated every day. With the ever-increasing scale and dimension of data, how to effectively mine valuable information from these data has become a hot issue [22]. Machine learning algorithms are generally divided into supervised learning and unsupervised learning, and the DBSCAN clustering algorithm belongs to unsupervised machine learning [23]. For the supervised learning of DBSCAN clustering algorithm, it mainly trains the collected tennis match data and then sends the data of the number of times the ball crosses the net into the trained model to obtain classification or regression results. The characteristic of unsupervised machine learning is that there is no training process, the data is directly input into the model, and then, the result is obtained. Unlike classification problems, clustering algorithms generally do not define the number of classifications in advance. Different clustering algorithms must divide a batch of samples into multiple classes according to their own rules to ensure that samples in the same class are similar, but different. The samples of the classes are different [24]. The types into which samples are classified are also called "clusters."

DBSCAN is a common density-based clustering algorithm, and the full English name is Density-Based Spatia

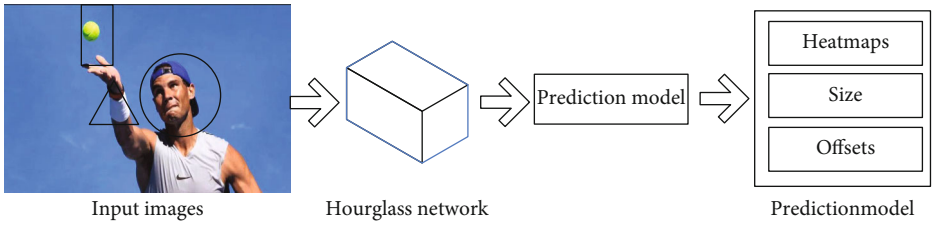


Figure 1: Center Net algorithm structure diagram.

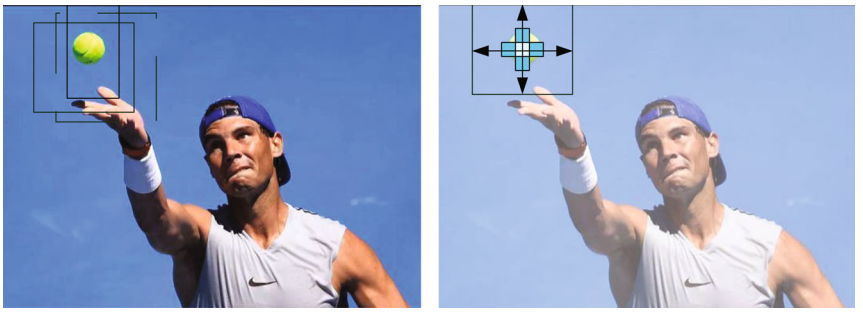


Figure 2: Center Net target center point prediction.

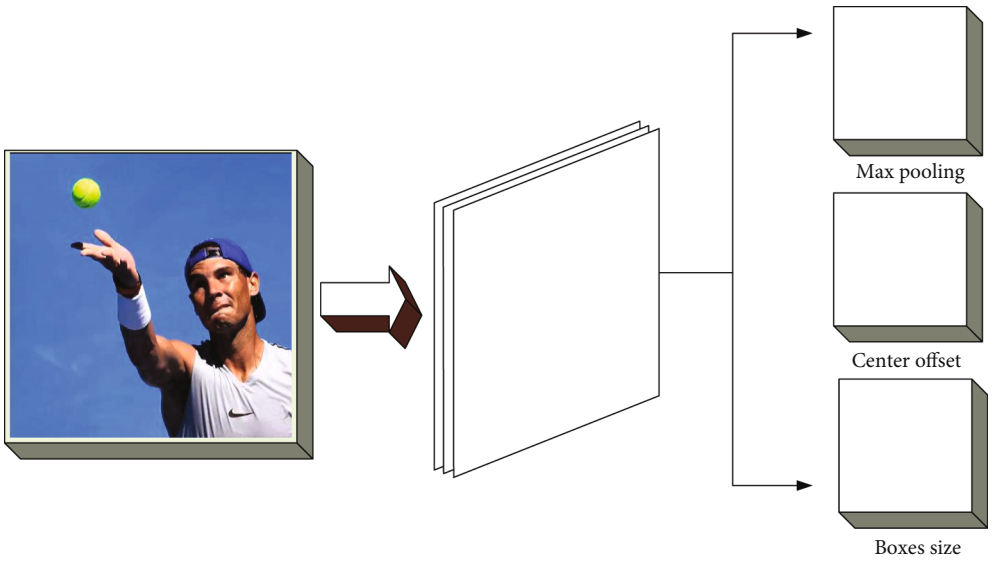


Figure 3: Overall structure of Center Net.

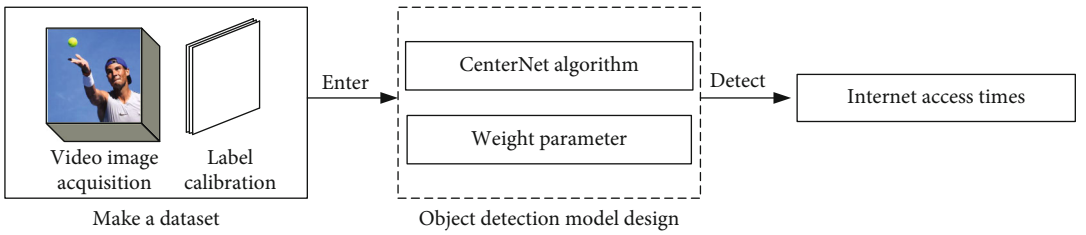


Figure 4: Center Net object detection model.

Clustering of Applications with Noise [25]. At the beginning of clustering, the algorithm will use any data points that have not been visited as core points and divide adjacent points within the core point radius Eps into the same cluster; then, the algorithm will use these new points as core points and then expand according to Eps to the surrounding and continue to include qualifying points in this cluster. Repeat this process until there are no nearby data points that can be expanded. Those points that do not meet the radius and minimum number will be marked as noise. After retrieving the data, label each point as belonging to a cluster or noise. Compared with other clustering algorithms, density-based clustering algorithms have great advantages. First, the number of clusters to be divided does not need to be entered before the algorithm starts. Second, this algorithm can identify outliers as noise, which means it can input noise filtering parameters when needed. Third, this algorithm can find clusters of any size and shape. However, this algorithm needs to set parameters Eps and Min Pts in advance, and it is difficult to set the parameters when the spatial cluster density is not uniform.

For the detection of abnormal behavior in the game, the first problem is to give a clear definition of the so-called abnormal behavior, and it is necessary to ensure the correctness and rationality of the regular tennis net passing behavior. In general, the definition of abnormal behavior needs to be compared with normal behavior. Anything that does not match normal behavior can be regarded as abnormal behavior. Different scenarios have different definitions of abnormal behavior. The scientific principle is the first basic principle that any academic research activities must follow. The principle of scientificity means that the theoretical basis of the evaluation index system should be sufficient and reasonable, and the selected index should be able to scientifically reflect the object of knowledge, so as to realize the accurate diagnosis of the number of times the men's tennis players pass the net. For this paper, we consider the movement state of the crowd in the tennis match from the perspective of the drone, and the abnormal behavior is defined as the tennis net passing behavior and landing state.

The evaluation of the counting algorithm based on target detection needs to consider the classification performance and regression performance. When the algorithm detects the correct passenger flow, the IOU is greater than the threshold set by the model, and vice versa. Therefore, the precision rate, recall rate, F_1 value, and mean precision are selected as the evaluation indicators of the algorithm. The formula of the evaluation index is as follows:

$$\mathrm{IOU} = \frac{\left|K_y \cap G_y\right|}{\left|K_y \cup G_y\right|}, \tag{10}$$

$$K = \frac{TK}{TK + FK}, \tag{11}$$

$$R = \frac{TK}{TK + FN}, \tag{12}$$

$$F_1 = \frac{2K^* R}{K + R}, \tag{13}$$

$$mAK = \int_0^1 K(R)d(R), \tag{14}$$

$$\mathrm{MAE} = \frac{1}{m}\left|t_x - z_x\right|, \tag{15}$$

$$\mathrm{MSE} = \sqrt{\frac{1}{m}\sum_{x=1}^{m}\left(t_x - z_x\right)^2}, \tag{16}$$

$$\mathrm{Acc} = \left(1 - \frac{1}{m}\frac{\left|t_x - z_x\right|}{t_x}\right) * 100\%, \tag{17}$$

$$R^2 = 1 - \frac{\sum_{x=1}^{m}\left(t_x - z_x\right)^2}{\sum_{x=1}^{m}\left(t_x - \bar{z}_x\right)^2}. \tag{18}$$

The DBSCAN algorithm is used to judge the recall rate of the number of times the sample crosses the network, and the precision of the recall data is calculated, so that the evaluation performance of the algorithm is obtained. The DBSCAN algorithm can find all dense areas of sample points and define these dense areas as clusters. This feature is very suitable for the characteristics of crowd distribution from the perspective of drones, so try to use the DBSCAN clustering algorithm to analyze the number of tennis nets in tennis matches.

4. Effect of the Method of Recording the Number of Tennis Passes over the Net in Tennis Matches

4.1. Data Collection of Tennis Matches. Competitive tennis is a sport with the most fundamental purpose of winning. The competitive level of athletes in the game is comprehensively reflected in five aspects: physical fitness, intelligence, mental ability, skills, and tactical ability. The video of the tennis match was filmed by drone. The video, using video observation, intelligent monitoring, and other methods, observed the tennis men's double match system and tested the match data. The net diagnosis index system of tennis game is composed of a series of diagnosis indicators and corresponding evaluation standards. The evaluation and diagnosis indicators reflect the overall situation of judgment and identification of the target. Through partial correlation analysis and stepwise regression analysis, a secondary tactical diagnostic index system is obtained, as shown in Table 1.

Tennis is one of those ball games, usually played between two singles players or a combination of two, in which the tennis player hits the ball over the net with a strap on the tennis court in order to prevent the player from hitting the ball back normally. Diagnosis ideas are mainly studied from the two dimensions of time (hitting sequence) and space (field) "segmentally," analyzing the tactical application characteristics and scoring characteristics of the world's outstanding men's tennis players and preliminarily determining the distribution law of the basic unit of tennis competition process stages. According to the distribution

Table 1: Tennis net diagnostic index system.

I level indicator	Send-and-receive segment
	Link attack stage
	Stalemate stage
II level indicator	Record the first over the net during the serving session
	Record the second pass over the net during the catch
	Record the third and fifth net crossings in the connection link
	Record the 4th and 6th net crossing in the pick-up link
	Record the seventh net crossing in the first stage of the stalemate
	Record the eighth net crossing in the first stage of the stalemate

Table 2: Network training environment.

System hardware	Model
System	Win 8
ARM	128 GB
Framework	Pytorch2.4.0
Programming language	Python

characteristics of the basic unit competition process of the world's outstanding men's players, the diagnostic indicators of tennis over the net are preliminarily determined, and expert interviews and investigations are conducted to determine the overall tactical ability of men's double tennis competition in the form of "stage division" from the perspective of expert experience. The video shows that the 55th, the highest number of strikes at the time of scoring, is set as the upper limit of the number of counts, and the first shot is set as the lower limit. The use of techniques and tactics for winning or losing each point refers not only to the use of techniques and tactics of kicking the ball itself, but also to the use of techniques and tactics of rhythm, serving or controlling the ball. If the points scored and won are the 5th loss, the combination of the 1st, 3rd, and 5th strokes of the serve demonstrates the player's application of technique and tactics.

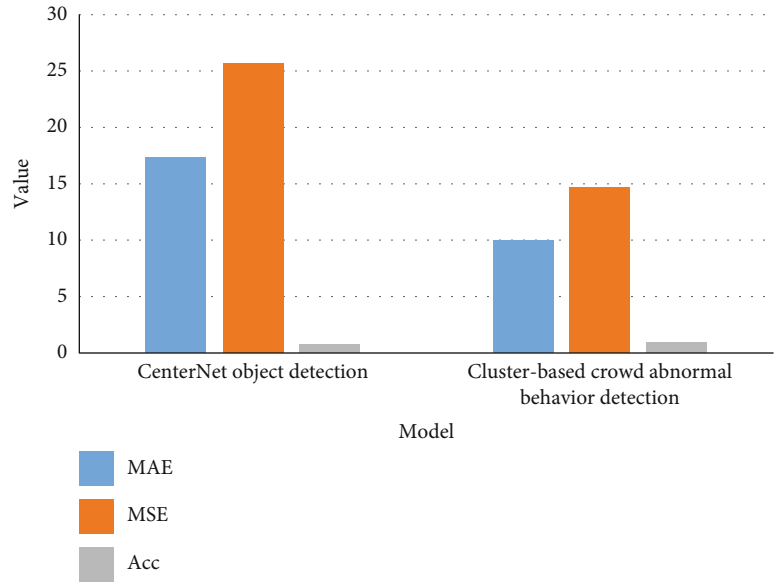
The video selection of the men's double match in tennis is performed by drone, and the data is mainly from the video. The dataset consists of a video sequence of up to 1 hour of images, and the dataset has a relatively low crowd density, with an average of 2-3 people per image. A dataset with different lighting conditions was collected. In addition, the crowd density of the scenes contained in this dataset is not very different, so there is no big difference in the size and appearance of the objects in the pictures. The pictures in this dataset are at least 2 people and at most 4 people. In order to verify the performance of the algorithm for recording the number of tennis passes in a tennis match, the controlled laboratory environment is shown in Table 2.

4.2. Comparison of DBSCAN Clustering Algorithm and Center Net Target Detection Performance. Through the diagnostic index system and evaluation criteria of tennis net passing in tennis matches, the number of tennis net passing times in the match can be effectively recorded. For men's tennis double tennis over-the-net diagnostic indicators in advance, by exploring the relationship between the diagnostic indicators, quantify the relationship between the diagnostic indicators and their importance to the winning rate of the game, so as to more effectively formulate training plans and game tactics and strategies provide data support. Using the constructed diagnostic index system and its evaluation criteria, the DBSCAN clustering algorithm and the Center Net target detection, analysis, and diagnosis are used to improve the intelligence of the number of tennis passes in the tennis men's double match.

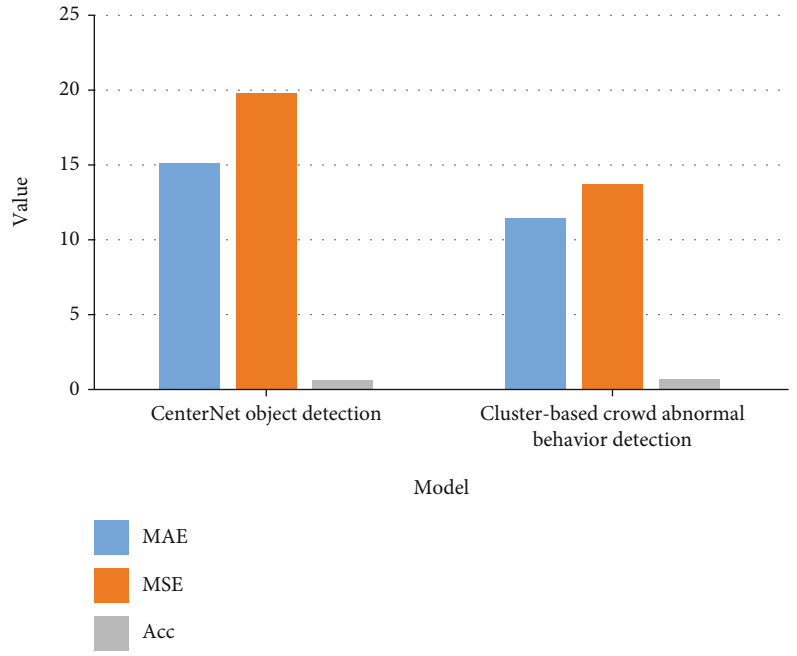
In order to compare the performance of the model, only the video l dataset is used for training on the DBSCAN clustering algorithm and the Center Net target detection model. The comparison results of the test set MAE, MSE, and Acc are shown in Figure 5. It can be seen from the figure that the performance of DBSCAN clustering algorithm is significantly better than that of Center Net object detection. In the Center Net target detection model, the MAE and MSE are 17.33 and 25.68, respectively, and the error is significantly higher than that of the DBSCAN clustering algorithm, but the error range of the Center Net target detection is still within the acceptable range.

Figure 5 uses the DBSCAN clustering algorithm and Center Net object detection to test the training video 1 dataset to compare the robustness of different models. "Robustness" refers to the tendency of a control system to maintain some other performance characteristics under parameter disturbances. According to different definitions of performance, it can be divided into stability robustness and performance robustness. It is not difficult to see from the figure that the DBSCAN clustering algorithm model is better than the Center Net target detection in the robust performance of the tennis net counting model at different times, but compared with the test results on the same dataset, its model performance has dropped a lot, and the accuracy has dropped. This may be due to the correlation between the background environment of the tennis net data shot at different times, the color characteristics, and density distribution of the tennis ball itself, which makes the model unable to adapt to the tennis balls at different times, resulting in a large drop in counting accuracy.

This paper analyzes the evaluation parameters of the three links of serving skills and tactics, the evaluation parameters of the receiving skills and tactics links, the temporal and spatial dimensions of tennis matches, the correlation



(a) Comparison of the performance of different models on video 1



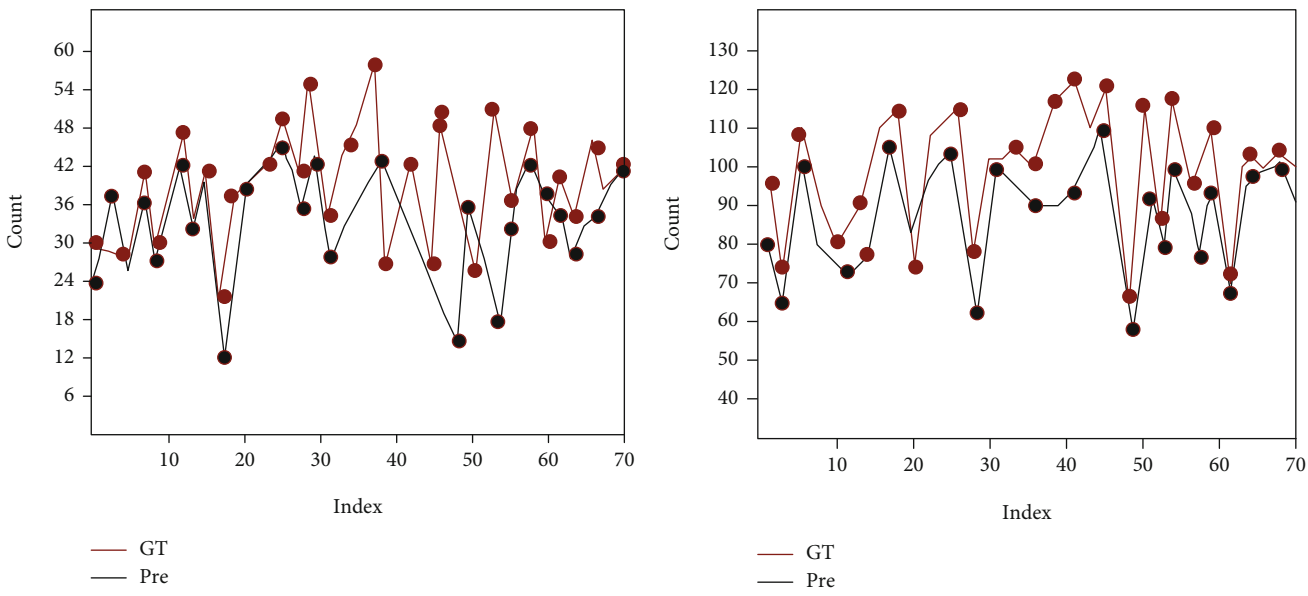
(b) Robust Performance comparison of different model

Figure 5: Performance comparison of different recognition methods.

Table 3: Accuracy comparison of different algorithms for the number of tennis passes in the tennis men's double match.

Method	DBSCAN clustering algorithm	Center Net object detection (%)
R	0.982	0.971
R^2	0.963	0.941
Absolute error	0.013 ± 0.0009	0.024 ± 0.0012
Relative error	0.023 ± 0.018	0.025 ± 0.015

differences of various diagnostic indicators, and the probability of winning. R is the multiple correlation coefficient, which represents the closeness of all independent variables in the model to the dependent variable. The larger the R value, the closer the linear regression relationship is; R^2 is the square of the complex correlation coefficient, which is positively related to the model fitting, and the larger the value, the better. Absolute error means the absolute difference between the log value and the actual value; relative error is the absolute difference between the log value and the actual value as a percentage of the actual value. The



(a) Video 1: predicted and actual number of Internet visits

(b) Video 2: predicted and actual number of Internet visits

Figure 6: Comparison of the predicted tennis net passing times and the actual net passing times in two videos.

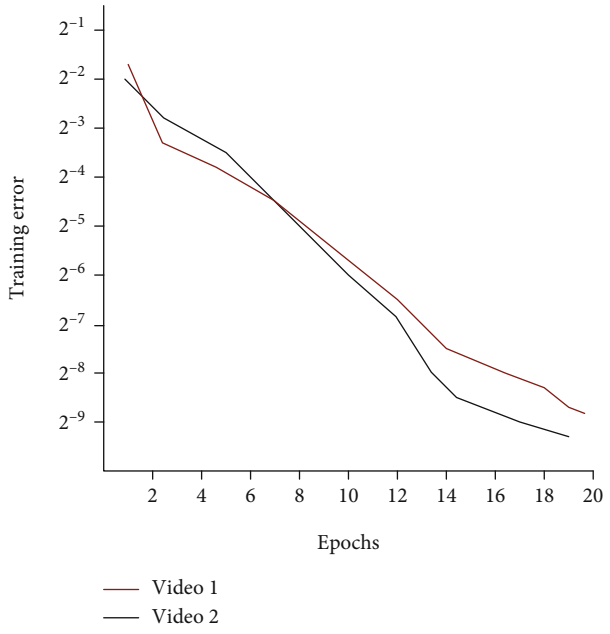


Figure 7: The training error curve of the prediction model for the number of net passes in the men's tennis double match.

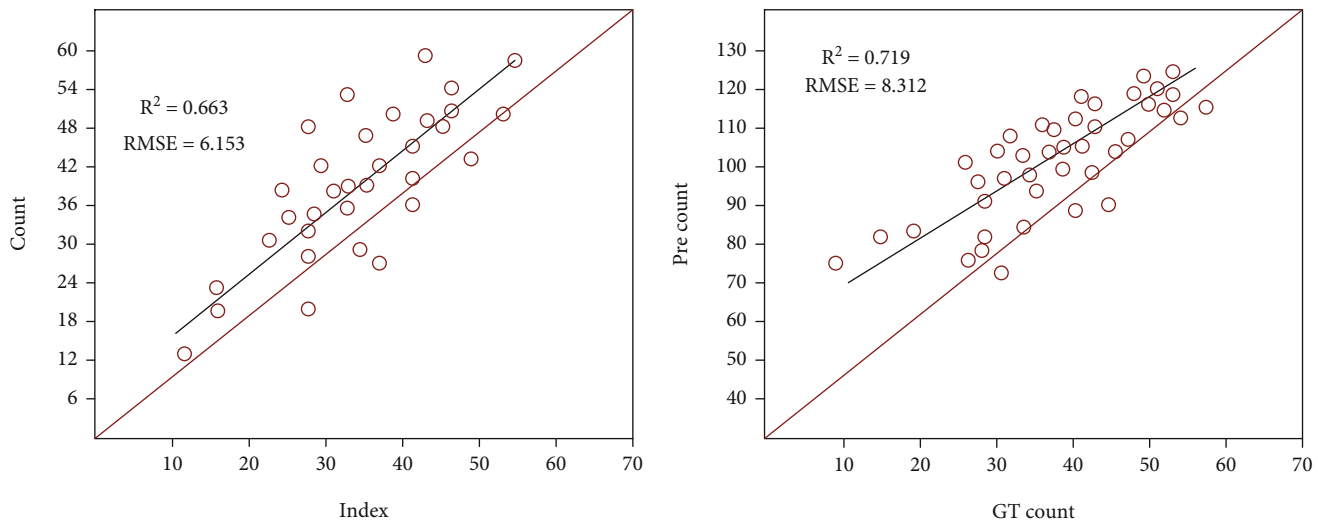
smaller the absolute and relative errors, the higher the accuracy of the fitted model.

The R values of DBSCAN clustering algorithm and Center Net target detection in men's tennis double match in Table 3 are 0.982 and 0.963, respectively, R^2 is higher than 0.94, the mean absolute error is only 0.013 and 0.023, and the standard deviation is 0.0009 and 0.018. The relative errors are only 0.024% and 0.025%, and the standard deviations are 0.012% and 0.015%. The error values are small, and the fitting accuracy of the two models is higher than 95%. It shows that the two established models have high fitting accuracy, but each index value of DBSCAN clustering algorithm is better than Center Net target detection.

4.3. DBSCAN Clustering Algorithm to Predict the Number of Tennis Passes. Due to the outstanding performance of DBSCAN clustering algorithm in counting accuracy, we only study the counting performance of DBSCAN clustering algorithm for different tennis nets. Clustering analysis is a rigorous data analysis process, which mainly consists of four parts: feature selection or mutation, clustering algorithm selection or design, clustering result evaluation, and clustering result physical analysis. At present, clustering algorithms play an important role in the field of data analysis, and each method has its own characteristics, so there is no unique way of dividing the clustering method. The DBSCAN clustering algorithm is used to compare the actual and predicted net passing times in tennis matches in different periods.

In order to effectively estimate the number of times the tennis passes the net in the game, the video frame of the tennis passing the net in the tennis match video 1 is cut down along the rectangular box in the figure and counted. The actual number of tennis passes over the net is counted manually. By recording the number of tennis balls that were marked manually and the number of shoots predicted by the model trained by the network, the results of the experimental prediction of the number of tennis balls passing over the net and the actual number of tennis balls being marked are shown in Figure 6.

The model's prediction of the number of tennis passes over the net in two different periods is close to the actual count, which indicates that the model can predict the number of tennis passes over the net well. The black curve in the figure represents the actual tennis pass count, and the red curve represents the model. For the video 1 dataset, the predicted tennis net times ranged from 12 to 60, and the actual



(a) Video 1: linear regression of predicted and actual values

(b) Video 2: linear regression of predicted and actual values

Figure 8: Comparison of predicted and actual tennis passes over the net.

number of markers ranged from 20 to 60. For the video 2 dataset, the model predicted a range of 60 to 110. The range of labels is between 65 and 1200. It is not difficult to see from the two figures that most of the tennis nets predicted by the model are higher than the actual number of labels. This may be due to factors such as light intensity and shooting. Some rackets are blurred in color and shape, which may be misjudged.

Regression analysis is a hypothetical description. There is a hypothetical causal relationship between the input and output variables. By examining the relationship between the input and output variables, a predictive model is formed to clarify the affinity relationship, and then, the output variables are estimated based on the input variables. The predicted value of the dependent variable can be obtained by mathematically correlating this regression model with the given independent variables. The error curve refers to the difference between the value obtained in the actual game and the value in the prediction model. The smaller the difference, the better the prediction model. According to video 1 and video 2 as the test set, the DBSCAN clustering algorithm is used for modeling. The training error of the model network is shown in Figure 7. The smaller the error value, the faster the training speed of the men's tennis double match prediction model network and the good training effect.

The fitted regression graph of the discriminant model for men's tennis double matches refers to the direct correlation between the output data and the target data. The data points of the model are evenly distributed near the fitting curve, indicating that the discriminative model for men's tennis double competition constructed in this study has good training effect, discriminative ability, and overall fitting effect.

According to the DBSCAN clustering algorithm, a linear regression analysis is performed on the actual marked value and the predicted value. The experimental results are shown in Figure 8. The linear fit of the model is good, with R^2 values of 0.663 and 0.719 and RMSE of 6.153 and 8.312, respectively, indicating that the number of tennis passes predicted by the model has a strong positive correlation with the actual number of net passes. This also shows that the DBSCAN clustering algorithm has better performance for the records of tennis passing times. In addition, the regression lines in the two figures are above the red line in the figure, which also shows that the number of tennis passes predicted by the model is higher than the actual number of markings.

Although the variables are highly correlated, the algorithm can still find their respective effects on the target variable, and the effects are significant. Through the internal training samples of the model and the test samples, the test results are basically the same, and there is no obvious sign of deterioration, indicating that the research direction conforms to empirical expectations or theories. For predictive models, the function of explanation is secondary. The primary task of predictive models is to make some kind of prediction about the future, and this prediction needs to rely on the overall ability of the model, including all the factors involved in the model. As for the accuracy of a single factor, as long as it does not affect the overall ability of the model, there is no need to care too much.

5. Discussion

The Center Net object detection and DBSCAN clustering algorithms are the most commonly used algorithms in machine learning. By setting relevant rules, they can simulate and replace human beings. Use Center Net object detection and DBSCAN clustering algorithm to track the tennis trajectory in tennis games and calculate the reasonable times of passing the net. Identifying the process of tennis netting through the set diagnostic criteria and evaluation criteria can not only improve the accuracy of the number of tennis passes over the net but also predict the winning or losing

results of the entire game. Although Center Net object detection has a good effect on tracking the trajectory of tennis balls in tennis games, it will miss detection behavior when recording the number of tennis nets passing over the net due to the abnormality of the game. According to the experimental comparison of DBSCAN clustering algorithm, the evaluation results of the number of times of passing the net are basically consistent with the actual game, which can effectively evaluate the overall tennis game, mainly because the algorithm can accurately record the trajectory of the tennis ball in the abnormal process of the game. By combining artificial intelligence technology with sports competitions, it replaces the traditional competition people to judge the results of the competitions, and the fairness and justice of the competitions are guaranteed.

Data Availability

No data were used to support this study.

Conflicts of Interest

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

References

[1] W. Jie and X. Fei, "Research of tennis player detection and shadow removal algorithm in tennis matches," *Journal of Electronic Measurement and Instrument*, vol. 32, no. 6, pp. 155–160, 2018.

[2] J. R. Lever, A. P. Murphy, R. Duffield, and H. H. K. Fullagar, "A combined sleep hygiene and mindfulness intervention to improve sleep and well-being during high-performance youth tennis tournaments," *International Journal of Sports Physiology and Performance*, vol. 16, no. 2, pp. 250–258, 2021.

[3] D. Meffert, C. O'Shannessy, P. Born, R. Grambow, and T. Vogt, "Tennis at tiebreaks: addressing elite players' performance for tomorrows' coaching," *German Journal of Exercise and Sport Research*, vol. 49, no. 3, pp. 339–344, 2019.

[4] Y. Cui, H. Liu, and H. Liu, "Data-driven analysis of point-by-point performance for male tennis player in Grand Slams," *Motricidade*, vol. 15, no. 1, pp. 49–61, 2019.

[5] X. Zheng, X. Yin, X. Shao, Y. Li, and X. Yu, "Collaborative sleep electroencephalogram data analysis based on improved empirical mode decomposition and clustering algorithm," *Complexity*, vol. 2020, Article ID 1496973, 14 pages, 2020.

[6] T. W. Chin, C. L. Yu, M. Halpern, H. Genc, S. L. Tsao, and V. J. Reddi, "Domain-specific approximation for object detection," *IEEE Micro*, vol. 38, no. 1, pp. 31–40, 2018.

[7] O. O. Khalifa, N. A. Malek, and K. I. Ahmed, "Robust vision-based multiple moving object detection and tracking from video sequences," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 10, no. 2, pp. 817–826, 2018.

[8] J. Han, D. Zhang, G. Cheng, N. Liu, and D. Xu, "Advanced deep-learning techniques for salient and category-specific object detection: a survey," *IEEE Signal Processing Magazine*, vol. 35, no. 1, pp. 84–100, 2018.

[9] Q. Zhan and W. Hu, "An epilepsy detection method using multiview clustering algorithm and deep features," *Computational and Mathematical Methods in Medicine*, vol. 2020, Article ID 5128729, 11 pages, 2020.

[10] C. Gallo and V. Capozzi, "A wafer bin map "relaxed" clustering algorithm for improving semiconductor production yield," *Open Computer Science*, vol. 10, no. 1, pp. 231–245, 2020.

[11] Z. Wang, K. Wang, S. Pan, and Y. Han, "Segmentation of crop disease images with an improved K-means clustering algorithm," *Applied Engineering in Agriculture*, vol. 34, no. 2, pp. 277–289, 2018.

[12] Y. H. Lee, "A study on analytical machine learning method applying discretization and hierarchical clustering algorithm," *The Journal of Korean Institute of Information Technology*, vol. 19, no. 1, pp. 55–61, 2021.

[13] H. Y. Wang, J. S. Wang, and L. F. Zhu, "A new validity function of FCM clustering algorithm based on intra-class compactness and inter-class separation," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 6, pp. 12411–12432, 2021.

[14] C. H. Botts, "A novel metric for detecting anomalous ship behavior using a variation of the DBSCAN clustering algorithm," *SN Computer Science*, vol. 2, no. 5, pp. 1–16, 2021.

[15] G. Jemilda and S. Baulkani, "Moving object detection and tracking using genetic algorithm enabled extreme learning machine," *International Journal of Computers Communications & Control*, vol. 13, no. 2, pp. 162–174, 2018.

[16] N. Xu, R. B. Finkelman, S. Dai, C. Xu, and M. Peng, "Average linkage hierarchical clustering algorithm for determining the relationships between elements in coal," *ACS Omega*, vol. 6, no. 9, pp. 6206–6217, 2021.

[17] Y. Wang, Y. Zhang, and X. Fan, "Similarity detection English text and teaching evaluation based on improved TCUSS clustering algorithm," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 4, pp. 1–10, 2020.

[18] B. Sarada, "Enhanced evolutionary computing assisted K-means clustering algorithm for big data analytics," *International Journal of Advanced Trends in Computer Science and Engineering*, vol. 9, no. 4, pp. 6007–6017, 2020.

[19] L. Krause, D. Farrow, R. Pinder, T. Buszard, S. Kovalchik, and M. Reid, "Enhancing skill transfer in tennis using representative learning design," *Journal of Sports Sciences*, vol. 37, no. 22, pp. 2560–2568, 2019.

[20] J. H. Thrall, X. Li, Q. Li et al., "Artificial intelligence and machine learning in radiology: opportunities, challenges, pitfalls, and criteria for success," *Journal of the American College of Radiology*, vol. 15, no. 3, pp. 504–508, 2018.

[21] M. Taddeo and L. Floridi, "Regulate artificial intelligence to avert cyber arms race," *Social Science Electronic Publishing*, vol. 556, no. 7701, pp. 296–298, 2018.

[22] J. Osakabe, T. Ohya, J. Koizumi, R. Inada, T. Matsumoto, and Y. Umemura, "Tennis singles match play induces inspiratory muscle fatigue in female tennis players," *The Journal of Physical Fitness and Sports Medicine*, vol. 10, no. 1, pp. 33–37, 2021.

[23] M. T. Smith, M. Reid, S. Kovalchik, Woods TO, and R. Duffield, "Heat stress incident prevalence and tennis match-play performance at the Australian Open-Science Direct," *Journal of Science and Medicine in Sport*, vol. 21, no. 5, pp. 467–472, 2018.

[24] Y. Yang, M. Li, and X. Ma, "A point cloud simplification method based on modified fuzzy C-means clustering

algorithm with feature information reserved," *Mathematical Problems in Engineering*, vol. 2020, Article ID 5713137, 13 pages, 2020.

[25] B. Azat and H. Tang, "Destination based stable clustering algorithm and routing for VANET," *Journal of Computer and Communications*, vol. 8, no. 1, pp. 28–44, 2020.

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Research Article

An Approach for Verification of Secure Access Control Using Security Pattern

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According to OWASP-2021, more than 3,00,000 web applications have been detected for unauthenticated and unauthorised access leading to a breach of security trust. Security patterns are commonly used in web applications to address the problem of broken access. Web developers are not experts in implementing security patterns. Therefore, it is necessary to verify that the security pattern has been applied, specifying the original intent of the security pattern. In this paper, an approach has been proposed that analyses the behavioural aspect of security patterns to verify that it meets the security requirement of the web application. The proposed approach extracts the class diagram's structural properties, relations, associations, and security-related constraints and verifies it using the first-order predicate logic. Experiments have been conducted using class diagrams of security patterns to detect instances of broken access control early in the design phase. The proposed approach will help minimise the risk of unauthenticated and unauthorised access to a web application.

1. Introduction

According to OWASP-2021, security vulnerabilities causing broken access control have moved to the first position from fifth in the last three years [1]. 94.5% of web applications have been detected with security weaknesses causing unauthorised disclosure, distortion, disruption, or data destruction by allowing users to perform actions, not within their respective limits [1]. Such weaknesses of broken authentication and unauthorised access have been reported in more than 318,000 web applications [1]. The percentage of vulnerabilities due to broken access control is increasing [2], as shown in Figure 1. These vulnerabilities exist in web applications due to inadequate design, hardcoding of access control and rights, and overlooking security best practices during the software development life cycle [3]. Moreover, frequent changes in software applications to patch security vulnerabilities bring new challenges for testing and removing the bugs [4–6].

Security patterns are commonly used in web applications and framework to address the problem of broken access [7]. In literature, the design and description of security patterns are commonly characterised by classes consisting of an interface class, abstract class, method, data members, and their respective implementations in concrete classes. The UML description, code examples, and design recovery regarding security patterns are not yet as mature as their counterparts in the software design patterns [8]. The organisation, structure, relationships, and dependencies of member data, methods, and classes in a security pattern represent a recurring design concept that can be utilised to verify and validate before implementation [9]. A sample code may not accompany the security pattern description for implementation. Therefore, during the software design phase, the class diagram of the security patterns requires a thorough examination to vouch for any unintentional security breach or hidden vulnerability. This vulnerability may be caused at run time due to the establishment of undesired connections among various objects of a class diagram. An attacker may exploit such a connection and access confidential data with time. The security patterns, thus applied, need to be verified for their consistency and usability. The class diagram in the design document provides a structural and behaviour view of member elements and functions. If not

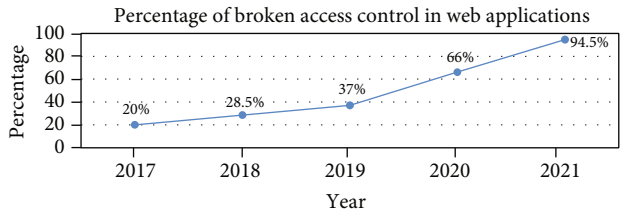


Figure 1: Increasing trend of broken access control detected in web applications in the last five years [1].

applied appropriately, the properties of relationships and accessibility lead to unauthorised access to resources by the users. This leads to a hidden vulnerability that goes unnoticed until the attacker exploits the vulnerability. For example, consider an operation update op1 on a data element $d1$ is meant only for a role R_x.

In contrast, other operation read op2 on the same data element $d1$ is meant for various R_x, R_y, and R_z roles. The secure visitor pattern is applied to ensure role-based data access. However, suppose the accessibility (public, private, protected, and friend) of data elements in abstract and concrete classes is not defined appropriately. In that case, it will allow restricted roles to access the data elements and operations for which the role is not authorised.

Moreover, certain security constraints are not shown in the class diagram but are written in textual statements in security patterns. The textual statements that could not be depicted in the class diagram also go unnoticed during the implementation of the security pattern. These security issues leave vulnerability that goes unnoticed even during rigorous security testing. The attackers take advantage of these hidden security vulnerabilities and take over resource control.

This paper proposes an approach to verify the relationships and accessibility among various objects created during the execution of a security pattern. The proposed approach extracts the microarchitecture from the class diagram of the security pattern applied. The security constraints specified in the security pattern description are written in first-order predicate logic. The proposed approach has been applied to secure visitor, secure strategy factory, and authenticator patterns to check the consistency of relationships among various concrete elements of the abstract security pattern. The extracted microarchitecture and security constraints are analysed by generating their instances using Alloy. The experiments show that connections indicating unauthorised access and broken access control are detected in one or more instances. The detected instance is rectified using the proposed approach, and a metamodel is generated for the security pattern. The approach will facilitate the appropriate implementation of security-dependent logic in a web application and helps in the identification of hidden vulnerabilities at an early stage.

The rest of the paper is organised into four sections describing Related Work, Proposed Methodology, Experimental Results, Analysis, and Discussion, and Conclusion and Future Work.

2. Related Work

In this section, various approaches for verifying and validating security patterns have been discussed. Dong et al. [10] represented the composition of security patterns using Calculus of Communicating System- (CCS-) based model checker of sequence diagrams. The approach proposed by Dong et al. [10] verified the states and its transitions in the sequence diagram of a security pattern. Mourad et al. [11] proposed an aspect-oriented two-phased approach to verify integrated security patterns in an application. The approach defines security objects, methods, and events and manually verifies them with security requirements. Pedroza et al. [12] proposed a verification approach using block and state machine diagrams in the SysML environment for the safety and security of critical real-time embedded systems.

Heyman et al. [13] modelled and verified compositional and trust properties of a software security architecture using security patterns based on abstract and concrete levels. Castellanos et al. [14] presented a verification method of security and dependability patterns in preconditions, post-conditions, and model transformations. Devyanin et al. [15] performed a data flow analysis of the operating system security model using role-based access control to prove its conformance and consistency to ensure integrity and confidentiality. Vaca and Gasca [16] defined security patterns using Feature-Oriented Domain Analysis (FODA) and represented mandatory forces of security patterns in the Backus Naur Form. Hamid et al. [17] proposed a semiformal approach for representing security patterns at domain-independent, domain-specific, and pattern-specific metamodel. Alzahrani [18] demonstrated the use of codecharts for formal specification and verification of security patterns in terms of generalisation and abstraction. Dwivedi and Rath [19, 20] presented verification of five security patterns of web applications and one security pattern of Service-Oriented Architecture (SOA) using Alloy [21]. The security patterns verified by Dwivedi and Rath [19, 20] are secure proxy, single-sign-on, check point, authenticator, and access policy.

He and Fu [22] modelled and analysed six security patterns, namely, account lockout, authenticated session, client data storage, encrypted storage, password authentication, and password propagation, to check their completeness, consistency, and ambiguity in their textual descriptions. He and Fu [22] used high-level petri nets to ensure the correct implementation of these six security patterns. Near and Jackson [23] showed that previously unknown security bugs could be easily identified using their proposed formal approach SPACE (Security Pattern Checker), which finds implementation bugs in access control security patterns. In an approach to improve security pattern definition, Beherens [24] provided abstractions and their implementations using formalised notation. The constraints were represented as a finite state machine recognised by regular language for analysis and verification.

Berghe et al. [25] focused on defining security patterns using a modelling language and proposed four data-specific building blocks, namely, data types, data flows, data

creation, and data storage, to support security patterns. Security analysis of the web in terms of cache usage, temporal logic, and state transitions was presented by Shimamoto et al. [26]. Shimamoto et al. [26] also verified Web Deception attack, CSRF attack, and exact origin and cross-origin Browser Cache Poisoning (BCP) attack using Alloy and temporal logic syntax. Obeid and Dhaussy [27] presented a message, resource, and access-based approach for formalisation, verification, and composition of security patterns with increased complexity measures.

Gadouche et al. [28] used Event-B correct-by-construction methodology to specify declarative and behavioural aspects of Role-Based Access Control. Gabillion et al. [29] designed a model for representing dynamic and contextual authorisation rules using first-order predicate logic for security administration and policy in the Internet of Things. Gupta et al. [30] proposed a formal approach to represent security constraints of a security pattern using first-order predicate logic. The formal specification facilitated early detection of hidden security vulnerabilities in a software or a web application.

The approaches available in the literature for specification and verification of security patterns are based on transitions and a set of actions and cover few security patterns. The existing approaches have considered transactions, temporal logic, request, response, and resource messages to verify the security of an application. As the application grows in size bringing variations in code, the greater efforts are required to verify security properties and detect vulnerabilities [31]. However, the existing approaches grow exponentially as the number of transitions and states becomes larger in terms of complexity and execution time. The relationships and security-related constraints among various objects created in the execution of security patterns have not been analysed in existing approaches. The existing approaches have not verified the behavioural aspect of security patterns among various instances of concrete objects.

3. Proposed Approach

This paper proposes an approach to verify secure access control and detect unauthenticated and unauthorised access arising from the inadequate implementation of security patterns. The class diagram of the security pattern available in literature has been used to extract its microarchitecture in the proposed approach. The microarchitecture of the class diagram contains structural properties such as interface class, abstract class, concrete class, methods, fields, and their respective relations and accessibility. An interface class is identified along with its member functions, data, and accessibility specifiers. The approach then identifies the abstract class and its concrete implementations. The private and protected data fields and member functions are identified for every concrete class. The private and protected member elements are the restricted elements to be verified for their non-accessibility from other elements. Subsequently, other member elements with public and friend accessibility are also identified and checked for the parameters passed and consistency. The interface, abstract, and concrete classes are analysed for the relationships of inheritance, association, composition, aggregation, and creation of objects.

Further, security constraints are written in first-order predicate logic and modelled with the microarchitecture. For example, suppose in a security pattern, it is defined that a concrete class should not have a public method. In that case, it is written as $\nexists$ispublic(operations(ConcreteClass)), in which $\nexists$ is a negative existential quantifier of predicate logic. Similarly, a class may have only one member function and the predicate logic for same is Operations $(\text{ConcreteClass}X) = \{\text{Op}X()\}$. The identified microarchitecture is then analysed and executed using Alloy Specification Language. The security pattern is then executed by creating multiple instances and objects. Each execution is verified for the existence of any counterexample instance in its respective instance. If a counterexample is detected, the constraints and structure are rectified suitably to present an accurate design of security pattern. All nodes in an instance are checked for reachability [32, 33] to verify the complete and unambiguous implementation of the security pattern. The proposed approach for verifying applied security patterns and identifying any hidden vulnerabilities is shown in Algorithm 1.

4. Experiments, Results, and Analysis

The proposed approach has been applied to three security patterns: authenticator, secure visitor, and secure strategy. The microarchitecture has been extracted and detailed in Section 4.1 for each applied security pattern in the first step. The subsequent modelling, execution of multiple instances, results, and analysis for each security pattern have been discussed.

4.1. Extracting Microarchitecture of Security Patterns

4.1.1. Authenticator Pattern. The class diagram of the authenticator pattern [34] is shown in Figure 2(a). The microarchitecture from the class diagram of the authenticator pattern is extracted by identifying its classes, member functions, security constraints, and relations and is shown in Figures 2(b) and 2(c).

4.1.2. Secure Visitor Pattern. The secure visitor pattern class diagram [35] is shown in Figure 3(a). The secure visitor pattern separates conditional security logic from the business logic in hierarchical data nodes in a web application. It enables data nodes to authenticate the visitors requesting their access for certain operations. The usage of the secure visitor pattern helps prevent unauthorised access to data by implementing security logic in a separate code segment or class. The secure visitor pattern provides a solution to prevent such attacks by making data nodes lock themselves from being read by a visitor unless the visitor supplies the proper credentials to unlock the data node. The secure visitor pattern consists of an interface, abstract, and concrete classes representing secure visitors, unlocked and locked data nodes, various member data and functions, and their respective access specifiers. The abstract

```
Input   class diagram of security pattern
Process
Step 1   extraction of microarchitecture
  For each security pattern
  Identify classes, member functions, and member data from the class diagram.
    For each class identified, label it as an interface, abstract class, or concrete class.
      For each function identified, label it as an abstract function or a concrete function.
        For each member, data and function
          Identify the accessibility
        End for
      End for
    End for
  Look into the textual description of security patterns to identify security constraints.
    For each security constraint
      Write first-order predicate logic.
    End for
  End for
Step 2   model the security pattern in Alloy using the mapping of extracted microarchitecture, assertion, and facts
Step 3   run and execute the assertion for multiple instances
Step 4   check for counterexample
  If counterexample found
    Rectify the relation, association, and function calls
    Go to step 1
  Else
    Terminate with metamodel
Output   metamodel for security pattern for code implementation
```

Algorithm 1: Algorithm for analysing and identifying vulnerabilities in the implementation of security patterns at the design phase.

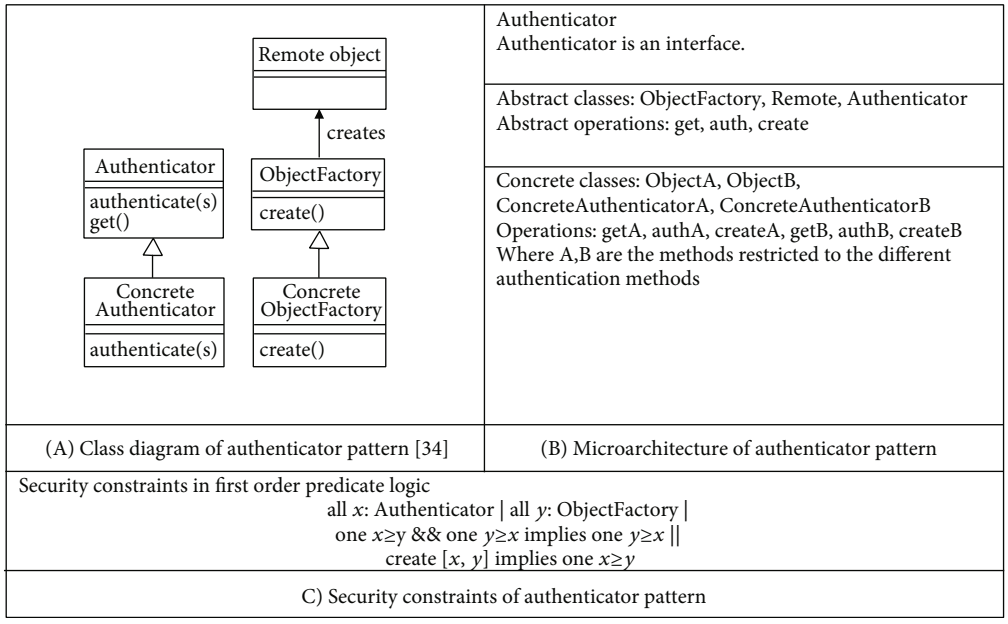
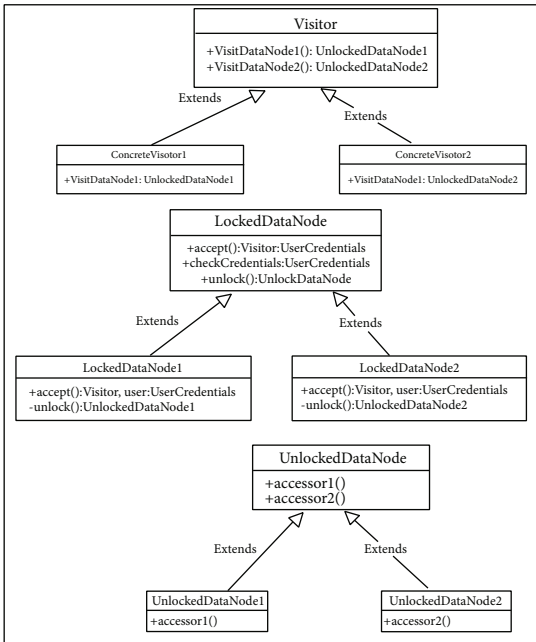


Figure 2: Extracting microarchitecture of authenticator pattern.

function 'accept()' is implemented in concrete classes of locked data node type(s) that, in turn, unlock the respective data node after checking a user's credentials. The microarchitecture of the secure visitor pattern extracted is shown in Figure 3(b). Security constraints such as for every locked data node, there should be an unlocked data node, restriction of access to parent and child data nodes, and restrictions on member functions of abstract and concrete classes are represented in predicate logic and shown in Figure 3(c). These security constraints are crucial for providing secure access and preventing broken access in web applications.



SecureVisitor
Secure visitor is an interface

Abstract classes: UnlockedObject, UnlockedDataNode, LockedDataNode, UserAndRolesCredentials
Operations: accept, unlock, checkCredentials, Visit

Concrete classes: VisitorX, UnLockedDataNodeX, LockedDataNodeX
Where X ranges from 1 to n.

a) UnlockedObject → UnlockedDataNode ∈ associations
b) relations(UnlockedObject, UnlockedDataNode, associations)
c) accept∈ operations(LockedDataNode)
d) unlock∈ operations(LockedDataNode)
e) accept∉ operations(UnlockedDataNode)
f) CheckCredentials ∈ operations (LockedDataNode)
g) VisitX⊆ operations(SecureVisitor)
h) isProtected(checkCredentials)
i) isPublic(accept)
j) isPrivate(unlock)

(A) Class diagram of secure visitor pattern [34]

(B) Microarchitecture of secure visitor pattern

Security constraints in first order predicate logic

a) Association is from UnlockedObject to UnlockedDataNode
   a. type (UnlockedObject) = Object ∧
   b. type (UnlockedDataNode) = UnlockedDataNode ∧
   c. multiplicity (UnlockedDataNode) = "*"
b) Client depends only on SecureVisitor and UnlockedObject
   a. Such that:
      i. access (SecureVistor, UnlockedObject),
      ii. {UnlockedDataNode} ∪ subclasses (UnlockedDataNode) ∪ subclasses (SecureVisitor)
c) Accessor is the only operation in UnlockedDataNode
      i. Operations (UnlockedDataNode) = {accessor}
d) For every subclass of UnlockedDataNode, there exists a subclass belonging to LockedDataNode and an operation VisitX belonging to the subclass of SecureVistitor. The function visit () takes the parameter UnlockedDataNode of typeX as its subclass such that each concrete node in the data hierarchy has both a locked and unlocked version. Only a locked node will be able to create an unlocked node.

$$\forall x \in \text{DataHierarchy}\ \exists!\ x\ (l, u) \text{ such that}$$
$$\{\exists\ u \in \text{subclasses (UnlockedDataNode)} \wedge \exists\ l \in \text{subclasses (LockedDataNode)} \wedge \text{create } (l, u)\}$$

e) No UnlockedDataNode should be able to access its parent or child data node.

$$\forall x \in \text{subclasses (UnlockedDataNode)} \sim \text{access } (x, x.child) \wedge \sim \text{access } (x, x.parent)$$

f) LockedDataNodes has no public operations

$$\nexists\ \text{ispublic (operations (LockedDataNode))}$$

g) To access UnLockedDataNode, visitor should call LockedDataNode, which in return create UnLockedDataNode after checking user credentials.

$$\forall x \in \text{DataHierarchy}$$
$$\exists accept \in \text{operations (LockedDataNodeX)} \wedge$$
$$\exists checkCredentials \in \text{operations (LockedDataNodeX)}$$

such that

if return(checkCredentials)=true

create (l, u)

C) Security constraints of Secure Visitor Pattern in first order predicate logic

Figure 3: Extracting microarchitecture of secure visitor pattern.

4.1.3. Secure Strategy Factory Pattern. The class diagram of the secure strategy factory pattern [35] is shown in Figure 4(a). The secure strategy factory pattern separates the security-dependent logic associated with each role from the basic functionality of object creation and selection. Secure strategy factory implements the creation and selection of an object for executing an operation depending on a set of security credentials. The given security credentials are used to select and return the role-specific object. The different secure functions are implemented in various concrete

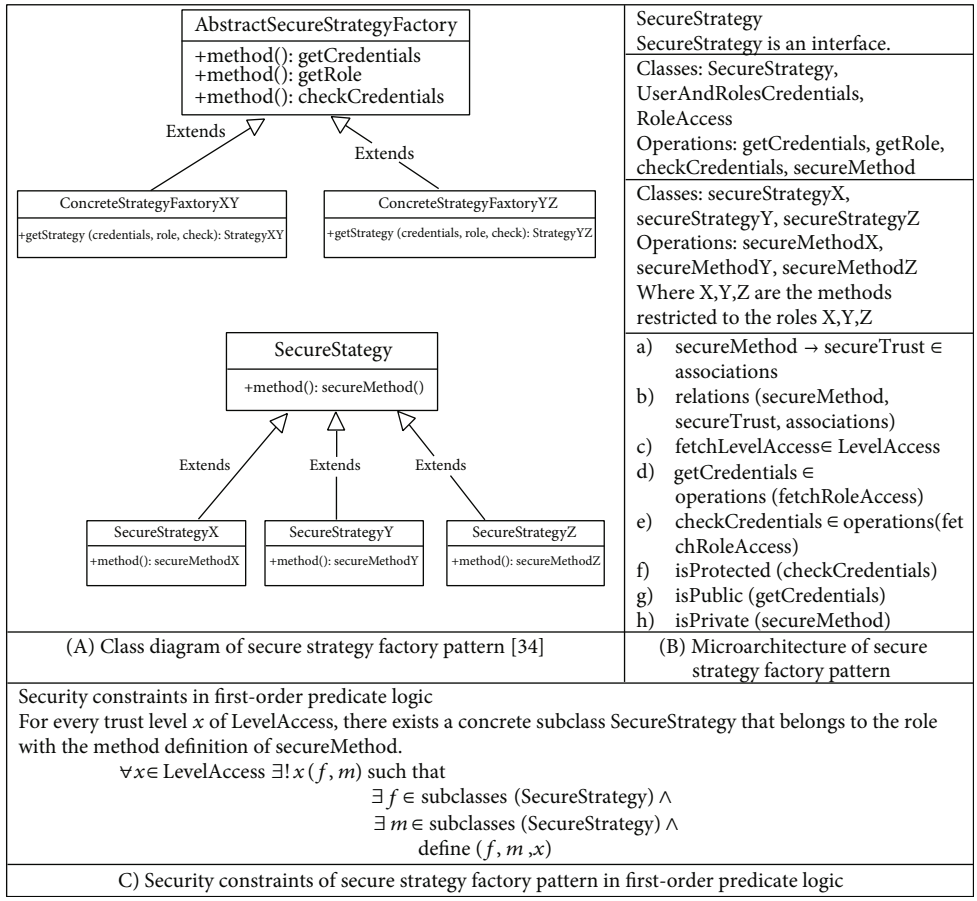


Figure 4: Extracting microarchitecture of secure strategy factory pattern.

implementations of abstract secure strategy factory for each set of roles defined by the security requirements. For example, in a web application, there are three roles having complete, little, or no trust, and then, three concrete implementations of secure strategy will be created, one for each level of trust. A concrete implementation of secure strategy factory will only contain functionality restricted to a secure role or trust level. The microarchitecture of the secure strategy factory pattern is extracted using the proposed approach as in Figure 4(b), and the security constraints written in first-order predicate logic are shown in Figure 4(c).

4.2. Detection of Broken Access Control. In this section, the class diagram of the security pattern is executed in the Alloy tool to detect any violation of security requirements. Each pattern has been executed for multiple instances to create objects, and each instance is analysed for the existence of any counterexample. On detecting a counterexample, the nodes in the graph are analysed for the inappropriate link. The security pattern is then rectified by correcting the definition of concrete classes and methods and implementing the security predicate to verify the security requirement.

4.2.1. Authenticator Pattern. The class diagram of authenticator pattern is executed to detect any hidden vulnerabilities. In Figure 5, while executing two or more concrete authenticators, it is found that concrete authenticator0 is creating an object for the concrete authenticator1. It is detected that the concrete object of concrete authenticator1 is inheriting the abstract method instead of overriding it. It is also detected that an object created by one authenticator can create an object of another authenticator by an inherited method of abstract authenticator. The security error is rectified by ensuring that pred creates $[x : \text{one ConcreteAuthenticator}, y : \text{one Object}A]\{\}$ and overriding the method create() in each concrete authenticator.

4.2.2. Secure Visitor Pattern. The secure visitor pattern class diagram is executed, and hidden vulnerabilities are detected using the proposed approach. The predicate logic for the security constraint is that only a locked data node can create its unlocked data node. However, on the execution of the predicate visit for two or more instances in secure visitor, an instance is found in Figure 6 that shows unlocked data node2 could unlock data node1. The instance creates unauthorised access to data node2 via data node1, against the security requirements. On analysing the microarchitecture, it is detected that the function visit() has been implemented inappropriately.

$$\text{pred visit}\,[v : \text{SecureVisitor}, l : \text{LockedDataNode}]\,\{\}. \quad (1)$$

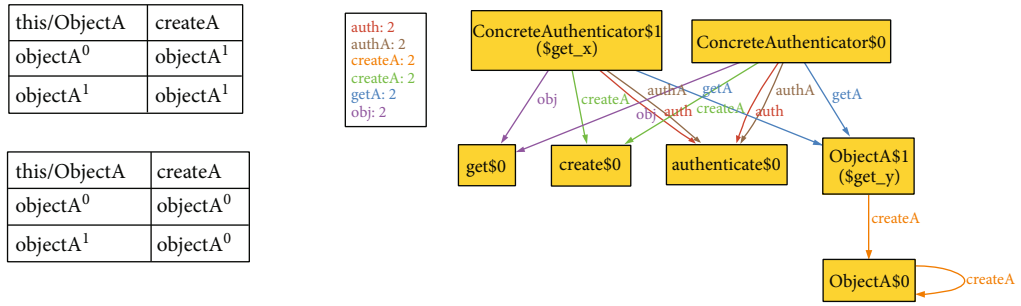


Figure 5: An instance generated for the authenticator pattern showing the creation of multiple objects and broken authentication.

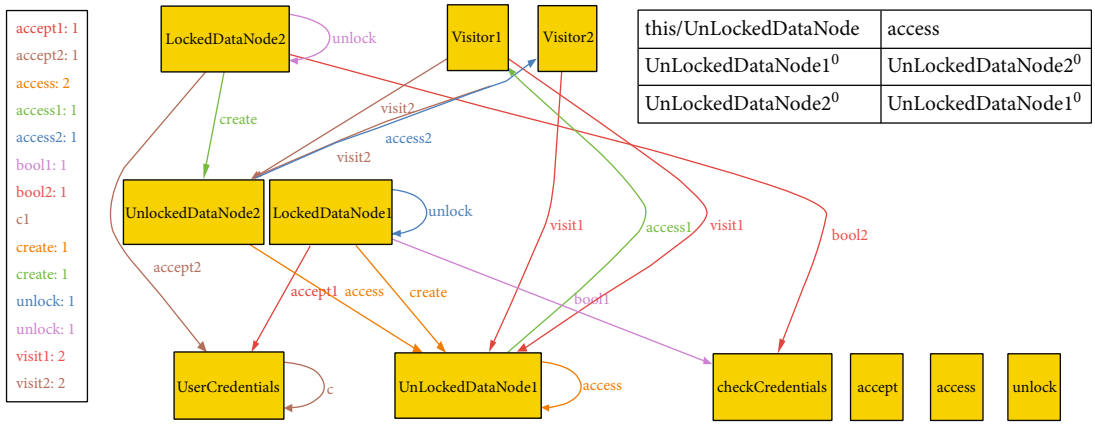


Figure 6: A broken instance detected through the proposed approach in the implementation of secure visitor.

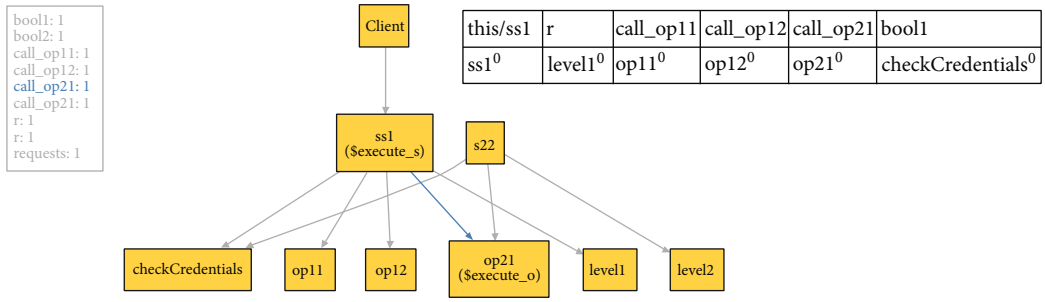


Figure 7: A broken instance detected through the proposed approach in the implementation of the secure strategy factory.

The pattern is rectified by incorporating the predicate for accepting using credentials and creating an unlocked data node that the user will visit. Predicate create and assertion unique is added in the implementation of secure visitor pattern for specifying the constraint. One locked data node will create only one unlocked data node, and unlocked data node should not access are not or child data nodes.

$$\begin{aligned}&\text{pred accept}\,[v : \text{SecureVisitor}, u : \text{UserCredentials}]\{\},\\&\text{pred create}[l : \text{LockedDataNode}, u : \text{UnLockedDataNode}]\{\}.\end{aligned} \tag{2}$$

4.2.3. Secure Strategy Pattern. The class diagram of secure strategy factory is executed to detect any hidden broken access to operations. The secure strategy factory concrete classes are built for two trust levels. TrustLevel-1 can perform op11 and op12, and TrustLevel-2 can operate op21. On executing the predicate *created* for two or more instances in secure strategy factory, an instance is found such that TrustLevel-1 could access the operation op21 restricted for TrustLevel-2. The broken instance is detected using the proposed approach while implementing the secure strategy factory pattern and is shown in Figure 7, without checking user credentials. It is detected through the broken connection that op21 has been inappropriately defined in class meant for TrustLevel-1 and called by TrustLevel-2. The security pattern is rectified by implementing the predicate that $\forall x \in \text{LevelAccess}\ \exists! x\,(f, m)$ such that

$$\begin{aligned}&\exists f \in \textit{su}\text{bclasses}(\text{SecureStrategy})\wedge,\\&\exists m \in \text{subclasses}(\text{secureMethod})\wedge,\\&\text{define}(f, m, x\}.\end{aligned} \tag{3}$$

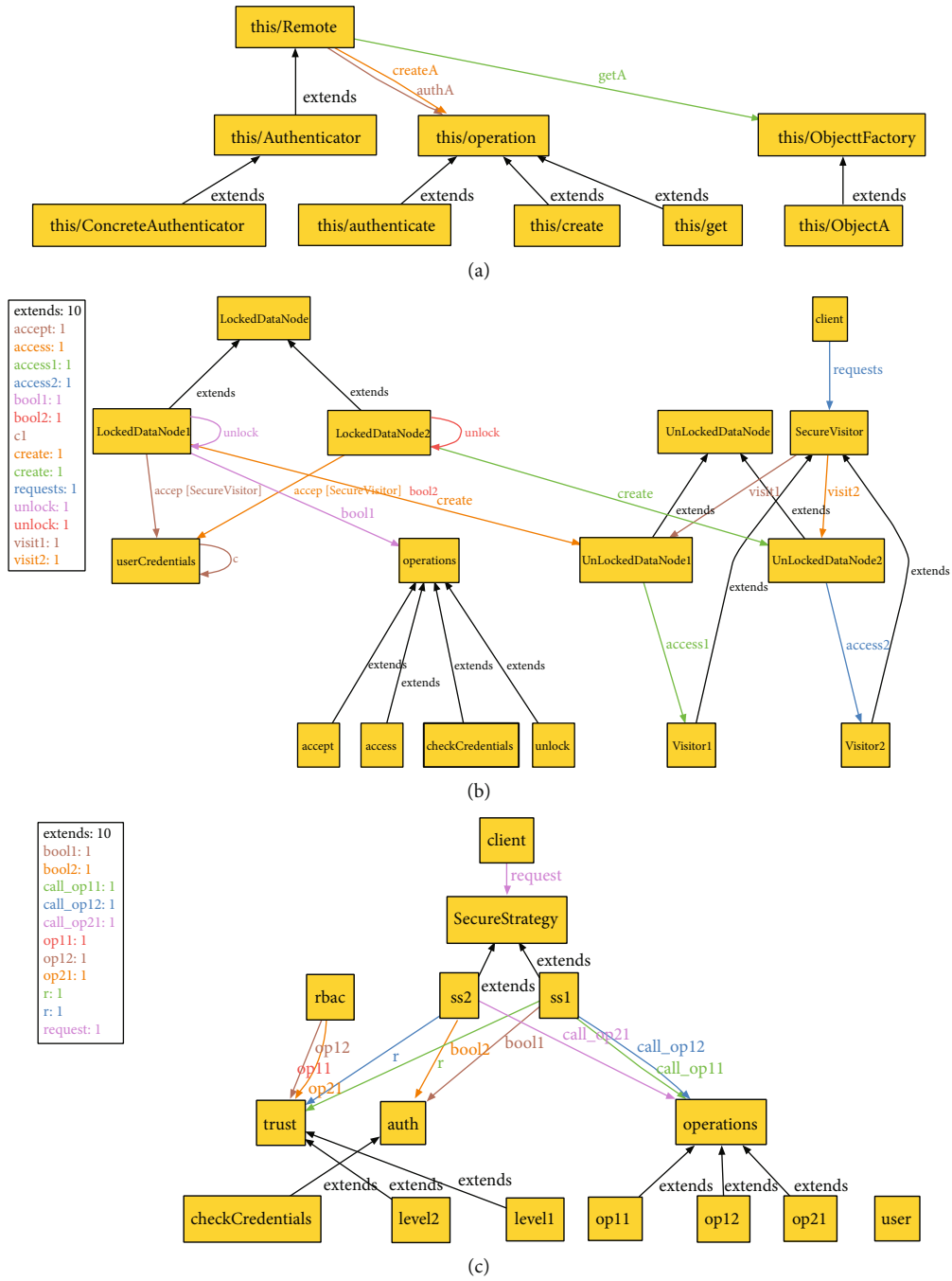


Figure 8: The metamodel generated by the proposed approach: (a) authenticator; (b) secure visitor; (c) secure strategy factory.

4.3. Metamodel of Authenticator Pattern, Secure Visitor Pattern, and Secure Strategy Pattern. In this section, the extracted microarchitecture of the security pattern and its rectified predicate logic is executed in the Alloy tool to verify that it meets the security requirement. Each pattern has been executed for multiple instances to create objects, and each instance is analysed for the existence of any counterexample. The metamodel of the authenticator pattern is generated and shown in Figure 8(a). Consider two different authentication systems in a web application. Each of the two authentication systems is implemented using a separate concrete class. The concrete authenticator defines its concrete object and authentication mechanism. The separation of different authentication mechanisms ensures that the other authenticator does not create the object of one authenticator. The arrangement is easily extendible if a third or more authentication mechanisms are appended to the application in future versions. The class diagram of the authenticator pattern is verified using the security constraints written in first-order predicate logic as an assertion *unique*.

In the metamodel of secure visitor pattern shown in Figure 8(b), the client requests SecureVisitor Interface to visit UnlockedDataNode through its concrete implementationsVisitor1 or Visitor2. SecureVisitor can implement any

Table 1: Concrete instances generated by the proposed approach for secure strategy factory.

Concrete instances	Authenticator pattern				Secure visitor				Secure strategy factory			
	No. of variables	No. of primary variables	No. of clauses	Time in ms	No. of variables	No. of primary variables	No. of clauses	Time in ms	No. of variables	No. of primary variables	No. of clauses	Time in ms
2	154	24	225	3	251	44	345	5	1250	285	2177	17
4	432	56	677	3	865	114	1329	8	2694	569	4737	15
6	806	96	1297	5	1699	216	2676	9	4050	861	7150	19
8	1276	144	2085	8	2837	350	4533	13	5618	1161	9920	25
10	1852	200	3121	13	3735	516	6073	15	7288	1469	12938	19
20	6132	600	10701	28	11025	1826	18243	20	16278	3129	29098	27
40	21892	2000	39061	74	42045	6846	70903	73	42178	7049	75878	69
60	47252	4200	85021	113	93065	15066	157963	911	77678	11769	140258	88
128	205824	17664	372933	196	416133	66950	711279	944	270186	33801	490798	270
256	803812	68096	1466821	11196	1651461	264966	2831599	10804	933610	100361	1702574	2125

number of concrete visitors as per the user requirement. LockedDataNode accepts concrete visitor and user credentials and verifies them from UserCredentials class. After checking the user credentials, the data node is unlocked by its respective locked data node and the access is passed to the respective concrete visitor.

In the metamodel of the secure strategy factory pattern shown in Figure 8(c), the client requests SecureStrategy Interface to create factory objects for two different TrustLevel-1 and TrustLevel-2. After checking the user credentials, each role can perform the operations restricted to its role. The class *RBAC* contains policies for TrustLevel and operation mapping. It defines the operations that are restricted to a particular TrustLevel. In the present instance, TrustLevel-1 can perform operations op11 and op12. TrustLevel-2 can perform operation op21. SecureStrategy ss1 creates an object for a user with TrustLevel-1 after checking the credentials. Accordingly, a user with role1 can perform actions op11 and op12 but not operation op21. Similarly, SecureStrategy ss2 creates an object for a user with TrustLevel-2 after checking the credentials. Accordingly, a user with TrustLevel-2 can perform actions op21 but not operations op11 and op12. The security feature of the secure strategy factory is verified using the predicate logic $\forall x \in \text{LevelAccess} \exists! x\,(f, m)$ such that

$$\begin{aligned} &\exists f \in \text{subclasses}(\text{SecureStrategy}) \wedge, \\ &\exists m \in \text{subclasses}(\text{secureMethod}) \wedge, \\ &\text{define}(f, m, x\}. \end{aligned} \tag{4}$$

4.4. Validation and Verification of Multiple Concrete Instances. The authors have used the Alloy analyser to verify the proposed approach. The analyser transforms predicate models into Conjunctive Normal Forms (CNF) and analyses using Satisfiability (SAT) solvers. The analyser generates two forms of valuations for the relations in the model: (1) instances, i.e., valuations such that the formulas hold, and (2) counterexamples, i.e., valuations such that the negation of the formulas holds. Using an analyser reduces the time required to verify the model having many literals and clauses in CNF. The microarchitecture of the security pattern extracted through the proposed approach is translated and executed using Alloy. The graphical representation of the metamodel of the security pattern is generated from the extracted microarchitecture and security constraints. The security pattern is executed multiple times for many concrete instances to check the consistency of relationships among the various member elements. Several concrete instances of authenticator, secure visitor, and secure strategy factory are created in the Alloy analyser to validate the model further. Alloy generates the number of concrete instances, primary variables, and clauses in CNF. The simulation time taken to verify each concrete instance for the authenticator, secure visitor, and secure strategy pattern is given in Table 1. No clause with broken access control for accessing the restricted data element has been found in these instances. The correctness of the proposed metamodel for each security pattern is verified.

4.5. Analysis and Discussion. The proposed approach represents the design, structure, dynamics, and other dependencies among various components of security patterns in the generated metamodel. The approach will enable web developers to implement code accurately and minimise threats to the web application. The proposed approach provides a general model that applies to every domain. It considers structural aspects and interrelationships among various structural elements and analyses behaviour based on possible relationships, states, transitions, and execution steps. The proposed approach verifies security patterns by defining the set of interface, abstract, and concrete classes and static methods and nonstatic method calls on the class and identifier and all dependencies at the design phase. It will be helpful in verifying applications. All security-related constraints, artefacts, and static and dynamic checks mentioned at different sections of a security pattern are represented and validated using the predicate modelling before implementation.

It provides precise semantics, verification and validation, and automated reasoning and is machine incomprehensible

due to the usage of predicate logic. This specification facilitates automated verification and validation of security patterns applied in web applications. For example, in the secure strategy factory pattern, the constraint for every trust level, i.e., complete, partial, and none, should be a separate unique ConcreteObject implementing each trust level. This constraint is specified in predicate as $\forall x \in \text{TrustLevel} \exists! y \in$ ConcreteObject. Such representations in predicate logic are easily verified using automated tools and help identify any counterexample(s) simple and error-free.

The proposed specification and its metamodel of security pattern defined various structural elements, their relations, and how these elements will communicate using directed edges and appropriate markers. This form of representation enables developers to understand the complete structure. It helps implement an effective and productive design that is instantly easy to verify, validate, and correct at early stages to ensure security properties of confidentiality, integrity, availability, accountability, nonrepudiation, authentication, and authorisation. The proposed approach provides a verifiable specification of structural design and implementation of security patterns covering all security patterns. Moreover, security constraints such as accessibility among micro architecture elements and parent and child nodes that require extraordinary validation, verification, and testing are also analysed.

In the proposed approach, any flaw in the system's design concerning security functionalities and role-based access to resources is found early through structural and behaviour validations, thereby preventing any consequent security breach.

5. Conclusions and Future Work

Security breach due to broken authentication and access control has been an essential concern for web developers. Though security patterns are applied in a web application, there is a need for a method that can verify the correctness of the class diagram built during the design phase. In this paper, the proposed approach verifies the relationships and accessibility among objects and classes of a security pattern applied in a web application. The approach extracts the structural properties, relations, associations, security-related constraints, artefacts, and static and dynamic checks of the class diagram of a security pattern. The extracted microarchitecture is executed using Alloy to identify unauthorised and broken access in the security pattern applied in a web application. The proposed approach detected inconsistencies at the design phase when applied to secure strategy factory, authenticator pattern, and secure visitor pattern. The detected inconsistencies are then rectified by redefining the methods, classes, relationships, and security constraints and subsequently verifying them using predicate logic. The experiments have generated more than 200 instances of concrete classes each for the secure visitor pattern, authenticator, and secure strategy factory pattern. These instances have been verified for the existence of any counterexample. The final metamodel is generated for each security pattern to develop and implement the code. The proposed approach is helpful for the developer community to verify the consistency of relationships among the various member elements of complex class diagrams restricted to different roles, trust levels, and authentication methods. The complex class diagram of the security pattern can be quickly evaluated and verified for secure access control during the design stage of the web application.

The authors intend to extend the approach to verifying the composition of security patterns in web applications in the future.

Data Availability

The proposed approach has been applied to security patterns: Authenticator, Secure Visitor, and Secure Strategy available at [34, 35].

Conflicts of Interest

The authors declare that they have no conflict of interest.

References

[1] OWASP Foundation, *OWASP Top 10 2021*, 2021, April, 2022, https://owasp.org/Top10/.

[2] PT Analytics Security, *CyberSecurity: Threat Landscape*, 2022, April, 2022, https://www.ptsecurity.com/ww-en/analytics/.

[3] C. Gupta, R. K. Singh, and A. K. Mohapatra, "A survey and classification of XML based attacks on web applications," *Information Security Journal: A Global Perspective*, vol. 29, no. 4, pp. 183–198, 2020.

[4] A. Agrawal and R. K. Singh, "Mining software repositories for revision age-based co-change probability prediction," *International Journal of Open Source Software and Processes (IJOSSP)*, vol. 11, no. 2, pp. 16–32, 2020.

[5] A. Agrawal and R. K. Singh, "Predicting co-change probability in software applications using historical metadata," *IET Software*, vol. 14, no. 7, pp. 739–747, 2020.

[6] A. Agrawal and R. K. Singh, "Ripple effect identification in software applications," *International Journal of Open Source Software and Processes (IJOSSP)*, vol. 11, no. 1, pp. 41–56, 2020.

[7] C. Gupta, R. K. Singh, and A. K. Mohapatra, "Securing web applications using security patterns," in *Proceedings of International Conference on Information and Communication Technology for Competitive Strategies*, Udaipur, India, 2019.

[8] M. Bunke, "Software-security patterns: degree of maturity," in *EuroPLoP 2015: 20th European Conference on Pattern Languages of Programs*, pp. 1–17, Kaufbeuren, Germany, 2015.

[9] M. Bunke, *Security-Pattern Recognition and Validation*, Doctoral dissertation, Universität Bremen, 2018, https://media.suub.uni-bremen.de/bitstream/elib/1571/1/00107086-1.pdf.

[10] J. Dong, T. Peng, and Y. Zhao, "Automated verification of security pattern compositions," *Information and Software Technology*, vol. 52, no. 3, pp. 274–295, 2010.

[11] A. Mourad, H. Otrok, and L. Baajour, "New approach targeting security patterns development and deployment," *Information Security Journal: A Global Perspective*, vol. 20, no. 4-5, pp. 231–244, 2011.

[12] G. Pedroza, L. Apvrille, and D. Knorreck, "AVATAR: a SysML environment for the formal verification of safety and security

properties," in *2011 11th Annual International Conference on New Technologies of Distributed Systems*, pp. 1–10, Paris, France, 2011, May.

[13] T. Heyman, R. Scandariato, and W. Joosen, "Reusable formal models for secure software architectures," in *2012 Joint Working IEEE/IFIP Conference on Software Architecture and European Conference on Software Architecture*, pp. 41–50, Helsinki, Finland, 2012, August.

[14] C. Castellanos, T. Vergnaud, E. Borde, T. Derive, and L. Pautet, "Formalisation of design patterns for security and dependability," in *Comparch '13: Federated Events on Component-Based Software Engineering and Software Architecture*, pp. 17–26, Vancouver, British Columbia, Canada, 2013.

[15] P. N. Devyanin, A. V. Khoroshilov, V. V. Kuliamin, A. K. Petrenko, and I. V. Shchepetkov, "Formal verification of OS security model with Alloy and Event-B," in *International Conference on Abstract State Machines*, pp. 309–313, Berlin, Heidelberg, 2014, June.

[16] A. J. Varela-Vaca and R. M. Gasca, "Formalization of security patterns as a means to infer security controls in business processes," *Logic Journal of the IGPL*, vol. 23, no. 1, pp. 57–72, 2015.

[17] B. Hamid, S. Gürgens, and A. Fuchs, "Security patterns modeling and formalization for pattern-based development of secure software systems," *Innovations in Systems and Software Engineering*, vol. 12, no. 2, pp. 109–140, 2016.

[18] A. A. Alzahrani, *Using Codecharts for Formally Modelling and Automating Detection of Patterns with Application to Security Patterns*, Doctoral dissertation, University of Essex, 2016, http://repository.essex.ac.uk/16112/1/Thesis%20Final%20To%20Library.pdf.

[19] A. K. Dwivedi and S. K. Rath, "Formalization of web security patterns," *INFOCOMP Journal of Computer Science*, vol. 14, no. 1, pp. 14–25, 2015.

[20] A. K. Dwivedi, S. K. Rath, and S. L. Chakravarthy, "Formalisation of SOA design patterns using model-based specification technique," in *Proceedings of International Conference on Computational Intelligence and Data Engineering*, pp. 95–101, Singapore, 2019.

[21] D. Jackson, "Alloy," *Communications of the ACM*, vol. 62, no. 9, pp. 66–76, 2019.

[22] X. He and Y. Fu, "Modelling and analyzing security patterns using high-level petri nets," *SEKE*, pp. 623–627, 2016.

[23] J. P. Near and D. Jackson, "Finding security bugs in web applications using a catalogue of access control patterns," in *ICSE '16: 38th International Conference on Software Engineering*, pp. 947–958, Austin, Texas, 2016, May.

[24] A. Behrens, "What are security patterns? A formal model for security and design of software," in *ARES 2018: International Conference on Availability, Reliability and Security*, pp. 1–6, Hamburg, Germany, 2018, August.

[25] A. van Den Berghe, K. Yskout, and W. Joosen, "Security patterns 2.0: toward security patterns based on security building blocks," in *2018 IEEE/ACM 1st International Workshop on Security Awareness from Design to Deployment (SEAD)*, pp. 45–48, Gothenburg, Sweden, 2018, May.

[26] H. Shimamoto, N. Yanai, S. Okamura, J. P. Cruz, S. Ou, and T. Okubo, "Towards further formal foundation of web security: expression of temporal logic in Alloy and its application to a security model with cache," *IEEE Access*, vol. 7, pp. 74941–74960, 2019.

[27] F. Obeid and P. Dhaussy, "Formal verification of security pattern composition: application to SCADA," *Computing and Informatics*, vol. 38, no. 5, pp. 1149–1180, 2019.

[28] H. Gadouche, Z. Farah, and A. Tari, "A valid and correct-by-construction formal specification of RBAC," *International Journal of Information Security and Privacy*, vol. 14, no. 2, pp. 41–61, 2020.

[29] A. Gallon, R. Gallier, and E. Bruno, "Access controls for IoT networks," *SN Computer Science*, vol. 1, no. 1, pp. 1–13, 2020.

[30] C. Gupta, R. K. Singh, and A. K. Mohapatra, "A formal approach for implementing security constraints in security patterns," in *2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)*, pp. 1–7, Noida, India, 2021, September.

[31] C. Gupta, R. K. Singh, and A. K. Mohapatra, "GeneMiner: a classification approach for detection of XSS attacks on web services," *Computational Intelligence and Neuroscience*, vol. 2022, Article ID 3675821, 12 pages, 2022.

[32] I. Bayley and H. Zhu, "Formal specification of the variants and behavioural features of design patterns," *Journal of Systems and Software*, vol. 83, no. 2, pp. 209–221, 2010.

[33] H. Zhu, "On the theoretical foundation of meta-modelling in graphically extended BNF and first order logic," in *2010 4th IEEE international symposium on theoretical aspects of software engineering*, pp. 95–104, Taipei, Taiwan, 2010, August.

[34] E. B. Fernandez, N. Yoshioka, H. Washizaki, and J. Yoder, "Abstract security patterns and the design of secure systems," *Cybersecurity*, vol. 5, no. 1, pp. 1–17, 2022.

[35] C. Dougherty, K. Sayre, R. C. Seacord, D. Svoboda, and K. Togashi, *Secure Design Patterns (No. CMU/SEI-2009-TR-010)*, Carnegie-Mellon Univ Pittsburgh Pa Software Engineering Inst, 2009.

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Research Article

Early Warning of Financial and Business Management Based on Three Improved BP-NN Algorithms

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To address the issue of early warning in financial management and economics, this article presents a study based on our improved BP-NN algorithms. This approach improves the benefits of early warning systems in financial and business management based on BP neural network algorithm technology and improves BP neural network algorithms. Based on the analysis and calculation of the results, the inconsistency of the financial model industry estimates is 66.3% and 72.7% for CT and non-CT companies. The actual discrimination rate of the hedge fund model is 81.3% and 83.9% for ST and ST companies, respectively. Compared with the net structure of the financial index, the general guidance model improved the ability of ST companies and non-ST companies to withstand risks by 14.27% and 8.76%, respectively. It can be concluded that the integration of nonfinancial indicators into the estimation model can improve the accuracy of the estimation of the model. Experiments have shown that research based on our improved BP-NN algorithms can not only eliminate BP network inadequacies but also improve the accuracy of early warning in financial markets.

1. Introduction

In today's world, as the business environment continues to improve, businesses will face many challenges in entering a competitive market, and financial issues have always been an important aspect of business confusion. The sector is facing more risks and challenges in its development. How to prevent a financial crisis is an important concern for businesses. At this stage, a study of the financial crisis warning system has been conducted, and its application suggests that the financial crisis warning system began with financial market research. At the same time, more business management procedures need to be integrated, financial crisis early warning and management procedures need to be tightened, and strong support for forecasting models and forecasting technology is needed. Early successful and cost-effective financial reporting can help businesses better manage their finances.

The emergence of BP neural network has strong operability, and the prediction accuracy of crisis is relatively high. It is based on this feature that has attracted much attention. On this basis, it began to study from different fields, such as the combination of hierarchical genetic algorithm and BP neural network, the combination of grey theory and neural network, and the construction of financial early warning based on neighborhood rough set and neural network. These studies have played a certain role in preventing the outbreak of enterprise financial crisis to a certain extent, but from the reality, the standard BP-NNs still have some disadvantages, such as local optimization and relatively slow network training speed, which requires us to further improve the BP-NN algorithm [1]. Based on this, combined with the needs of enterprise financial and economic management early warning and crisis early warning management, this paper proposes a network

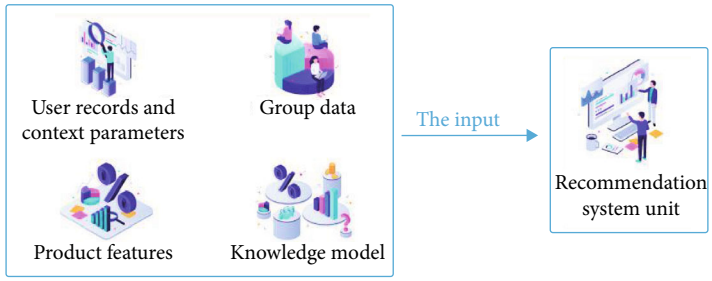

Figure 1: BP-NN improved algorithm.

algorithm based on HSDM-BP to further improve the BP neural network algorithm, as shown in Figure 1.

2. Literature Review

Exploring and constructing the system and method of predicting the operating risk of listed companies is the focus of the current theoretical and practical circles. In the current economic downturn situation, there is no significant upward inflection point, the increasing competition among companies and the rising business risks, establishing and improving the crisis prediction system of listed companies, and revealing the company's business problems in advance have become an issue of extraordinary concern to the company. The research on crisis prediction mainly includes the construction of prediction modeling and the setting of prediction indicators.

Schweiger et al. put forward many financial prediction models, such as univariate prediction model, multivariate linear discriminant model, principal component analysis, factor analysis, logistic regression model, combination of factor analysis and logistic regression, cluster analysis, decision tree, probit regression model, and y-score model [2]. Abreu et al. found that the previous prediction methods do have certain prediction functions, but there are some defects. For example, the financial information used in univariate prediction is one-sided, and the financial indicators themselves have limitations in evaluating the real income of the company [3]. Dai and Liu found that the multivariate linear discriminant model has strict requirements for the data used for prediction, but it lacks wide application and universality [4]. Zhang et al. proposed improved prediction models based on data mining technology, such as BP neural network, intelligent neural network, recursive partitioning algorithm (RPA), and artificial neural network system model (ANN) [5]. Han and Huang found that although the model adopts the latest research results of system science and informatics and has a certain scientificity, it is difficult to operate and does not have universality [6].

The research on financial crisis early warning continues to deepen with the improvement and perfection of the capital market. Some scholars used the univariate analysis method in econometrics to analyze and judge 19 companies as samples. The results show that among all the judgment indicators, the net interest rate of shareholders' equity and the ratio of shareholders' equity to liabilities have the best prediction effect, and these indicators have obvious signs in the three years before bankruptcy. Based on the principle of statistics, a unitary financial crisis early warning model based on single financial ratio is established. He selected samples according to the size of assets and the matching principle, selected 30 variable indicators from all report items, and tested the prediction of the selected samples within 5 years before bankruptcy. The study found that the misjudgment rate in the year before the dilemma was only 13%. The research results play a connecting role in the field of financial crisis early warning and lay a solid foundation for the next multivariable prediction model [7]. In addition to the above studies, many experts and scholars have developed mixed research models. Select listed companies that have been successful in the commodity exchange industry for the last 20 years, study data extraction techniques, and provide a variety of applications (analytical discrimination, logistic regression analysis, neural network, and timber decision making). Develop a hybrid approach. Empirical experiments show that the hybridization process has more accurate predictions than one method, which opens up new possibilities for early financial warning. Some scholars are constantly improving the neural network algorithm. On the one hand, cluster analysis is used to reclassify the degree of enterprise distress, which is more in line with the development trend of enterprise management. On the other hand, the rough set theory is used to screen the variable indexes, which increases the fitting degree of the network model to a certain extent. It can be seen that the model formed by the organic combination of the three is obviously better than the prediction ability of traditional ANN. In the study, factor analysis was used to eliminate the collinearity between indicators. The results show that the model has good predictability. Among all indicators, the influencing factor coefficient of profitability is the largest.

3. Related Algorithm Theory

3.1. Theoretical Basis of Harmony Search Algorithm. HS algorithm is similar to simulated annealing algorithm, which imitates physical annealing mechanism; particle swarm optimization algorithm imitates bird predation; genetic algorithm imitates biological evolution, etc. However, compared with other metaheuristic algorithms, the principle is simpler and easier to understand, less mathematical expressions and parameters are applied, and it is easier to be applied to various

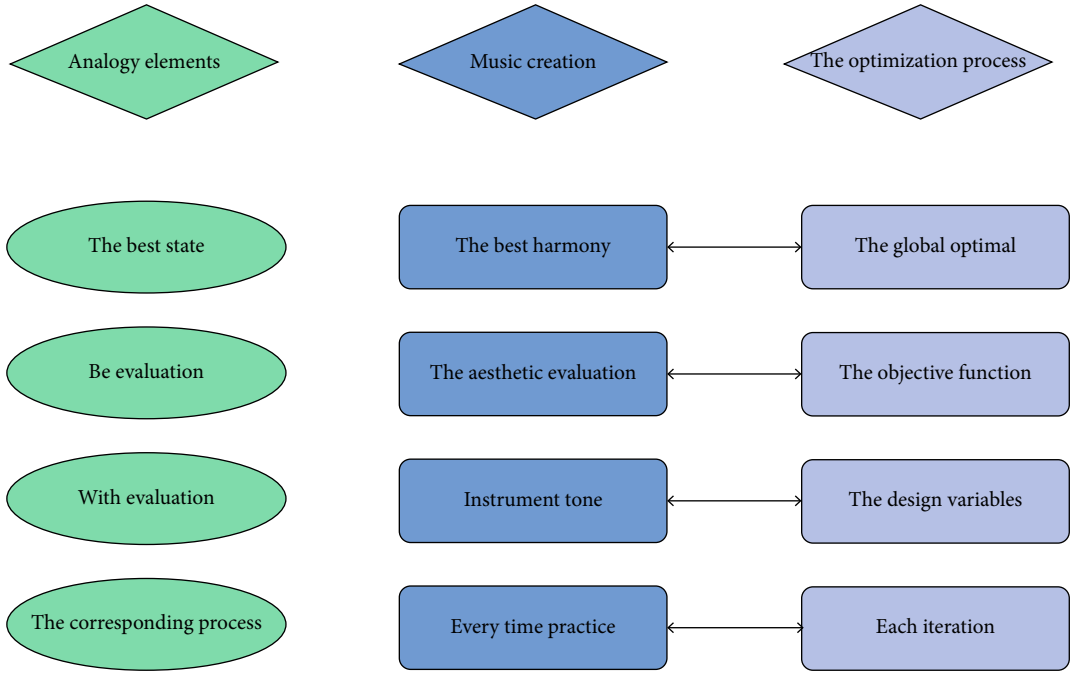

Figure 2: Comparison of music creation and optimization process.

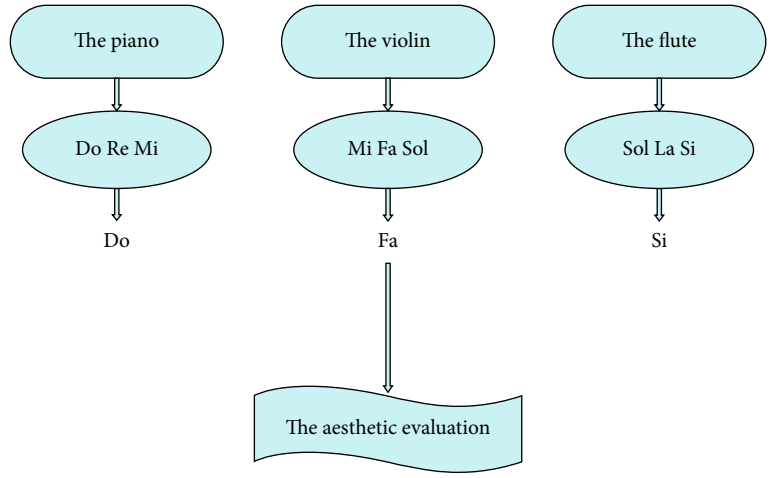

Figure 3: Schematic diagram of music creation.

engineering optimization problems. It is a prominent advantage of harmony search algorithm [9], as shown in Figure 2.

Harmony memory (HM) is a unique set of solution vectors in harmony search algorithm. Firstly, initialization operation is required, and then, new harmony is randomly generated. Compared with the original worst harmony in harmony memory, by worst case scenario, the best update is changed by HM and done in a cycle until the last event is encountered, as shown in Figure 3.

In the actual optimization problem, each musical instrument (piano, violin, and flute) in Figure 3 corresponds to a decision variable $\{x1, x2, x3\}$. At this time, the corresponding value of $\{\text{Do, Re, Mi, Fa, Sol, La, Si}\}$ is $\{100, 200, 300, 400, 500, 600, 700\}$. For the new harmony $\{\text{Do, Fa, Si}\}$, the corresponding new solution is $\{100,400,700\}$. If the target value obtained from the new drug f (100,400,700) is greater than that of the worst drug, the old drug is replaced by the new drug and repeated until the best solution [10].

Before the implementation of the algorithm, clarify the problem, determine the objective function $f(x)$ and constraints, and set parameters, harmony memory size HMS, decision variable size D, variable value range (xL, xU), iteration number Ni, harmony memory retention probability HMCR, tone adjustment probability par, tone bandwidth BW, etc. [11]. Determine the number of solutions HMS in HM, and each solution vector is composed of D solution

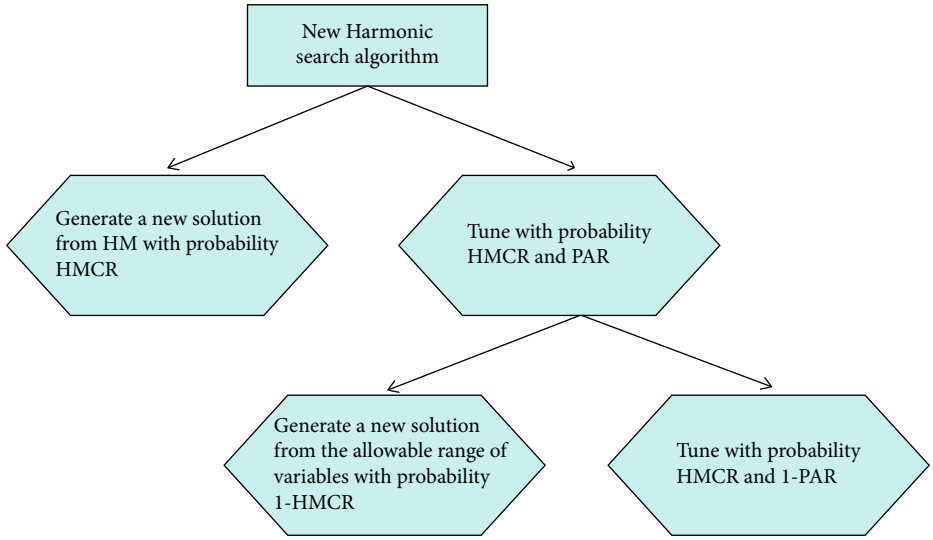

Figure 4: Probability tree of HS new solution generation.

components. A solution vector $xi(j) = \{xi(1), xi(2), \cdots, xi(D)\}$ is randomly generated in the way shown in formula (1), and the harmony memory is created, as shown in

$$\begin{aligned} x_i(j) &= x^L + \left(x^U - x^L\right), \\ i &= 1, 2, \cdots, \text{HMS}, \\ j &= 1, 2, \cdots, D. \end{aligned} \tag{1}$$

The probability tree of the new solution of harmony search algorithm is shown in Figure 4.

Compare new drugs with the worst drugs of memory loss. If the new solution is worse than the worst solution, replace the worst solution; otherwise, do not operate, as shown in

$$\text{if}\left(f\left(X_{\text{new}}\right)\right) < f\left(X_{\text{worst}}\right) X_{\text{worst}} = X_{\text{new}}. \tag{2}$$

If the algorithm reaches the maximum number of iterations Ni or meets the convergence conditions, stop the operation; otherwise, return to step (3) to continue. For function optimization problems, standard differential evolution algorithm is a special genetic algorithms based on real numbers as well optimization-preserving greedy strategy. Considering the two operations of mutation and crossover, differential evolution algorithms can describe different kinds in the general way of DE/*a*/*b*/*c* [12], where *c* generally takes bin or exp, representing binomial crossover and exponential crossover, respectively. DE/rand/1/bin is the most commonly used version of all differential evolution algorithms.

3.2. Selection of Early Warning Indicators

3.2.1. Selection of Early Warning Indicators. Reasonable selection of early warning indicators is the premise and basis of establishing financial crisis early warning model. It is related to the early warning effect of the final model and whether the research conclusion is correct [13]. Although there is no unified opinion and standard on the selection of financial crisis early warning indicators in the academic circles, this paper will select according to the following principles to make the prediction effect reach the best state.

3.2.2. Specific Selection and System Construction of Early Warning Indicators. Based on the above options and research scientists, a financial crisis prevention system was created based on the specifics of high-tech companies and the choice of financial measures based on the specifics of problem solving, operational efficiency, and effectiveness (as shown in Table 1).

3.2.3. Optimization of Early Warning Indicators. In this paper, Spss17.0 software is used for principal component analysis of early warning indicators in T-1 and T-2 years. The correlation test between index variables by KMO sample measurement method and Bartlett sphere test method is provided in SPSS statistical software [14]. Only when there is correlation between variables, it is suitable for principal component analysis. This paper applies KMO test to detect the correlation of 28 financial crisis early warning indicators. The criterion of KMO test results is as follows: the test value is between 0 and 1. The closer it is to 1, the stronger the correlation between variables is, and vice versa, the more suitable for the analysis of the main components. The relative affinity of the allergen for the identification of the essential properties can be seen from the following table. A sample KMO test of 0.812 indicates a correlation of differences, and a SIG value of $0.007 < 0.05$ indicates a correlation of 28 differences. The options cannot be optimized by the analysis of the main components [15]. The results of the KMO test can be seen in the Table 2.

Then, we extract the principal components of the variables and extract the common factors according to the

Table 1: Financial early warning index system.

Serial number	Indicator name	Formula calculation
1	Current ratio	$\frac{\text{Ending current assets}}{\text{ending current liabilities}}$
2	Fast young ratio	$\frac{\text{Current assets} - \text{inventory}}{\text{current liabilities at the end of the period}}$
3	Cash ratio	$\frac{\text{Monetary capital} + \text{trading financial assets}}{\text{current liabilities}}$
4	Asset liability ratio	$\frac{\text{Total liabilities at the end of the period}}{\text{total assets at the end of the period}}$
5	Interest cover	Total profit + financial expenses
6	Inventory turnover	$\frac{\text{Cost of goods sold}}{\text{average inventory balance}}$
7	Total asset turnover	$\frac{\text{Sales revenue}}{\text{average total assets}}$
8	Turnover rate of accounts receivable	$\frac{\text{Net sales revenue}}{\text{average balance of accounts receivable}}$
9	Turnover rate of fixed assets	$\frac{\text{Net sales revenue}}{\text{average total fixed assets}}$
10	Turnover rate of current assets	$\frac{\text{Net sales income}}{\text{average total current assets}}$
11	Return on net assets	$\frac{\text{Net profit}}{\text{owner's equity}}$
12	Return on total assets	$\frac{\text{Total profit}}{\text{average total assets}}$
13	Operating net interest rate	$\frac{\text{Gross operating profit}}{\text{residential business income}}$
14	Cost interest rate	$\frac{\text{Total profit}}{\text{cost of residential business} + \text{period expenses}}$

Table 2: KMO and Bartlett's inspection.

KMO measurement of sampling adequacy		0.812
Bartlett's sphericity test	Approximate chi-square	2745.246
	df	349
	Sig.	0.007

criteria self-esteem more than 1 and their contribution more. All the differences described are shown in Table 3.

As can be seen from the above table, there are eight eigenvalues greater than 1 in the correlation coefficient matrix, which are 8.235, 3.126, 3.077, 2.690, 1.568, 1.266, 1.563, and 1.159, respectively, and the cumulative contribution rate of these eight factors is as high as 85.042%, which can reflect most of the financial characteristics of high-tech enterprises [16]. The eight main factors can also be seen intuitively through the gravel diagram, as shown in Figure 5.

In addition, based on the result of the unification of events (Table 4), the association of eight elements of difference is shown. This indicates that most of the key points of the early warning indicator are higher than 0.8, which shows that the key points of the early warning indicator are well explained by eight points [17].

In order to facilitate factor interpretation, based on 8 main factors, the factor load is converted by the maximum variance method in the orthogonal rotation method, so as to obtain the rotated factor load.

4. Financial Early Warning System Based on HSDM-BP

4.1. Error Back Propagation Neural Network

4.1.1. Artificial Neuron Model. For easy building of a neural network device, artificial neuron not only simulates the structure and function of biological neurons but also abstracts the information processing process of biological neurons. The main functions of artificial neurons include weighting function, summation function, and transfer characteristics [18].

Let the input vector of neuron J be as equation (3), $xi\,(i = 1, 2, \cdots, n)$ represents the input of the i-th neuron, and

Table 3: Total variance explained (%).

Ingredients	Initial eigenvalue			Extract sum of squares load			Rotation sum of squares loading		
	Total	Variance	Total	Variance	Total	Variance	Total	Variance	Total
1	8.235	29.322	29.322	8.235	8.235	29.322	7.356	25.604	25.443
2	3.126	13.177	42.338	3.126	3.126	42.338	3.422	13.499	38.781
3	3.077	11.026	53.203	3.077	3.077	53.203	3.369	12.261	50.881
4	2.690	9.733	62.775	2.690	2.690	62.775	2.120	8.608	59.328
5	1.568	7.285	69.899	1.568	1.568	69.899	1.965	7.318	66.485
6	1.266	6.521	76.259	1.266	1.266	76.259	1.458	7.275	73.600
7	1.563	4.992	81.09	1.563	1.563	81.09	1.897	7.174	81.09
8	1.159	4.113	85.042	1.159	1.159	85.042	1.381	4.430	85.042

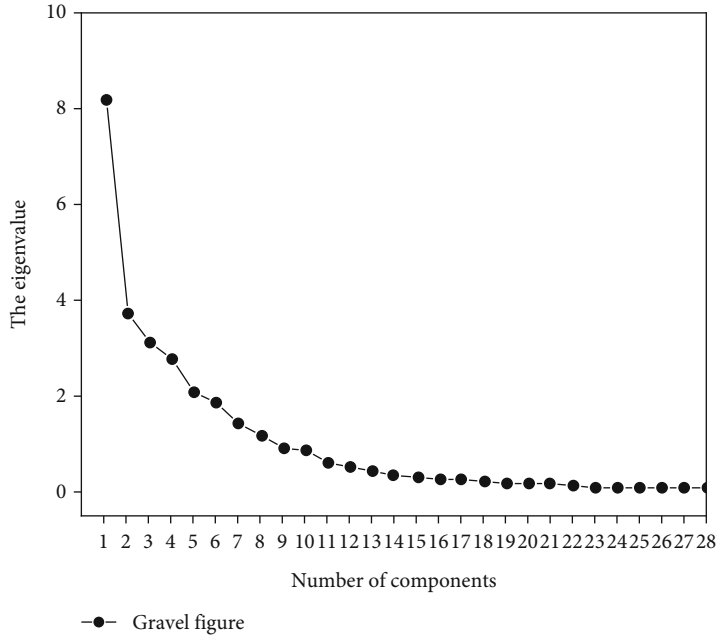

Figure 5: Gravel diagram.

Table 4: Common factor variance.

	Initial	Extract		Initial	Extract
Current ratio	1.000	0.967	Earnings per share	1.000	0.758
Quick ratio	1.000	0.971	Growth rate of operating revenue	1.000	0.948
Cash ratio	1.000	0.952	Net profit growth rate	1.000	0.850
Asset liability ratio	1.000	0.778	Growth rate of net assets	1.000	0.655
Interest cover	1.000	0.956	Growth rate of total assets	1.000	0.891
Inventory turnover	1.000	0.609	Net profit cash Net content	1.000	0.658
Total asset turnover	1.000	0.916	Business income Cash ratio	1.000	0.810

N is the number of input neurons.

$$X_j = (x_1, x_2, \cdots, x_n)^T. \quad (3)$$

Weighting vector of the input neuron node connected to the neuron node j is shown in equation (4), and $wij(i = 1, 2, \cdots, n)$ represents the weighting value from the input node i to the node j.

The weighting vector of the input neuron node connected to the neuron node j, as shown in equation (4), represents the weighting value from the input node i to the node j.

$$X_j = \left(w_{1j}, w_{2j}, \cdots, w_{nj}\right)^T. \tag{4}$$

The threshold value of neuron j is θj, and its input weighted sum is shown in formula (5). $x0 = 1$ fixed offset input node is used to represent the threshold node, and the connection strength between neuron j and neuron j is

$$w_{0j} = \theta_j. \tag{5}$$

Thus, equation (6) can be obtained:

$$s_j = \sum_{i=1}^{n} x_i w_{ij} - \theta_j. \tag{6}$$

The output of neuron j is shown in equation (7). Function $f(\cdot)$ reflects the nonlinear relationship between neuron input and output, which is called transfer function. The final output value yj can be obtained only after artificial neuron input excitation sj is processed by transfer function.

$$y_j = f\left(s_j\right). \tag{7}$$

4.1.2. Neural Network Learning Methods. If any neural network needs to realize some function, it must be trained first; that is, the network connection weight must be adjusted [19]. No matter what kind of learning algorithm is used, the network learning results before adjustment need to be evaluated according to the evaluation criteria. According to different evaluation criteria, it can be divided into guided or unsupervised learning. Guided learning needs to provide a certain evaluation standard to the network output. The network will judge the direction and size of the error according to the comparison results between the actual output and the expected output, so as to determine the adjustment method of network connection weight and reduce the error between the actual output and the expected output. Unsupervised learning does not need to provide network evaluation criteria. The learning system can independently adjust the connection weight according to its own unique network structure and learning rules.

4.2. Error Back Propagation Neural Network. Usually, the multilayer perceptron model of BP learning algorithm is called error back propagation neural network. The hidden layer neurons of BP neural network can have learning ability, which is closely related to its use of nonlinear continuous transformation function, with a typical three-layer structure [20].

N processing units in L1 layer are fully connected with P processing units in L2 layer. $W = \{wij \mid i = 1, 2, .., n, j = 1, 2, .., p\}$ represents the unit connection weight, $X = (x1, ..xi, .., xn)T$ is the unit input column vector, and $\theta j(j = 1, 2 \cdots, p)$ represents the unit threshold; then, the input weighted sum of each processing unit in L2 layer is shown in

$$s_j = \sum_{i=1}^{n} x_i w_{ij} - \theta_j. \tag{8}$$

This section introduces the artificial neuron model, learning rules, and error back propagation neural network process algorithm and points out the limitations of BP neural network. Aiming at the harmony search algorithm, this paper expounds the inspiration source and development status of harmony search algorithm [21]. At the same time, the mutation mechanism of differential evolution algorithm is introduced, and the important parameters and algorithm steps involved in the two algorithms are described in detail.

5. Construction of HSDM-BP Financial Early Warning Model

5.1. HSDM Algorithm Optimization BP Neural Network. In order to reflect the advantages of HSDM algorithm, the similar improved algorithms of two existing algorithms are selected for comparison [22]. The proposed differential harmony search algorithm DHS (differential harmony search) also uses differential evolution algorithm to improve the harmony algorithm, but DHS algorithm does not consider the original O3 operation but uses a pair of differential mutations to act on the decision variables generated by O1 operation and O2 selection operation. The scaling factor is sampled in a distribution between 0 and 1. In fact, it is not reasonable to use differential mutation to generate decision variables in O2 random selection operation. The effective icons provided by this method are only applicable to HM subregion. However, the decision variables generated by O2 operation often exceed this range. The adaptive harmony search algorithm SAHS (self-adaptive harmony search) proposed in literature modifies the original O3 operation through spacing adjustment to adjust the harmony distribution within HM, but the median range of memory cannot accurately express the global attributes; especially when changing in turn, it cannot provide a considerable mutation direction [23]. The global complexity of HS, DHS, SAHS, and HSDM algorithms is tested in 10 to 30 dimensions through five common test functions, as shown in the following formula:

$$f_1(x) = \sum_{i=1}^{n-1}\left[100\left(x_{i+1} - x_i^2\right)^2 + \left(x_i - 1\right)^2\right], \tag{9}$$

$$f_2(x) = \sum_{i=1}^{n}\left[x_i^2 - 10\cos\left(2\pi x_i\right) + 10\right], \tag{10}$$

$$f_3(x) = \frac{1}{400}\sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n}\cos\left(\frac{x_i}{\sqrt{i}}\right) + 1, \tag{11}$$

$$f_4(x) = -20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n}x_i^2}\right) - \exp\left(-\frac{1}{n}\sum_{i=1}^{n}\cos 2\pi x_i\right) + 20 + e, \tag{12}$$

$$f_5(x) = \sum_{i=1}^{n}\left(x\sin\sqrt{|x_i|}\right). \tag{13}$$

In the test, different algorithms are applied to each test problem for 25 times, and each independent operation is guaranteed to be given the same random initial value. At the same time, two termination criteria of the maximum order of magnitude and the minimum error function value EFV (error function value) of the test function are set. The optimization performance of the algorithm is evaluated by the best EFV and calculation success rate. The test function under 10 d and 30 d evaluates the empirical accumulation function distribution of the success times of each algorithm calculation function under the accuracy of 10-8. It can be seen that after 5000 (10 d) to 19000 (30 d) iterations, HSDM is always better than the other three algorithms.

5.2. HSDM Algorithm Optimization BP Neural Network. Gradient descent is similar to a person standing on a hillside, always looking for the section with the largest gradient and moving down the mountain, as shown in Figure 6. When someone falls along the maximum slope at point A, he will reach the local minimum point B. At this time, he cannot see a lower place than himself. If he is at point C and moves down along the maximum slope, he will reach the global minimum point D.

To sum up, the convergence of BP neural network depends on the initial position of the learning mode. Appropriately changing the initial connection weight can effectively avoid the local minimum in the convergence process. Compared with the original random initialization method, this paper adopts the method of optimizing the connection weight and threshold. Formulas (14)– (17) are the error formula:

$$E^k = \frac{1}{2}\sum_{t=1}^{q}\left(\delta_t^k\right)^2, \tag{14}$$

$$E^k = \frac{1}{2}\sum_{t=1}^{q}\left(y_t^k - c_t^k\right)^2, \tag{15}$$

$$E^k = \frac{1}{2}\sum_{t=1}^{q}\left[y_t^k - f\left(\sum_{j=1}^{p}v_{jt}b_t^k - \lambda_t\right)\right]^2, \tag{16}$$

$$E^k = \frac{1}{2}\sum_{t=1}^{q}\left[y_t^k - f\left(\sum_{j=1}^{p}v_{jt}\left(\sum_{i=1}^{n}w_{ij}x_i^k - \theta_j\right) - \lambda_t\right)\right]^2. \tag{17}$$

Each harmony vector in the harmony memory (HM) is regarded as a complete set of connection weights and thresholds of BP neural network [24]. Among them, SSE represents the sum of squares of errors between the expected target output and the actual output value. If the sum of squares of errors is smaller, it indicates that the individual is better. On the contrary, if the SSE value is larger, it indicates that the individual is worse.

In Table 5, the connection weight from the entry of j of the primitive layer is represented by the node of the i layer W_{xiyj}, and the beginning of the j node of the hidden layer is denoted by θyj. The weight of the connection from node j of the latent process to the output phase P node is expressed as W_{yjzp}, and the initialization of the output layer P node is denoted by θzp. At the same time, they jointly form a harmony vector. In addition, since the network weight values are often in the same range, the value range $[xL(d), xU(d)]$ should be determined for the decision variables according to the premise.

5.3. Empirical Analysis of Improved BP Neural Network

5.3.1. Prediction Index Screening. In order to reduce the computational complexity in the empirical analysis and ensure the significance of the model, 37 prediction indexes such as profit, debt repayment, operation, development, EVA, ownership structure, and management structure of the sample companies in T-3 years were screened [25]. Sample screening procedure: firstly, calculate Kolmogorov-Smirnov value and test the normal distribution of each index variable. Secondly, if the variable conforms to the normal distribution, the Levene test of the variance equation and the t-test of the mean equation are carried out. If the variable does not conform to the normal distribution, the Wilcoxon rank is calculated and the nonparametric test is carried out. Finally, the correlation analysis of each variable is carried out to eliminate the significantly interrelated variables and determine the final prediction index system. Data processing software includes Excel, Spss19, and MATLAB.

K-S test is used to check whether the experimental data conform to the normal distribution, while Kolmogorov-Smirnov value reflects the probability that the distribution function $f(y)$ meets the normal distribution standard in a specific range. The criterion for determining the significance level of the test is 0.05 (the same below), according to the results of K-S test and significance test. It can be seen that the P values of the seven indicators of operating gross profit margin, growth rate of total assets, growth rate of basic earnings per share, turnover rate of current assets, shareholding proportion of the largest shareholder, equity concentration, and number of senior executives are greater than the significance level of 0.05 and obey the normal distribution, while the P values of other indicators are less than 0.05, which does not meet the normal distribution.

For variables that do not fit into the normal distribution, count the Wilcoxon measurement and make the measurement nonparametric. The test results are shown in Table 5. The earnings analysis shows that real estate is stable, revenue growth, property growth rate, commodity exchanges, stock exchanges, fairness, management comparisons, business associations, business owners, the separation of the two rules, the president and the appointment, ride wide of directors,

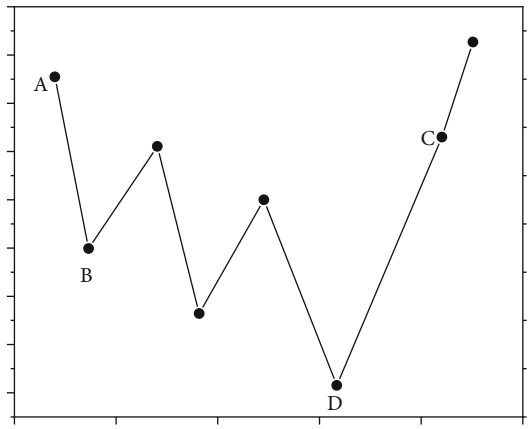

Figure 6: Local minima and global minima.

financial index prediction model for ST company and non-ST company is 66.3% and 72.7%, respectively. The discrimination accuracy of the comprehensive early warning model for the financial crisis early warning of ST companies and non-ST companies is 81.3% and 83.9%, respectively. Compared with the pure financial index model, the comprehensive index model improves the crisis early warning ability of ST companies and non-ST companies by 14.27% and 8.76%, respectively. It can be concluded that the integration of nonfinancial indicators into the prediction model can significantly improve the prediction accuracy of the model. At the same time, the study also found that ST companies and non-ST companies have differences in financial indicators, ownership structure, and management structure. In practical application, corporate controllers, managers, investors, and other stakeholders can focus on the changes of these indicators and then make judgments and take measures in time in

Table 5: Network link weight and threshold of each layer.

Weight and threshold from hidden layer to output layer				Weight and threshold from hidden layer to output layer			
W_{X1Y1}	W_{X1Y1}	W_{X1Y1}	W_{XiYj}	W_{Y1Z1}	W_{Y1Zp}	W_{YjZ1}	W_{YjZp}
	...				...		
Θ_{Y1}		Θ_{Yj}		Θ_{Z1}		Θ_{Zp}	
Y_1		Y_j		Z_1		Z_p	

numberof directors, and all supervisors. The result p of Mann-Whitney U's test for 11 negative ions was greater than the value of 0.05; i.e., there was no significant difference between the "ST" and "non-ST" groups of 11 negative values. They are excluded from the study. The remaining 19 measures ($P < 0.05$) reject the initial assumption and assume that there is a significant difference between the two groups, so that the severity is maintained as an estimate of the difference between the two groups.

5.3.2. Correlation Analysis. After the above screening, 14 indicators were eliminated from the 37 alternative indicators, and now, 23 indicators are retained for correlation test. After inspection, the financial prediction model is constructed by retaining 8 financial indicators: net profit margin of total assets (X3), operating gross profit margin (X4), return on investment (X5), current ratio (X6), asset liability ratio (X8), receivables turnover rate (X12), fixed assets turnover rate (X14), and EVA (X21). There are also five nonfinancial indicators, namely, the largest investor fairness (Y1), the largest market share (Y2), real manager fairness (Y3), valuation and equity (Y8), and the president and the appointment of the CEO (Y9), selected as the input indicators of the comprehensive prediction model together with the above eight financial indicators.

The financial LM-BP neural network model constructed in this paper has good predictive power for enterprise financial crisis. From the calculation results of experimental samples, it can be seen that the discrimination accuracy of pure combination with other factors that should be considered, so as to reduce or even avoid losses. Specific differences are as follows:

(1) In terms of financial indicators, ST company generally has negative profitability indicators such as operating gross profit margin and net profit, serious losses and continuous insufficient return on investment, high asset liability ratio, poor solvency, and high risk

(2) The operating turnover capacity is poor, which is reflected in the significantly low turnover rate of accounts receivable and other indicators

(3) Compared with traditional financial indicators, EVA indicators can more objectively and completely reflect the long-term operating results of listed companies. The average EVA of ST enterprises is negative, far behind the normal operating enterprises, showing negative growth

(4) In terms of ownership structure, ST companies are more likely to occur in listed companies not controlled by the state. The reason is that there are different degrees of agency contradictions between the controlling shareholders and external investors of non-state-owned listed companies, which will undoubtedly hinder the improvement of corporate performance

6. Conclusion

Based on the standard BP-NN prediction model, this paper uses three different training functions as the technical route to improve the BP network algorithm, namely, additional momentum method, conjugate gradient method, and L-M (Levenberg-Marquardt) optimization method, to make an empirical analysis on the sample data of nonfinancial listed companies. By comparing the training process and simulation and regression results of the three improved algorithms, it is found that LM-BP is significantly better than the additional momentum improvement method and conjugate gradient improvement method in terms of network convergence speed, training error, and satisfaction of output results. By comparing the financial index prediction model and the comprehensive prediction model, the prediction results show that the introduction of nonfinancial indicators significantly improves the diagnosis efficiency and prediction accuracy of the model and can better meet the purpose of financial crisis early warning in practical application. Based on the findings of the study and the current situation of early warning of emergencies of some listed companies, the following recommendations are made in this paper:

(1) Improve the crisis awareness of listed companies and improve the crisis early warning system. When a listed company has financial abnormalities, the early warning system can give timely warning before the enterprise falls into financial crisis and assist the company controller to take effective measures in advance, so as to avoid the further deterioration of potential financial problems. The premise is to establish and improve an effective early warning system and enhance crisis awareness. At the same time, we should constantly improve the prediction index system, optimize the prediction model, timely collect information and make prediction, find the problems existing in the production and operation process of the company and apply the remedy to the case, prevent the occurrence of financial crisis in time, and maintain the normal operation of the enterprise

(2) Correctly understand EVA and strengthen its application in crisis prediction. The traditional financial system does not deduct the opportunity cost when calculating the company's profit, which may lead to the serious consequence that the profit is overestimated. Correspondingly, EVA index just makes up for the shortcomings of the traditional financial index system. When calculating the economic value of the company, we fully consider debt capital and equity capital and deduct them as the cost of net profit. Therefore, the introduction of EVA index system in financial early warning can strengthen the prediction ability of the early warning system and enable listed companies to better prevent financial problems

(3) Strengthen the internal management of the company and optimize the equity allocation. Listed companies need to select financing methods in combination with their own reality, optimize the equity allocation, actively guide major shareholders to play a positive role, and prevent the rupture of cash flow in a certain link due to excessive debt and reducing their ability to pay, which affect the payment of due debts and lead to the possibility of financial crisis. In addition, a perfect internal management system can provide a solid internal foundation for listed companies and take timely measures in the face of financial problems, so as to quickly get rid of the crisis

Data Availability

No data were used to support this study.

Conflicts of Interest

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

References

[1] L. I. Zhi-Qing and F. U. Xiu-Fen, "Performance study on three kinds of improved BP algorithm based on principal component analysis," *Computer Engineering*, vol. 37, no. 21, pp. 108–110, 2011.

[2] C. R. Schweiger, G. Soeregi, S. Spitzauer, G. Maenner, and A. L. Pohl, "Evaluation of laboratory data by conventional statistics and by three types of neural networks," *Clinical Chemistry*, vol. 39, no. 9, pp. 1966–1971, 1993.

[3] P. Abreu, W. Adam, T. Adye, E. Agasi, and G. Zumerle, "Mean lifetime of theb s 0 meson," *Zeitschrift für Physik C*, vol. 71, no. 1, pp. 11–30, 1996.

[4] Q. Dai and N. Liu, "The build of n-bits binary coding ICBP ensemble system," *Neurocomputing*, vol. 74, no. 17, pp. 3509–3519, 2011.

[5] Y. Zhang, D. Guo, and L. Zhan, "Common nature of learning between back-propagation and hopfield-type neural networks for generalized matrix inversion with simplified models," *IEEE Transactions on Neural Networks & Learning Systems*, vol. 24, no. 4, pp. 579–592, 2013.

[6] Z. Han and H. Huang, "Gan based three-stage-training algorithm for multi-view facial expression recognition," *Neural Processing Letters*, vol. 53, no. 6, pp. 4189–4205, 2021.

[7] Y. Zhang, "An improved algorithm for three-dimentional surface reconstruction based on contour data of medical images," *Computer Engineering and Applications*, vol. 40, no. 13, pp. 215–218, 2004.

[8] J. N. Han, Q. Zhang, and P. Yang, "Research and realization on improved algorithm for image segmentation based on brain images three-dimensional reconstruction. Zhongbei Daxue Xuebao (Ziran Kexue Ban)/Journal of North University of China Natural," *Science Edition*, vol. 35, no. 3, p. 354-358 +364, 2014.

[9] S. Yang, F. Wang, and Z. Zhang, "Decoupling research of a novel three-dimensional force flexible tactile sensor based on an improved BP algorithm," *Micromachines*, vol. 9, no. 5, p. 236, 2018.

[10] Q. U. Changwen, X. U. Zheng, S. U. Feng, and B. Deng, "Research on an improved PLKF algorithm based on three-dimensional location model," *Journal of Projectiles,*

Rockets, Missiles and Guidance, vol. 30, no. 3, pp. 226–228, 2010.

[11] X. Huang, D. Han, M. Cui, G. Lin, and X. Yin, "Three-dimensional localization algorithm based on improved A and DV-hop algorithms in wireless sensor network," *Sensors*, vol. 21, no. 2, p. 448, 2021.

[12] J. Hao, "Research on an improved differential evolution algorithm based on three strategies for solving complex function," *International Journal of Smart Home*, vol. 9, no. 11, pp. 313–322, 2015.

[13] T. Zhao, X. Wei, and P. Yi, "Evolutionary design based on an improved genetic algorithm and generative three-dimensional shape," *Journal of Mechanical Engineering*, vol. 46, no. 19, pp. 147–154, 2010.

[14] Y. Tian, H. Cui, Z. Pan et al., "Improved three-dimensional reconstruction algorithm from a multifocus microscopic image sequence based on a nonsubsampled wavelet transform," *Applied Optics*, vol. 57, no. 14, pp. 3864–3872, 2018.

[15] R. Li, Y. Liu, M. Yang, and H. Zhang, "Three-dimensional point cloud segmentation algorithm based on improved region growing," *Laser & Optoelectronics Progress*, vol. 55, no. 5, article 051502, 2018.

[16] P. Bologna, "Structural funding and bank failures," *Journal of Financial Services Research*, vol. 47, no. 1, pp. 81–113, 2015.

[17] P. Cumperayot, "Stability of Thai baht: tales from the tails," *Bulletin of Economic Research*, vol. 69, no. 4, pp. 355–383, 2017.

[18] Z. Zhu and N. Liu, "Early warning of financial risk based on k-means clustering algorithm," *Complexity*, vol. 2021, Article ID 5571683, 12 pages, 2021.

[19] X. Zheng, G. Zhu, N. Metawa, and Q. Zhou, "Machine learning based customer meta-combination brand equity analysis for marketing behavior evaluation," *Information Processing and Management*, vol. 59, no. 1, article 102800, 2022.

[20] E. Cabezon, L. Hunter, P. Tumbarello, K. Washimi, and Y. Wu, "Enhancing macroeconomic resilience to natural disasters and climate change in the small states of the pacific," *Social Science Electronic Publishing*, vol. 15, no. 9, pp. 865–879, 2015.

[21] B. Zhao, X. Lyu, and N. Qi, "Construction and optimization of transboundary business financial credit network in the era of 5G communication," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 6481340, 14 pages, 2022.

[22] S. Shriram, J. Jaya, S. Shankar, and P. Ajay, "Deep learning-based real-time AI virtual mouse system using computer vision to avoid COVID-19 spread," *Journal of healthcare engineering*, vol. 2021, Article ID 8133076, 8 pages, 2021.

[23] Y. Yan and B. Suo, "Risks analysis of logistics financial business based on evidential Bayesian network," *Mathematical Problems in Engineering*, vol. 2013, Article ID 785218, 8 pages, 2013.

[24] C. Shao and X. Chen, "Deep-learning-based financial message sentiment classification in business management," *Computational Intelligence and Neuroscience*, vol. 2022, Article ID 3888675, 9 pages, 2022.

[25] A. Cunha and F. L. Almeida, "Online social and financial management medium for non-business enterprises," *Int. J. Web Appl.*, vol. 11, no. 3, pp. 97–109, 2019.

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Research Article

Design and Application of English Online Learning Platform

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In order to solve the problems of the existing English online learning platforms, such as the single way of providing learning content and the unclear learning purpose, this article proposes to build a cloud computing online learning platform based on data correlation mining label distribution learning algorithm. With the help of distributed computing and virtualization technology, the software and hardware resource virtualization resource pool is integrated to build an open online learning system, which can change the defects of traditional English online learning system to the maximum extent. At the level of 10000 iterations, the average number of system requests is 2.17/s. The system runs steadily and can meet the English learning needs of student users; it can be popularized and applied in English teaching practice.

1. Introduction

With the deepening of globalization, English plays an increasingly important role in our real life. Nowadays, people are becoming more and more enthusiastic about learning English. With the continuous development of smart terminal devices and the upgrading of smart products such as mobile phones and iPads, English online learning is becoming more and more popular. At present, there are more and more English online learning platforms. However, from the overall situation of the development of the existing platforms, the English learning content provided by online learning platforms is relatively single. No matter what the audience's learning purpose is, the learning content they eventually see is the same. The learning effect behind the single and solidified platform learning content can be imagined. Based on this problem, this study uses data mining algorithm to deeply explore the learning needs of the audience, develop an online learning platform based on user needs, further improve the knowledge structure of the online learning platform, and provide personalized English learning content selection for users [1].

In foreign online learning, the study of learners is mainly reflected in the study of learning support services, which can meet the needs of learners by providing a variety of services for learners and improve the quality of online learning. These support services are provided after a detailed analysis of learners. Online learning is the third generation of distance education. Learners learn through the Internet, with little teacher involvement and students learning completely on their own. So student learning support services are very important. Every online international learning center has great value for student support services. For example, it is true that some online courses have a model called "Educational Support Services" that outlines the content of the educational support services they provide on their platform and how people learn differently on their platform [2]. Educational programs for foreign scholars can be divided into research programs and non-research programs. In terms of academic support, foreign online learning platforms mainly provide services about problems encountered by learners in course learning, and their services in this aspect are very mature. In terms of non-academic support, foreign online learning platforms mainly provide learning consulting services, personalized daily management, online learning process monitoring services, technical failure services, emotional care services, etc. These services are very mature in foreign countries and have been recognized by many online learners [3].

In China, theoretical research on learner characteristics is emphasized, but the research results are seldom applied in practice. There are many theoretical studies on online

learner characteristics in China. For example, some scholars have conducted in-depth studies on learner characteristics from some aspects. Many other scholars have studied the characteristics of learners through empirical research and case studies and have achieved certain results. However, these research results are rarely used in the construction of online learning platforms. Many online learning platforms are similar to traditional classroom teaching, which is suitable for learners in classroom teaching but not at all suitable for learners in online learning. Online courses lack uniform norms and standards, and there is no dedicated development team for the courses. Unlike foreign countries, many countries have online education standards, and online education can develop content based on this standard. There is currently no such model in China. Many online college courses replace the traditional classroom concepts used on the Internet, and some of the training topics even include instructors. Online courses are not developed by a team of educators and, of course, do not have a clear development process [4]. For example, many online college English courses, which can be said to be electronic versions of college English books, completely present the content of the books on the online learning platform, without any adaptation, such learning content can be seen on many learning platforms. Based on such online learning courses, of course, it is impossible to consider the correlation between learning content, and how the push of learning content should meet the actual needs of learners.

2. Marker Distribution Learning Algorithm Based on Data Correlation Mining

2.1. Algorithm Framework. The main purpose of label distribution learning is to learn a mapping from input space Formula (1) to label distribution space Formula (2).

$$X = [x_1 ; x_2 ; \cdots ; x_n]^{R^{n\times d}}, \tag{1}$$

$$D = [D_1 ; D_2 ; \cdots ; D_n]^{R^{n\times l}}. \tag{2}$$

Among which, x_i represents the ith example, D_i represents the label distribution of the ith example, n is the number of examples, d is the feature dimension, and l represents a total of l tags $\{y_1, y_2, \cdots, y_l\}$. Given a training set, as shown in Formula (3):

$$T = \{(x_1, D_1), (x_2, D_2), \cdots, (x_n, D_n)\}. \tag{3}$$

Formula (4) is as follows:

$$D_i = \left[d_{x_i}^{y_1} ; d_{x_i}^{y_2} ; \cdots ; d_{x_i}^{y_l}\right]. \tag{4}$$

$d_{x_i}^{y_j}$ is the description degree of the jth marker to the example x_i and satisfies $d_{x_i}^{y_j} \geq 0$, $\sum_{j=1}^{l} d_{x_i}^{y_j} = 1$, indicating that all markers completely describe an example. The label distribution learning algorithm can learn a conditional probability function $p(y|x)$ from it and then use the learned model to predict the label distribution for unknown examples [5]. Without loss of generality, we choose the maximum entropy model as the output model. Then, as elements of the predicted marker distribution vector, the degree to which each marker describes the example can be expressed as:

$$\bar{d}_{x_i}^{y_j} = p(y_i|x_i ; w) = \frac{1}{Z_i} \exp\left(\sum_r w_{jr} x_{ir}\right). \tag{5}$$

w is the model parameter to be learned.

$$Z_i = \sum_j \exp\left(\sum_r w_{jr} x_{ir}\right). \tag{6}$$

Equation (6) above shows a regularization term that makes the sum of all descriptors of an example equal to 1. Some studies have shown that KL divergence is the most stable in the field of marker distribution [6, 7]. Therefore, we choose KL divergence as the most basic objective function, as shown in Formula (7):

$$\min_W \sum_i D_{KL}\left(D_i \| \bar{D}_i\right) + \lambda_1 \| W \|_F^2. \tag{7}$$

In order to learn the global correlation of markers, this chapter constructs a marker correlation matrix S. Potentially, marker correlation can be obtained through the low rank of constraint matrix [8]. In addition, we hope that the correlation learned can modify the predicted results of marker distribution. Then, we can obtain the following objective function, as shown in Formula (8):

$$\begin{aligned} &\min_{W.E.S} \sum_i D_{KL}\left(D_i \| \bar{D}_i\right) + \lambda_1 \| W \|_F^2 + \lambda_2 \| E \|_{2,1} + \lambda_3 \| S \|_*, \\ &s.t. D = \bar{D}S + E. \end{aligned} \tag{8}$$

λ_2 and λ_3 are equilibrium factors. The regularization term about E controls the difference between the reconstructed label distribution $\bar{D}S$ and the real label distribution D.

In order to facilitate implementation, k-means method is adopted in this chapter to divide the samples into different clusters. In each cluster, Euclidean distance was used to measure the similarity of two markers. The smaller the distance between markers, the higher the correlation [9]. Then, the entire tag distribution learning framework based on global and local similarity of tags can be defined as shown in Formula (9):

$$\begin{aligned} &\min_{W.E.S} \sum_i D_{KL}\left(D_i \| \bar{D}_i\right) + \lambda_1 \| W \|_F^2 + \lambda_2 \| E \|_{2,1} + \lambda_3 \| S \|_* \\ &\quad - \frac{1}{2} \lambda_4 \sum_{v=1}^{k} \sum_{m=1}^{l} \sum_{n=1}^{l} S_{m,n} \| D_{.m}^v - D_{.n}^v \|_2^2, \\ &s.t. D = \bar{D}S + E. \end{aligned} \tag{9}$$

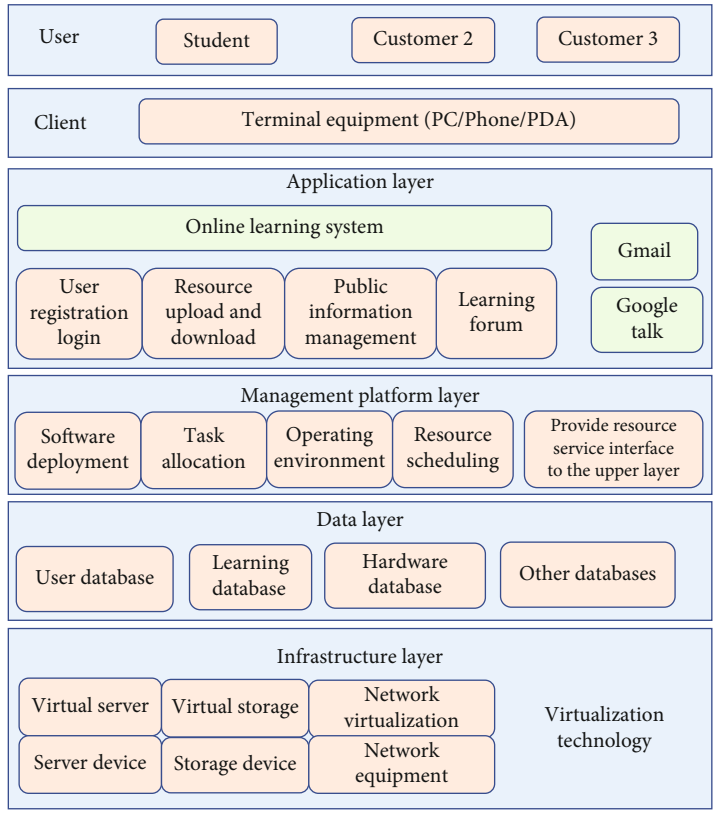

Figure 1: Overall architecture diagram of online learning platform.

λ_4 is the equilibrium factor and k is the number of clusters. $S_{m,n}$ is the similarity between the mth marker distribution $D_{.m}$ and the nth marker distribution $D_{.n}$. Note that in the last term, $S_{m,n}$ is the correlation we need to learn, and $\|D^v_{.m} - D^v_{.n}\|_2^2$ can be solved from what we know. When $\|D^v_{.m} - D^v_{.n}\|_2^2$ is smaller, we expect $S_{m,n}$ to be larger [10]. So the symbol for the last term is "_".

2.2. Optimization Method. Formula (9) is an optimization problem with equality constraints. This kind of problem should be transformed into an unconstrained problem before it is solved. In addition, Formula (9) contains two non-smooth items, so we first introduce redundant parameter Z to separate the non-smooth items, as shown in Formula (10):

$$\begin{aligned}\min_{W.E.S.Z} &\sum_i D_{KL}\left(D_i \| \bar{D}_i\right) + \lambda_1 \|W\|_F^2 + \lambda_2 \|E\|_{2,1} + \lambda_3 \|Z\|_* \\ &- \frac{1}{2}\lambda_4 \sum_{v=1}^{k} \sum_{m=1}^{l} \sum_{n=1}^{l} S_{m,n} \|D^v_{.m} - D^v_{.n}\|_2^2, \\ s.t. D &= \bar{D}S + E, S - Z = 0.\end{aligned} \tag{10}$$

Then, we use the augmented Lagrange multiplier method to transform the equal-constrained problem into an unconstrained problem, as shown in Formula (11):

$$\begin{aligned}\min_{W.E.S.Z} &\sum_i D_{KL}\left(D_i \| \bar{D}_i\right) + \lambda_1 \|W\|_F^2 + \lambda_2 \|E\|_{2,1} \\ &+ \lambda_3 \|Z\|_* - \frac{1}{2}\lambda_4 \sum_{v=1}^{k} \sum_{m=1}^{l} \sum_{n=1}^{l} S_{m,n} \|D^v_{.m} - D^v_{.n}\|_2^2 \\ &+ \frac{\rho}{2}\left\|D - \bar{D}S - E\right\|_F^2 + \frac{\rho}{2}\|S - Z\|_F^2 \\ &+ \left\langle \Gamma_1, D - \bar{D}S - E\right\rangle + \left\langle \Gamma_2, S - Z\right\rangle.\end{aligned} \tag{11}$$

Γ_1 and Γ_2 are Lagrange submatrices, ρ is a penalty factor, and $\langle \cdot, \cdot \rangle$ is the Frobenius dot product [11]. At this point, Formula (11) can be solved by using alternate directional multiplier minimization method, that is, the fourth variable can be minimized by fixing the other three variables. Specifically, during each iteration, we fix other variables and update one of the variables in $\{W, E, S, Z\}$. First, fix $\{E, S, Z\}$ and update W, then Formula (11) can be simplified as Formula (12) below:

$$\begin{aligned}W = \arg \min_W &\sum_i D_{KL}\left(D_i \| \bar{D}_i\right) + \lambda_1 \|W\|_F^2 + \frac{\rho}{2}\left\|D - \bar{D}S - E\right\|_F^2 \\ &+ \left\langle \Gamma_1, D - \bar{D}S - E\right\rangle.\end{aligned} \tag{12}$$

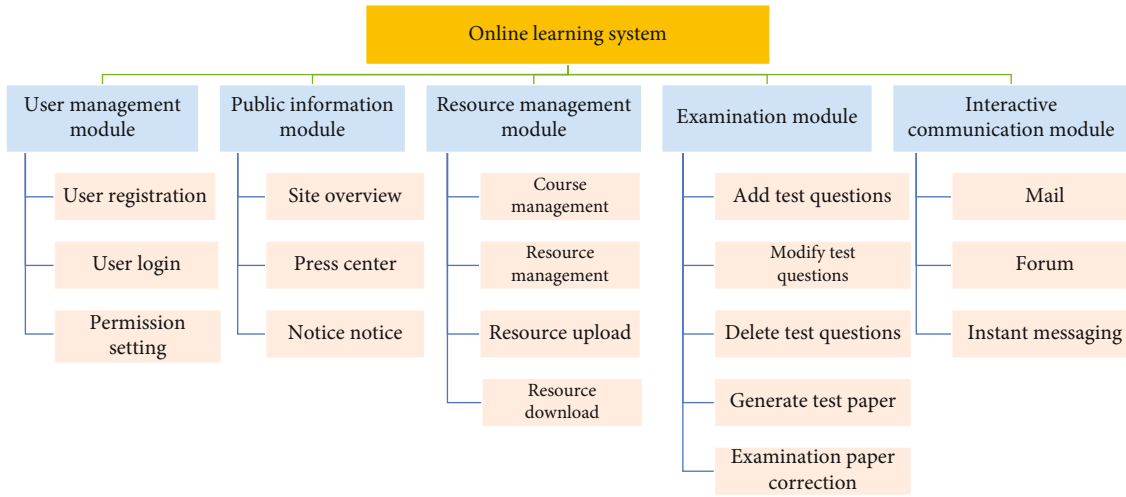

Figure 2: System function division diagram.

Formula (12) can be directly optimized by L-BFGS quasi-Newton method, whose basic idea is to avoid the calculation of inverse Hessian matrix [12]. This optimization method is mainly related to the first derivative of the objective function. The first derivative of Formula (13) below:

$$\begin{aligned}\nabla W = {} & X^T\left(\bar{D} - DX\right) + 2\lambda_1 W - X^T\left\langle \bar{D} - \bar{D}^2, \Gamma_1 \right\rangle S^T \\ & - \rho X^T\left(\bar{D} - \bar{D}^2, D - \bar{D}S - E\right)S^T.\end{aligned} \tag{13}$$

Similarly, fixed $\{W, E, Z\}$ updates S, so Formula (11) can be simplified into the following form, as shown in Formula (14):

$$\begin{aligned}S = \arg\min_S & -\frac{1}{2}\lambda_4 \sum_{v=1}^{k}\sum_{m=1}^{l}\sum_{n=1}^{l} S_{m,n}\left\|D^v_{.m} - D^v_{.n}\right\|_2^2 \\ & + \frac{\rho}{2}\left\|D - \bar{D}S - E\right\| + \frac{\rho}{2}\left\|D - \bar{D}S - E\right\|_F^2 \\ & + \left\langle \Gamma_1, D - \bar{D}S - E\right\rangle + \left\langle \Gamma_2, S - Z\right\rangle.\end{aligned} \tag{14}$$

Formula (14) can also be solved by L-BFGS quasi-Newton method, and the first derivative is shown in Formula (15):

$$\begin{aligned}\nabla S = {} & -\Gamma_1^T\bar{D} + \Gamma_2^T + \rho(S - Z) - \rho\bar{D}^T\left(D - \bar{D}S - E\right) \\ & - \frac{1}{2}\lambda_4 \sum_{v=1}^{k}\sum_{m=1}^{l}\sum_{n=1}^{l} S_{m,n}\left\|D^v_{.m} - D^v_{.n}\right\|_2^2.\end{aligned} \tag{15}$$

Similarly, E and Z can be obtained by solving the following two subproblems: Formula (16) and Formula (17):

$$E = \arg\min_E \lambda_2\|E\|_{2,1} + \frac{\rho}{2}\left\|D - \bar{D}S - E\right\|_F^2 + \left\langle \Gamma_1, D - \bar{D}S - E\right\rangle, \tag{16}$$

$$Z = \arg\min_Z \lambda_3\|Z\|_* + \frac{\rho}{2}\|S - Z\|_F^2 + \left\langle \Gamma_2, S - Z\right\rangle. \tag{17}$$

3. Design of English Online Learning Platform System Based on Cloud Computing

3.1. Structure of Online Learning Platform. Specific application software related to learning (education SaaS). Application layer includes online learning platform system. This online English learning platform system is the system support conditions, there is no actual data. All kinds of users can enter the cloud service platform through login, and all kinds of users can call various services of the platform through the interface [13]. The cloud English learning platform system in this article mainly includes public information module, user management module, interactive communication module, resource management module, and other specific modules. The overall design drawing of cloud English learning platform structure is shown in Figure 1.

The management platform layer is the core layer of the system, which is very important in the cloud English learning platform structure. The management platform layer mainly guarantees the operation support conditions to the cloud learning system of the application layer. The management platform layer corresponds to the PaaS of layer 3 cloud computing services. The data layer is the core of the architecture and is responsible for various types of data storage. For online learning system, the construction of learning resources is the core and foundation of online learning [14]. In today's fragmented environment of online English learning platforms, it is difficult to make full use of learning resources. The solution to this problem is to build a common and unified resource pool for users to share by integrating resources through cloud computing data storage service. The infrastructure layer is the foundation layer of the entire architecture and corresponds to the infrastructure-as-a-service in the cloud computing service hierarchy. It determines the service scope and service capability of online English learning cloud platform. The infrastructure layer provides hardware resources such as servers, storage space, and network devices. However, these hardware resources are not only physical devices, but servers, storage, and networks through virtualization technology.

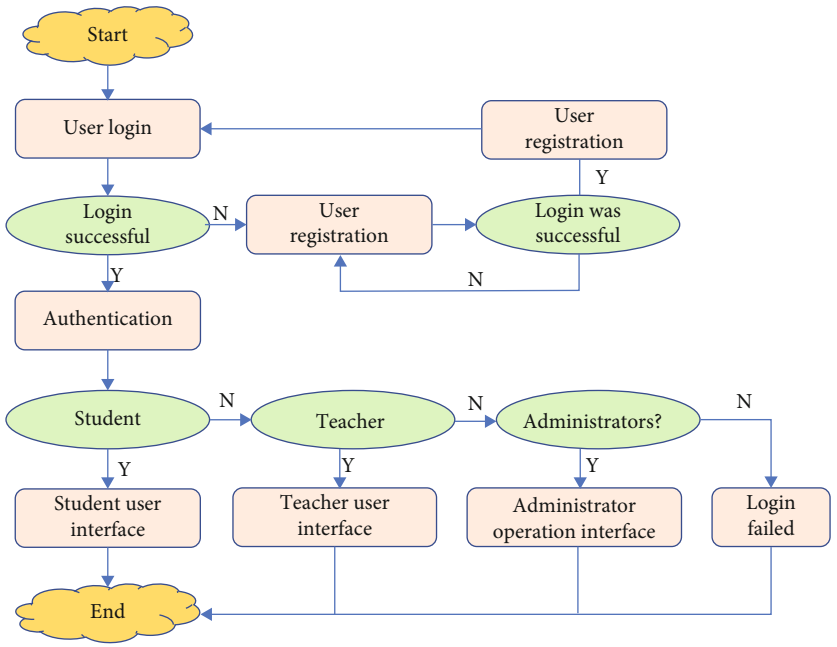

Figure 3: Flow chart of user management module.

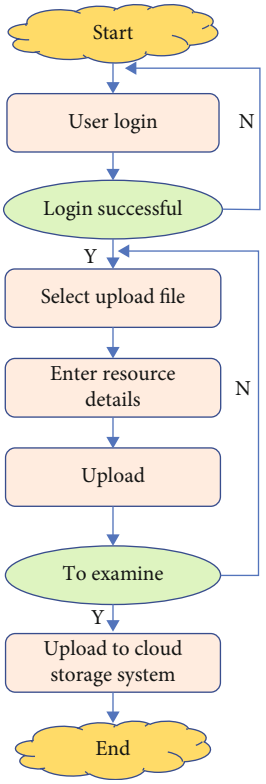

Figure 4: Flow chart of uploading learning resources.

3.2. Functional Module Design of Cloud Computing Online Learning Platform. This article divides the online English learning system into user management module, learning resource management module, test module, and interactive communication module, as shown in Figure 2.

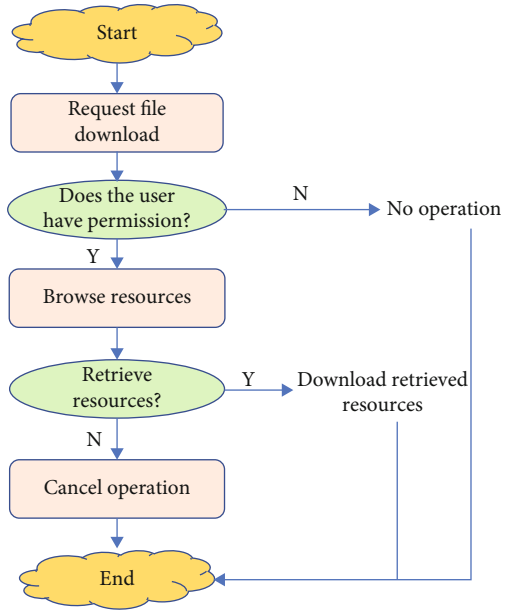

Figure 5: Resource download business flow chart.

3.2.1. Design of User Management Module. Online learning platform users can be divided into three types: students, teachers, and system administrators [15]. By logging into the online English learning platform, students can learn courses online, download courseware, exercises, and other learning materials, take self-tests, or exchange problems with teachers or classmates through the forum. Teachers use online English learning platforms to guide students through courses, assign homework online, and communicate with students online, while the system administrator is responsible for English learning platform of user information

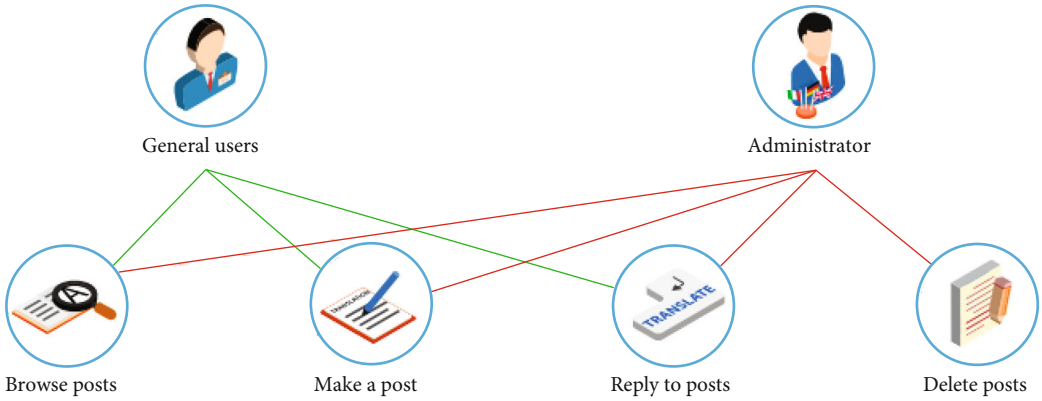

Figure 6: Use case analysis diagram of interactive AC module.

management, curriculum information management, BBS management, and other related work. The actual situation of the specific business process of this module is shown in Figure 3.

3.2.2. Resource Management Module Design. The resource management module realizes the system administrator and teachers to upload resources. During the resource uploading process, the cloud English learning platform adds specific resource information one by one according to the English learning resource information table of the MySQL database. The process of uploading learning resources is shown in Figure 4:

The resource management module can provide students with the function of browsing the historical traces of downloading and learning resources and can save the specific information that students feedback to teachers through the system in the system database. When students enter the download interface of learning resources through the system interface, they can select specific resources to learn and download corresponding resources to enter the system browsing interface. The cloud English learning system updates resources and statistics on the reading time and reading times of database tables [16], as shown in Figure 5:

3.2.3. Design of Public Information Module. Public information module includes website overview, news center, and announcement of three types of information release. Overview of the website describes the information about the English learning website, including the services provided by the website and the website dynamics. The press center is used to release hot English academic news or current events. Announcements and notices are information such as teaching plans and educational affairs notices issued to students, teachers, or administrators [17]. Different user identities have different operation rights. Students only have the permission to view information content, teachers can browse, publish, and delete information, etc. Administrators can also maintain English information classification in addition to having all the above operation permissions.

3.2.4. Interactive Communication Module Design. The interactive communication module is designed to allow students to interact with students, students and teachers, teachers, and teachers in three forms of information exchange. In terms of email and instant messaging, Google's third-party email service Gmail and instant messaging software Google Talk can be applied. The actual use case analysis of the interactive communication module is shown in Figure 6.

3.2.5. Data Model Design. This article is based on the Google App Engine development environment. GAE does not support traditional data storage, namely, relational database storage. But for the sake of convention, we describe the data model information in tables and then port it to a data store model that GAE can recognize using the data store described below. The main data tables involved in the system are shown in Tables 1–8.

3.3. Research on Concurrency Control Algorithm

3.3.1. Classification of Transaction Concurrency Control Algorithms. So far, various methods such as timestamp, optimistic, and lock-based database concurrency control have been proposed, such as Priority Inheriting (PI), Priority Ceiling (PC), and high-priority aborting [18]. The traditional transaction concurrency control algorithm is shown in Figure 7. Concurrency control is a key design link in cloud management service system database, which can maintain data consistency and orderly transaction concurrency. When multiple transactions are executed simultaneously in the database, the system must require the concurrency control protocol to control the interaction between them. The task of concurrency control is to ensure and coordinate the orderly execution of each transaction, so that the operation of these concurrent read and write transactions can be carried out under the condition of maintaining data consistency and integrity, so as to ensure that the N concurrent transactions can normally output the conclusion of the pair. Traditional database concurrency control algorithms cannot meet the requirements of cloud systems, and transaction scheduling of cloud service database systems must ensure the orderly consistency and stability of big data concurrent transactions [19].

3.3.2. Traditional Concurrency Control Protocol Algorithm—Two-Phase Locking (2PL). Blocking is the most commonly

Table 1: Basic user information. User data table.

Field name	Data type	Note
userlD	Long	The ID that marks the uniqueness of the user
userName	String	The user name
password	String	The user password
email	String	Email (Google account)
rolelD	Int	Users' roles

Table 2: Role data table.

Field name	Data type	Note
rolelD	Long	Marks the ID of the role entity
roleName	String	Including students, teachers, and administrators
roleType	Int	1 (student), 2 (teacher), 3 (administrator)

Table 3: Data model design of announcement classification category.

Field name	Data type	Note
categoryID	Long	The ID that marks the uniqueness of the classification
categoryType	String	Category name (news, announcements)
Description	String	Category description

Table 4: Design of notice data model.

Field name	Data type	Note
noticelD	Long	The ID that marks the uniqueness of the announcement
title	String	The announcement title
content	Text	Announcement details
cateogryID	Long	Announcement classification
userID	Long	ID of the bulletin publisher
publishTime	Date	Announcement time
updateTime	Date	Announcement modification time

used method to avoid read/write conflicts in database operations. Among them, two-stage locking is the most common and popular method [14]. The lock specifies that the transaction is processed in two phases: the first phase is to acquire the lock. During this time, a transaction can acquire any type of lock on any data item, but it cannot release any lock. The second stage is the unconditional release of the blockade. It is not possible to request a reopening of the exchange at this time. All operations are closed prior to access to data equipment. If the file is closed by another exchange, you must wait for the exchange to complete and open before the exchange can run. The size of the lock case is what we often refer to as the accuracy of the lock. Locking precision is the most common type of locking material.

Table 5: Resource information File data model design.

Field name	Data type	Note
filelD	Long	The ID that marks the uniqueness of the resource
Filename	String	The resource title
filecontent	Long	Resource content
username	String	User name of the resource publisher
Useremail	Email	Resource publisher email address
upldiadDte	Date	Resource upload time
description	String	The resource description
courselD	Long	Course of resource

Table 6: Course data model design.

Field name	Data type	Note
courselD	Long	The ID that marks the uniqueness of the course
courseName	String	Course name
courseInfo	String	Course introduction

Table 7: Design of post data model.

Field name	Data type	Note
postID	Long	The ID that marks the uniqueness of the post
posttitle	String	Post title
postcontent	String	Post content
usemame	String	Post publisher
adddate	Date	Post date
commentID	Long	Comments on the post

Table 8: Data model design of comments on posts.

Field name	Data type	Note
commentID	Long	ID that marks the uniqueness of the comment
commentcomtent	String	Comment on the content
usename	String	Comment publisher
commentdate	Date	Comment time

3.3.3. Distributed Collaboration 2PL Improved Protocol Algorithm. As the number of users and the cost of data increase, so does the data. Technological processes to improve the reliability and functionality of data entry are to separate written data from textual data. In order to meet the requirements of the system, this system was optimized according to the 2PL parallel control protocol. The author studies an improved 2PL protocol algorithm that can achieve real-time performance and relatively high security. In addition to reading and writing separation, we need to pay more attention to storing data correctly and consistently. Different

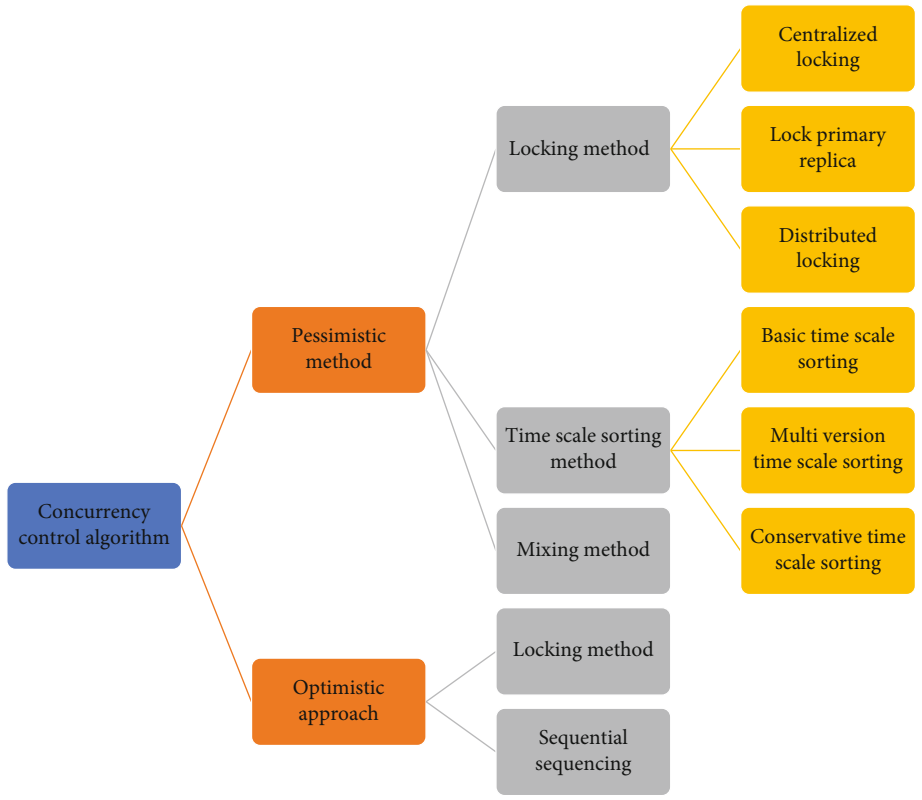

Figure 7: Classification of traditional concurrency control algorithms.

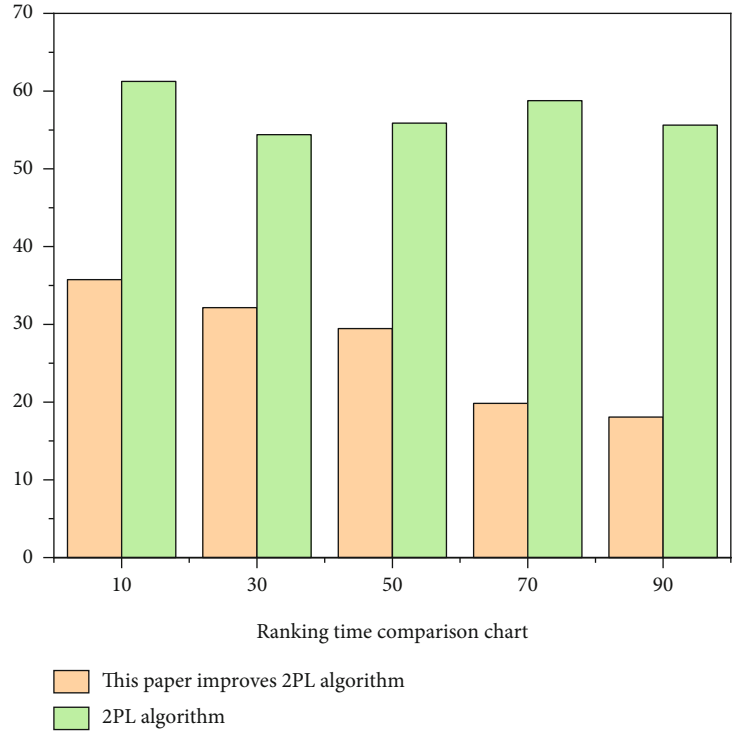

Figure 8: Execution time comparison of transactions with different read/write ratios.

from traditional transactions with conflicting and mutually exclusive access, the coordination and consistency requirements of cloud information management system can be operated on the design object, that is, the design activities according to certain principles can operate on a certain resource or object in the same time [20].

Figure 9: Architecture of the system.

Simulation system is used to evaluate the concurrency control performance of the algorithm. Transaction data is distributed evenly across tables in the database, with priority determined by the earliest deadline. We use the Application Center Test tool provided by Microsoft Visual Studio.NET to compare the performance of the two algorithms on the server when testing large-scale access. 1000 read and write transactions accessing the database were simulated and started. The experiment was carried out in several times and different read and write ratios were set [21]. The time for each transaction to run independently is set to 0.6 s. The time taken to complete the analysis transaction execution is compared at the same time. The results are shown in Figure 8.

3.4. Content Organization System Based on Genetic Algorithm. According to the system requirements, the author defines the structure of the process, which includes four stages: the content library layer, the student data layer, the process of explaining the layer process, and the process detail. Figure 9 is an overview of the organization's content created by the author.

The English learning content library is a system database that consists of four tables: the listening library, the speech library, the reading library, and the writing library. The four tables have the same structure, as shown in Table 9, respectively.

The content organization system is divided into three functional modules, namely, data input, data organization, and data output [22]. The data organization module adopts genetic algorithm. Figure 10 shows the functional structure of the content organization system.

The data input module is to set the basic information of learners, including learners' English level, learners' learning purpose, and the amount of learning content. The English level of learners is determined in the result of cluster analysis. In the system, only one level can be selected. Learners' learning purpose has been obtained when they register for learning, and most adult learners' learning purpose is to work. Therefore, the theme of learning content designed in the system is that the number of various vocational learning content is determined by teachers. They set the specific amount of learning content to be presented according to the level and learning purpose of learners, including the proportion of listening, speaking, reading, and writing.

4. System Performance Test

System testing process is the application of testing software for the entire computer system for computer hardware, software, external equipment, data, personnel, and other system factors fusion. In the actual implementation process, specific

Table 9: Table structure of the content store.

Field name	Data type	Description
Id	Automatic numbering	Content number, primary key
Type	Text	Types of exercises
Rank	Text	The level of the exercises
Scope	Text	The exercises belong to the module
Subject	Text	The topic expressed in the exercises

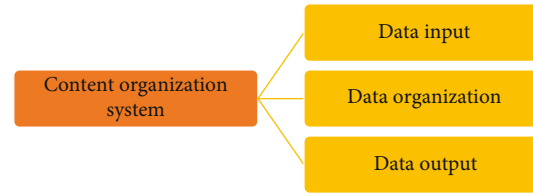

Figure 10: Functional modules of the content organization system.

system testing process is carried out for the computer system [23]. The purpose of system testing is to find system defects and evaluate the quality of software system, and perform the testing process according to the system function and performance requirements. The ultimate goal of system testing is to check whether complete software configuration items can be correctly connected with the system by comparing with the requirement definition of the system in the real system working environment, and find the inconsistencies or contradictions between software and system/subsystem design documents and software development contracts. Whether the internal operation of the system is performed according to the specification constraints, the program is tested according to the internal structure of the program and whether each software flow path of the system program can complete the correct work according to the expected requirements. White box testing methods mainly include basic testing and logic driver. White box testing is mainly used for software verification operations. Black box test is also known as functional test and data-driven test. Black box test is to test whether each specific function can be used normally by using test methods on related functions of existing products.

During testing, the application can be considered a black box that cannot be opened regardless of the user's dimensions, internal structure, and internal characteristics in the application interface. It only verifies that the operating functions specified in the special requirements have been used. However, the software can access data to generate accurate version data and manage the integrity of external data (databases, data, etc.). Black box testing procedures typically

include equal classification, boundary level analysis, graph efficiency, and error prediction, which are used to test control software. The "black box" method focuses on the external design of the program, regardless of the model in the process, and measures the impact and performance of the software. The "black box" method is a complete test to determine the error of the program only if all the hardware is used for testing. There are endless experiments, and one must test not only all the rules but also everything that is illegal but possible.

Common system testing methods include unit testing, white box testing, and black box testing. Unit test is to test the smallest unit module in the system. The test is usually carried out in the process of system development, mainly including the normal operation of each part of the code, whether the functional module according to the design requirements of the correct execution. White box testing and black box testing are complementary ways; it is precisely through testing software or system each module of the internal code to achieve the purpose of testing the system. White box testing can be viewed as a transparent box, requiring an understanding of the logical structure within its program. Black box testing is sometimes called "functional testing." Its main testing principle is to test whether all functions involved in the system run normally or not. During the testing process, it is not necessary to be familiar with the specific situation inside the program, but only regard it as a black box that has been packaged and only detect whether each function of the system is correctly implemented according to the design requirements.

System test can be divided into white box test method and black box test method. White box testing method is also known as structural testing method or the logical test method, white box testing through the master system within the specific implement workflow to products to be detected by testing, QTP is a software program that is widely used in the test tools, the main characteristic is a functional test automation, the current commonly used software development can use this to test, and test cases are reusable [24]. QTP focuses on the GUI, which is based on the things on the page, which is generally the controls on the interface, which are the objects that QTP captures. The working principle of QTP is to record people's manual operation, mainly record the object and order of people's manual operation, and then carry out some automatic tests according to the recorded operation and order. During testing, the focus was on the controls on the interface, such as a basic login interface with text boxes, labels, and buttons. These are the targets captured by QTP, and then a library is formed by capturing the objects. Then, the properties and methods of the corresponding objects are listed, and then, the properties and methods of the corresponding objects are called during recording, and the related operations of QTP are carried out.

The main purpose of the performance test is to ensure that the functions of the system can be fully realized as expected, and there are enough security guarantees in the process of realization. The main test items, expected results, and actual test results are shown in Table 10.

Table 10: Performance test method design table.

Test project	Expected results
Registered user enter the user name and password	Login user account
Registered user input user name and wrong password	Error message
Enter a user name that does not exist	Error message
Empty username or password	Error message
Change user information legally	Message changed successfully
Change user information illegally	Stop change
Illegal bank card binding	Message binding failed
Recharge the account through certificate verification	Prompt top-up success
Account recharge without passing certificate verification	Prompt top-up failure
Order payment made through certificate verification	Prompt payment success
Order payment without certificate verification	Prompt payment failure
Viewing learning records	Display transaction records correctly
Viewing order information	Display order information correctly
Refund through certificate verification	Refund success
Refund without certificate verification	Refund failure
Viewing logistics information	Display logistics information correctly

Table 11: System test table.

Test name	Search test
Run name	Report-search test
Start time 2	On January 20, 2016, 3 : 50 p.m
Duration of time	04 : 10
Number of iterations	04: 1500

Table 12: System test results table.

Test type	Dynamic
Number of concurrent browsers	10
Number of concurrent browsers	15
Preparation time (s)	00 : 04 : 10 : 04
Number of iterations	10000
Whether to generate test results	Yes
Abstract	
The total number of requests	10000
The total number of connections	10000
Average requests per second	2.17

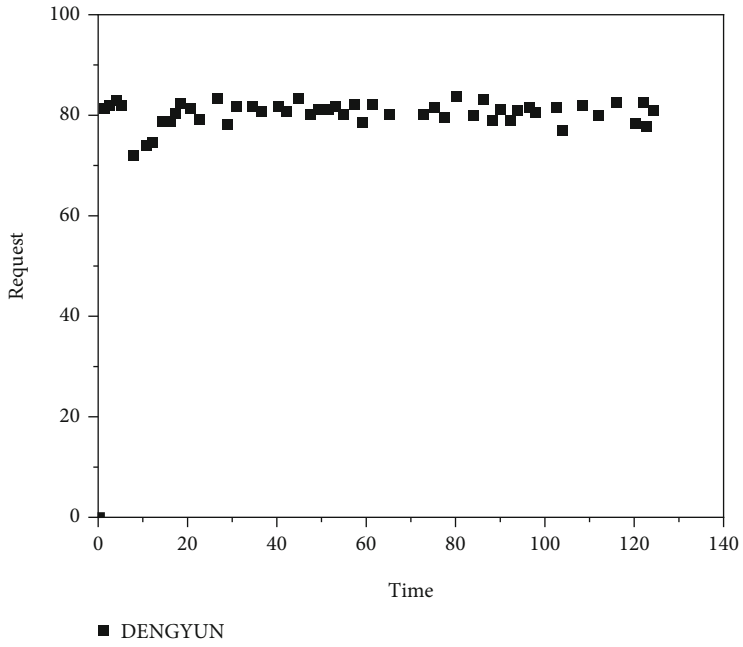

Figure 11: System test properties.

After the system test, the specific test results are shown in Tables 11 and 12.

Test run graph, as shown in Figure 11.

5. Conclusion

The popularity of online learning has triggered profound changes in the field of education. Universities and other educational institutions have established their own digital libraries, online learning platforms, and other modern educational information infrastructure. People no longer just rely on traditional classroom teaching methods for learning. As long as you have a computer or other terminal equipment connected to the network, you can enter the network learning platform to achieve learning behavior. As a convenient and flexible way of learning, online learning has promoted the level of education informatization in China to a new height. The role of online learning platform in online learning environment should not be underestimated. It should be rich in training services and be effective in meeting customer needs. With the advent of the internet and the rapid growth of information technology, more and more people are choosing online training. It is also an expanding use of cloud computing to create online learning platforms, which have advantages such as high security, high power consumption, and multiple storage space. This article utilizes the advantages of cloud computing to create an English online learning platform and provides detailed information on cloud computing-based online English learning platform design concepts, design, and terms used. There is an opportunity to build a cloud English learning platform in the future. The special tasks performed in this paper can be summarized as follows.

(1) Through the analysis of the current construction mode of online English learning platform, it points out that the system construction is independent, the regional information resource allocation is uneven, and there are information islands between English learning platforms and other problems. In view of the shortcomings of the current online English learning platform construction, combined with the services and characteristics of cloud computing, this article proposes a research scheme to build online English learning system based on cloud computing

(2) Combined with the actual needs of the current English online learning system, detailed analysis, and design of the data model and business process of each functional module of the online English learning system. This article analyzes and discusses the division of the architecture of online learning platform based on cloud computing and analyzes the responsibilities of each layer from top to bottom in combination with the three-layer service form of cloud computing

(3) This article describes the system testing process of online English learning platform based on cloud computing. This article introduces the purpose and principle of the system test and describes the process of the system test in detail. At the level of 10000 iterations, the average number of system requests is 2.17/s. The system runs steadily and can meet the English learning needs of student users

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 author declares that there is no conflict of interest regarding the publication of this article.

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References

[1] J. Xu, Y. Liu, J. Liu, and Z. Qu, "Effectiveness of English online learning based on deep learning," *Computational Intelligence and Neuroscience*, vol. 2022, Article ID 1310194, 10 pages, 2022.

[2] T. N. Fitria, "Teaching English through online learning system during Covid-19 pandemic," *Pedagogy Journal of English Language Teaching*, vol. 8, no. 2, p. 138, 2020.

[3] H. Hu, X. Wang, Y. Zhai, and J. Hu, "Evaluation of factors affecting student participation in peer-assisted English learning based on online education platform," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 16, no. 11, p. 72, 2021.

[4] J. Li, "Design, implementation, and evaluation of online English learning platforms," *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 5549782, 11 pages, 2021.

[5] W. K. Lee, "A study on pbl instructional design and application evaluation for tourism platform understanding and utilization: focusing on a case study of h university," *International Journal of Tourism and Hospitality Research*, vol. 34, no. 7, pp. 73–90, 2020.

[6] N. S. Alseelawi, E. K. Adnan, H. T. Hazim, H. Alrikabi, and K. W. Nasser, "Design and implementation of an e-learning platform using n-tier architecture," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 14, no. 6, 2020.

[7] H. Ding, Y. Chen, and L. Wang, "College English online teaching model based on deep learning," *Security and Communication Networks*, vol. 2021, Article ID 8919320, 11 pages, 2021.

[8] H. Dong and W. Han, "Design and application of bank big data platform based on hadoop technology," *E3S Web of Conferences*, vol. 214, no. 5, p. 01028, 2020.

[9] M. X. Pan and G. Hu, "Effectiveness of a cl-informed approach to english preposition acquisition by young chinese learners," *Cognitive Linguistic Studies*, vol. 9, no. 1, pp. 87–109, 2022.

[10] Y. Chai, "Design and implementation of english intelligent communication platform based on similarity algorithm," *Complexity*, vol. 2021, 10 pages, 2021.

[11] N. Peng, "Research on the effectiveness of English online learning based on neural network," *Neural Computing and Applications*, vol. 34, no. 4, pp. 2543–2554, 2022.

[12] A. Basal, "Learning collocations: effects of online tools on teaching English adjective- noun collocations," *British Journal of Educational Technology*, vol. 50, no. 1, pp. 342–356, 2019.

[13] X. Liu, F. Dong, W. Tang, Z. Yu, and M. Huang, "Reform and implementation of technical english course for brewing engineering undergraduates based on steam theory," *Chinese Journal of Biotechnology*, vol. 36, no. 9, pp. 1947–1954, 2020.

[14] W. S. Sartika, "The google classroom for learning writing: students' initial perceptions," *Journal of English Teaching Literature and Applied Linguistics*, vol. 4, no. 1, p. 59, 2020.

[15] A. Alobaid, "Smart multimedia learning of ICT: role and impact on language learners' writing fluency - YouTube online English learning resources as an example," *Smart Learning Environments*, vol. 7, no. 1, p. 24, 2020.

[16] F. Yusuf, "Design of English learning based on live streaming of digital era in Covid-19," *Jurnal Eduscience*, vol. 7, no. 2, pp. 33–39, 2020.

[17] K. M. Rafiq, H. Hashim, M. M. Yunus, and H. Norman, "iSPEAK: using mobile-based online learning course to learn 'English for the workplace'," *International Journal of Interactive Mobile Technologies*, vol. 14, no. 8, pp. 19–31, 2020.

[18] I. Oraif and T. Elyas, "The impact of Covid-19 on learning: investigating efl learners' engagement in online courses in Saudi Arabia," *Education Sciences*, vol. 11, no. 3, p. 99, 2021.

[19] Z. Amri and N. Alasmari, "Self-efficacy of saudi english majors after the emergent transition to online learning and online assessment during the Covid-19 pandemic," *International Journal of Higher Education*, vol. 10, no. 3, p. 127, 2020.

[20] D. Dong and W. Libo, "Implementation of English "online and offline" hybrid teaching recommendation platform based on reinforcement learning," *Security and Communication Networks*, vol. 2021, Article ID 4875330, 10 pages, 2021.

[21] A. Pinandito, Y. Hayashi, and T. Hirashima, "Online collaborative kit-build concept map: learning effect and conversation analysis in collaborative learning of English as a foreign language reading comprehension," *IEICE Transactions on Information and Systems*, vol. E104.D, no. 7, pp. 981–991, 2021.

[22] S. Balouchi and A. A. Samad, "No more excuses, learn English for free: factors affecting L2 learners intention to use online technology for informal English learning," *Education and Information Technologies*, vol. 26, no. 1, pp. 1111–1132, 2021.

[23] Y. Fang and J. Li, "Application of the deep learning algorithm and similarity calculation model in optimization of personalized online teaching system of English course," *Computational Intelligence and Neuroscience*, vol. 2021, Article ID 8249625, 11 pages, 2021.

[24] X. Hong, "Interactivity of English online learning based on neural network," *Neural Computing and Applications*, vol. 34, no. 5, pp. 3349–3364, 2022.

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Research Article

Influence of Emotional Factors (Positive, Negative) on the Usefulness of Product Reviews Based on Big Data

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In the era of prosperous online shopping, product reviews play a decisive role in users' decision to purchase products. At the same time, it can also help businesses understand the corresponding deficiencies, to make targeted improvements. However, users' comments are full of emotional colors, and these comments with strong emotional tendencies have a greater impact on consumers than ordinary comments, especially those with negative emotions. At present, most text sentiment analysis is oriented at the chapter and sentence level, and there are few sentiment analysis refined to product-specific attributes. Based on this, this paper is aimed at exploring the influencing factors of the emotional tendency of product reviews, analyzing a large number of reviews of a certain mobile phone product, and extracting the keywords of the influencing factors. This article summarizes six key influencing factors. Through the constructed conceptual model of emotional tendencies, it is concluded that the impact of negative emotional comments on consumption is much greater than that of positive emotional comments. Then, there is a further conceptual model of negative affective tendencies. This paper explores the causes of the influencing factors of negative affective tendencies. In this paper, the influencing factors of negative emotional tendencies are subdivided into 10 secondary factors. Through the reliability test, all secondary factors are above 87%. Then, after scoring the negative comment text code, a regression analysis was performed, and it was found that 10 secondary factors were significant, and the corresponding regression model was obtained.

1. Introduction

Product reviews are essential for any online business looking to increase Internet sales. Product reviews contain information about product attributes, customer requirements, and shopping experience. Today, research on product reviews and factors affecting usefulness has been carried out a little at home and abroad. However, most of the studies are fragmented, and most of them are studied from the perspectives of commodity types and review information content. However, when consumers collect product reviews and evaluate products, they will have personal emotions and different focuses. Therefore, the approval degree of reviews will be affected by some emotional tendencies of consumers, but few scholars take this as a research direction. However, this study analyzes by mining the emotional characteristics of consumers and integrating them into the model as influencing factors. This paper analyzes the affective factors of users' product reviews. By building a model of factors that influence usefulness, this paper explores which factors should be paid attention to when merchants build an effective review system. In this way, the merchant's review management strategy can be improved in the limited review resources, and the merchant can also gain the trust of consumers.

In today's environment of diverse and personalized customer needs, emotional needs are becoming more and more important in customers' decision to purchase products. This requires that the development and design of products not only meet the basic functional needs of customers but also meet the emotional needs of customers. Therefore, analyzing users' emotional tendencies helps subsequent consumers to make reasonable consumption decisions. It has the significance of promoting sales for merchants on the Internet. Comments with positive sentiments also have a positive

impact on the sales volume of businesses, while comments with negative sentiments will also have a negative impact on the sales volume of businesses. Therefore, it is necessary to analyze the emotional factors in the user's product reviews. Its research results provide theoretical basis for enterprises to understand customer needs, determine competition priorities, improve product quality, and improve service levels. It is of great significance to improve the competitiveness of enterprises and promote their development.

This paper studies the influencing factors of emotional tendencies of product reviews. In order to find the winning factors that stimulate positive emotional tendencies and the qualification factors that trigger negative emotional tendencies, through the reviews of a mobile phone product included, this paper extracts keywords and summarizes six influencing factors. The reliability test results indicated that the "agreement percentage" of the six factors were all greater than 80%. It shows that the set keywords have the necessary research reliability. The emotional influence factor model of linked product reviews shows that negative reviews with negative emotions have a greater impact than positive reviews with positive emotions. The regression coefficients of factors affecting negative emotional tendencies show that in product reviews, customers are more concerned about factors related to product quality. That is to say, merchants want to improve customer satisfaction, and they need to strictly control the quality of products.

2. Related Work

In recent years, many scholars have explored customer emotional factors to help companies better understand customer emotional needs. Exploring the emotional factors of product reviews can help companies understand their own shortcomings and control consumers' concerns. The main purpose of Haddad et al.'s study was to examine the technological factors that influence the net benefits of big data within UAE government agencies. In this study, they used probabilistic random sampling to give researchers the opportunity to make equal selections from the sample frame. After removing 12 cases, they evaluated and analyzed the data results of 407 respondents. The current findings show that PU, PEOU, and SI have a significant direct positive effect on ATT, exceeding ATT which has a significant direct effect on NB [1]. Wu and Lin examined the combined impact of brands' online product descriptions, eWOM content, digital retail platforms, and innovation adoption factors on consumer decision-making processes. The results from the intersubject experiment ($N = 231$) showed that consumers' usefulness of product description, technical mobility, and product usefulness, perceptions of product ease of use, consumer review credibility, consumer review usefulness, consumer reviews, and retail user ratings-platform credibility directly or indirectly affect their attitudes and purchase intentions towards technological products [2]. The aim of Horie et al.'s study was to develop a method of showing only helpful reviews in order to reduce the burden on consumers. Assuming that useful reviews vary from consumer to consumer, finding the usefulness of a comment is not the same as the purpose for which the consumer browses the comment nor the consumer's knowledge of the target product group for purchase. It can divide consumers into six categories. Next, it determines the factors for each set of useful reviews. Finally, it builds a model to evaluate the usefulness of each review for each group. It can confirm that the model can show more useful reviews to consumers [3]. Mccloskey and Koch integrated information systems and marketing research by considering the usefulness of online product reviews in the context of Wang and Strong's data quality framework. It examines product reviews for the degree of intrinsic impact on perceived usefulness of reviews. His examination of Amazon reviews for cheap experience products showed that word count, verified purchases, and grammatical errors had a significant positive effect on review usefulness. Ratings and the number of misspellings had a negative impact, suggesting that consumers used some discernment in assessing the credibility of reviews. Surprisingly, grammatical errors were found to have the opposite effect, with more grammatical errors being associated with more helpful comments [4]. The mentioned researches on the usefulness of reviews by emotional tendencies are relatively fragmented, and most of them are from the perspective of merchants.

The research on the emotional influencing factors of product reviews in the Internet has become the focus of research by many scholars. This study examined the determinants of online review usefulness and its impact on recipient purchase intentions. Thomas et al. developed and tested a model based on refined likelihood theory. The model applies structural formula modeling to data collected from 282 Yelp users. The findings suggest that ease of understanding, accuracy, counterpoint, completeness, relevance, and timeliness are important dimensions of argumentation quality. And review volume and consistency, reviewer reputation and expertise, product/service ratings, and website reputation are key peripheral cues. Furthermore, they identified argument quality and peripheral cues as determinants of review usefulness, which were ultimately found to have a positive impact on recipients' purchase intentions [5]. Xiang et al. applied text analysis to compare three major online review platforms, namely, TripAdvisor, Expedia, and Yelp. The results show differences in how hotel products perform on these platforms. Information quality, as measured by linguistic and semantic features, sentiment, ratings, and usefulness, varies widely. This study is the first to compare and explore data quality in hospitality and tourism social media research. This study highlighted methodological challenges and contributes to theoretical development of social media analysis [6]. Park and Kim extracted linguistic and psychological features from review texts, such as word count, emotional tone, and analytical thinking embedded in review texts. By analyzing the product review characteristics of electronic products and clothing products, they found that reviewers used more words and longer sentences when writing product reviews for electronic products. Judging from the content characteristics of product reviews, in addition to many negative words, these reviews also contain many analytical words, which have greater influence. It also correlates more with cognitive processes (CogProc) than clothing

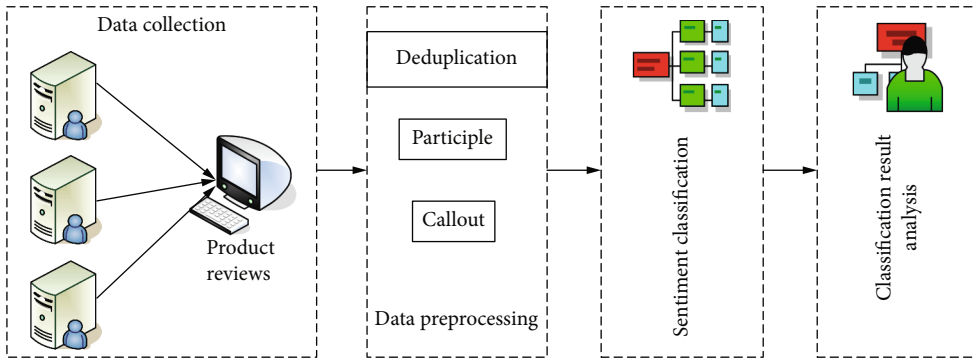

Figure 1: Schematic diagram of the sentiment analysis process.

product reviews. It was found that product reviews that were highly rated by reviewers in both product groups and deemed useful contained more total words, many expressions involving perceptual processes, and fewer negative emotions [7]. In response to the massive product reviews in Chinese Weibo (Weibo), Shi proposed an opinion-aware framework—PRSentiMiner—to perform sentiment analysis on product reviews in Chinese Weibo based on fuzzy opinion word ontology. He constructed a Chinese microblog product review sentiment calculation method and gave the specific application steps of the method. The results show that PRSentiMiner outperforms various baseline methods and has good application through experiments [8]. The above sentiment analysis requires a more complex process, and most of the comments have a large amount of data, that is, the sample collection is small, and it is impossible to correctly model the real environment.

3. Sentiment Factor Method in Product Reviews

This paper refers to finding out the key influencing factors affecting user satisfaction through sentiment analysis, which has positive significance for merchants to improve services and promote sales.

3.1. Process of Sentiment. In general, the conceptual model of sentiment analysis of comment text is mainly composed of comment text information acquisition module, comment text information preprocessing module, comment text sentiment classification model, and classification result analysis module [9]. Different users have different shopping experiences on business websites, and product reviews on business websites reflect the user's preference for the product. The acquisition of comment text information is the basic link of sentiment analysis, which selects comment information in a certain field according to the research purpose. There are duplicate or false information in the obtained user comment information, so it is necessary to preprocess the obtained text information, which is the basis for obtaining accurate sentiment analysis results [10, 11]. Then, it applies the appropriate sentiment classification model to judge the sentiment tendency of the preprocessed text information. Finally, a comprehensive analysis is performed on the sentiment classification results [12], as shown in Figure 1.

3.2. Influence of Product Reviews. The impact of product reviews on consumers: before shopping online, consumers must browse the product reviews. This work guides users through the entire process of purchasing items and making accurate purchasing decisions [13, 14]. First, it affects consumers' purchasing decisions. General consumers tend to read historical reviews of commodities before making consumption behaviors. Second, it affects the decision-making process of consumers [15, 16]. Based on the theory of consumer purchase decision-making, related scholars believe that consumers will search for relevant information about products as much as possible to reduce uncertainty and enhance purchase confidence [17]. When a research company conducted a survey on the influence of consumer reviews on purchases, they found that product reviews run through the entire decision-making process of users [18, 19].

The impact of product reviews on merchants: product reviews are an important factor for merchants to increase sales [20]. Merchants can perceive the real experience of buyers using products through the online reviews of products, and then grasp the advantages and disadvantages of their products, and grasp the needs of consumers, to improve the quality of products and services [21]. Moreover, since online reviews also influence consumers' purchasing decisions, online reviews are closely related to the sales volume and performance of merchants. It has been favored by many businesses [22, 23].

3.3. Factors Affecting Usefulness of Reviews. In the present Internet age, the sender of information, the receiver of information, the information itself, and the feedback of information are the basic elements of information dissemination given by the theory of dissemination of persuasion. The theory of communication persuasion refers to the communication activities that make the recipient accept a certain point of view or engage in a certain behavior through persuasion or propaganda. The first three elements will affect the effect of feedback [24, 25]. Generally speaking, the commenter is the publisher of the information. Comment readers are the recipients of information, the information itself is the content of the comment, and the vote on whether the comment is useful is feedback. This also constitutes a fundamental aspect of research in this field [26]. Recent research has found that the timeliness of comments also affects the

Figure 2: Data on the impact of product reviews on consumers.

Table 1: Definitions of influencing factors.

Influencing factors	Definition	Keywords
Product factor	Reasonable product design, fine craftsmanship, and good quality	Appearance, color, workmanship, etc.
Price factor	Competitive price, perceived price	Expensive, cheap
Service factor	Attitude of employees during sales	Attitude, service level
Information factor	Product information matches product description	Description consistent, consistent
Shipping factor	Delivery speed and time, delivery price	Logistics delivery, express time
Marketing strategy factors	Returns, promotions, product types	Returns, promotions, free shipping

feedback effect. Therefore, the timeliness of such data is also considered in the study of influencing factors, which is studied from the four dimensions of reviewers, review readers, review itself, and the number of days of publication [27, 28]. Sentiment analysis studies the information of review content, so this study only considers the textual features of review influencing factors.

In the current research, there are not many studies on the factors affecting the usefulness of the review information itself, but when people refer to product reviews, they first browse the information content of the review and then the other elements of the review [29]. Therefore, the characteristic influence of the comment itself has a leading role. If the content of the text cannot attract the attention of review readers, the rest of the impact is impossible to talk about [30]. For the features of reviews, this paper chooses to start from the content features of reviews and the review features of products.

4. Experiments on Emotional Factors in Product Reviews

4.1. Role of Product Reviews. With the rise of Internet shopping malls, in today's era of information explosion, customers decide whether to buy or not based on the feedback content of other users by querying product review information. To explore the importance of product reviews, this article presents survey data on the impact of product reviews on consumers over the past few years, as shown in Figure 2.

The survey data in Figure 2 shows that in the past few years, the proportion of people who strongly believe in relevant product reviews and make purchasing decisions through them has increased, from 67% in 2011 to 88% in 2014. The proportion of people who do not believe in related product reviews has shown a downward trend, from 33% in 2011 to 13% in 2014. It can be seen that merchants must pay attention to consumer product reviews, which play a vital role in the revenue and sales of merchants.

4.2. Data Sources. This paper takes the online users' comments on the products of mobile terminal products in an Internet mall as the research object. In order to facilitate the analysis of product reviews in the experiment, neutral reviews are not included in this experiment, and redundant data and invalid data are removed through preliminary processing. A total of 4400 positive sentiment comments and negative sentiment comments were collected in this paper, including 2200 positive comments and 2200 negative comments. And this paper combines the relevant research literature to extract the corresponding evaluation words. In this paper, the influencing factors are integrated into six aspects, namely, product factor, price factor, service factor, information factor, transportation factor, and marketing strategy factor. And the influence of each aspect on customer satisfaction is studied separately, and the influencing factors are used as independent variables. Customer satisfaction is the dependent variable, and the definitions of these six influencing factors are shown in Table 1.

Therefore, through the above summary, a conceptual model of the influencing factors of product review sentiment tendency is constructed, as shown in Figure 3.

4.3. Data Preprocessing. In this study, two researchers (both at the master's level) used the method of coding independent determinants of the same text to construct the coding table. It also uses the "Encoding Compare" query function in Nvivo8. NVivo is a software that supports qualitative and mixed research methods. Its coding comparison query compares codings done by two users to measure "reliability between raters" or the degree of agreement of coding between users. This article compares the factors identified and coded content by two researchers and measures the degree of agreement of the original data by calculating the "percentage of agreement T_x." Reliability refers to the consistency, stability, and reliability of test results. Generally, internal consistency is used to express the reliability of the test. The higher the reliability coefficient, the more consistent and reliable the results of the test are. And systematic error has no effect on reliability.

$$T_x = \frac{T_b}{T_b + N_b}. \tag{1}$$

Among them, T_b represents the number of mutually agreed codes; N_b represents the number of mutually disagreeable codes. The running result is shown in Figure 4.

Figure 4 is the query result of the reliability of keywords. It is generally considered that when the reliability is above 0.7, it is reliable. The figure shows that the "agreement percentage" of the 6 factors is greater than 80%, indicating that the coding consistency between the two coders is high, the coding results have the necessary research reliability, and the set keywords have high operability.

This article uses the keyword search in the query function provided by Nvivo8. Nvivo 8 is an easy-to-use data analysis tool; the software supports a variety of content import for data analysis. It can meet the operational needs of different researchers. It also has a simple interface and fast processing speed. With reference to the above factors and keywords, this article conducts a reference point query. The encoding result is shown in Figure 5.

The reference point query results are shown in Figure 5, in which Figure 5(a) is a reference point for good reviews, with a total of 954 reference points, and Figure 5(b) is a production test point for bad reviews; the total number of reference points is 1281. By linking the emotional influence factor model of product reviews, it can be seen that the impact of negative reviews with negative emotions is greater than that of positive reviews. There are four factors that have the greatest influence on negative emotional comments, which are information factor, marketing strategy factor, service factor, and product factor.

4.4. Determination of Negative Influencing Factors. In order to find out the reasons for the negative comments, this paper considers the above factors as first-level factors. Each primary factor is further divided into several secondary factors. For example, information factors include two secondary factors, information consistency and comprehensiveness of information, and quality factors are divided into manufacturing factors, design factors, and quality factors. The specific classification is shown in Figure 6.

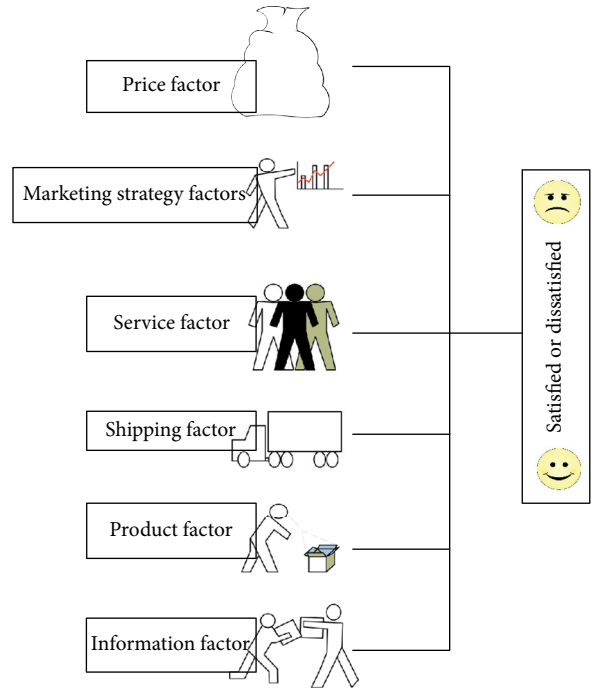

Figure 3: Conceptual model of influencing factors of product review sentiment tendency.

As can be seen from Figure 6, there are a total of 10 negative comments. These 10 factors serve as guidelines for our data analysis below. First, it scores negative reviews. The scoring process needs to compare the content elements of the evaluation and convert the comments into quantitative data one by one. In fact, the scoring process is a process of quantifying customer reviews with subjective attitudes. The scoring rules are as follows: (1) the scores of each factor are divided into 4 grades, ranging from -3 points (very bad) to -1 points (not good), and no mention is 0 points. (2) The total score of negative comments is -1, -2, and -3. Secondly, this paper conducts regression analysis on the data.

The reliability test results of its regression analysis are shown in Figure 7.

Figure 7 is the reliability test result of the regression analysis of the scoring data. The reliability test results show that the reliability analysis results of the listed secondary factors are all above 90%. It shows that the secondary factor keywords of the four influencing factors of negative sentiment in the figure have high consistency and credibility. And in the negative emotional tendency, the influence of service factors and product factors in Figure 7(a) is greater than that of information factors and marketing strategy factors in Figure 7(b).

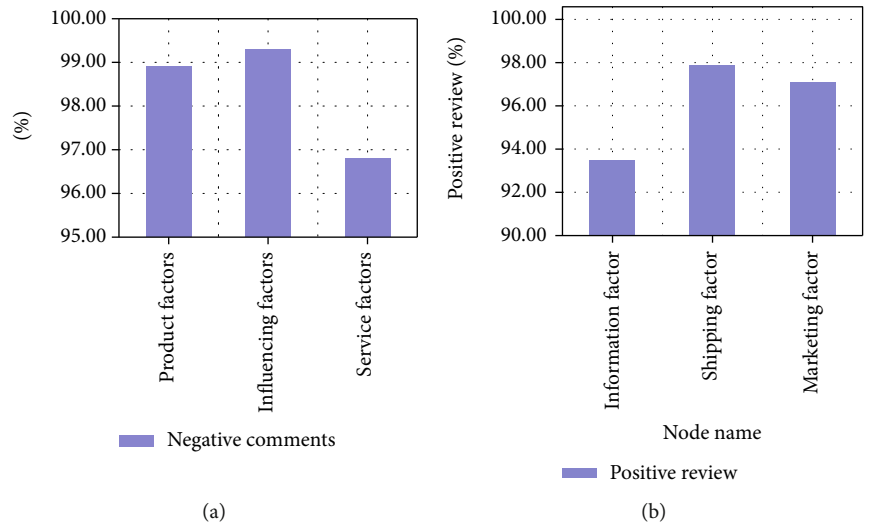

Figure 4: Query results for the reliability of keywords.

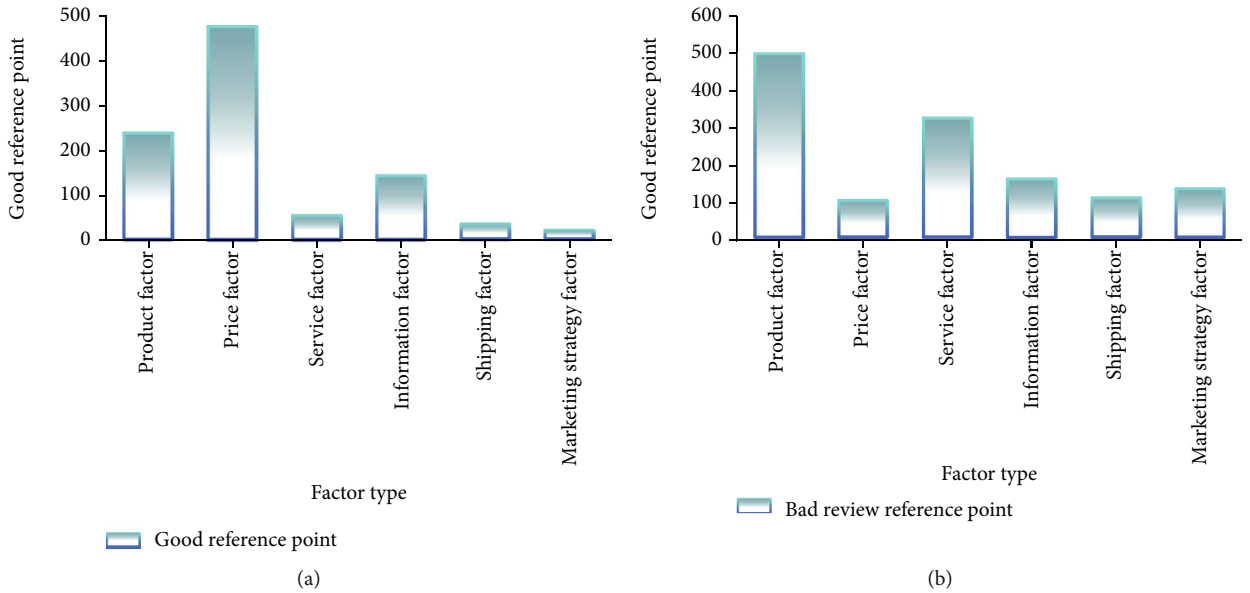

Figure 5: Query results for reference points.

5. Product Review Usefulness

5.1. Usefulness of Product Reviews by Influencing Factors of Emotional Tendencies. In order to better compare the importance of the influence of emotionally inclined product reviews on consumers, we extracted the number of occurrences of keywords of each influencing factor in the sample, and the statistics are shown in Table 2.

As shown in Table 2, among all the influencing factors, the product factor with the highest frequency is mentioned, followed by the price factor, and the mentioned frequency of these two factors accounts for 58.59% of the total sample. The least frequently mentioned factor is the impact of delivery.

Figure 8 shows the positive and negative statistical results of each influencing factor. Figure 8(a) shows the frequency of positive feedback of each factor. According to the frequency of mentions, the price factor appears the most in the positive feedback comments, followed by the product factor. It shows that if the customer is satisfied, in theory, the first factor is the price, followed by the product factor. Marketing policies are largely ignored. Figure 8(b) shows the negative feedback frequency of each factor, in which the product factor has the highest occurrence, followed by the service factor. That is, if the customer is not satisfied, it is mainly because of the product factor, followed by the price factor. Through the analysis, it can be seen that the frequency of mentioning the price factor in positive comments is most different from that in negative comments. And the number of mentions in positive comments is far greater than the number of mentions in negative comments. It shows that the price can easily lead to customer satisfaction, which will

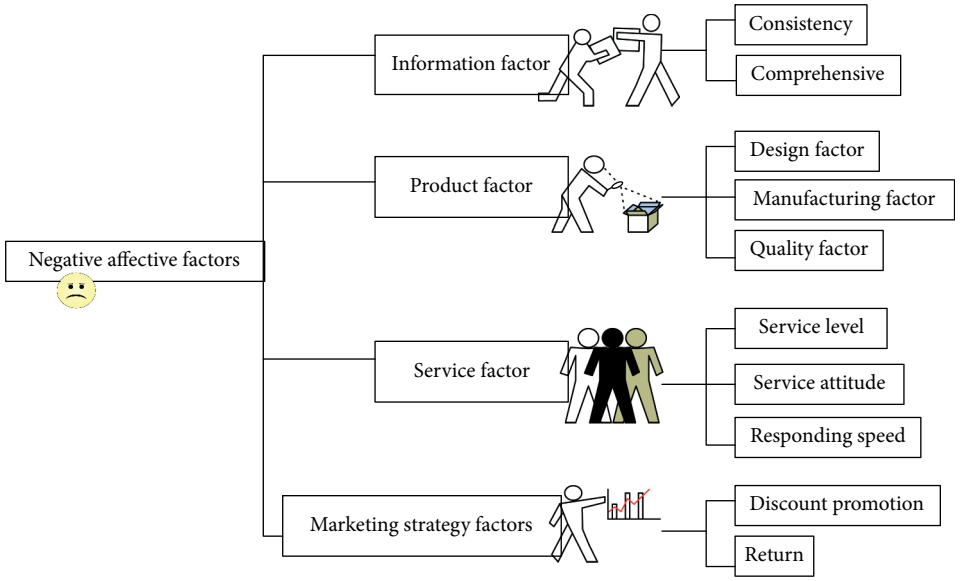

Figure 6: Conceptual model of negative affective factors.

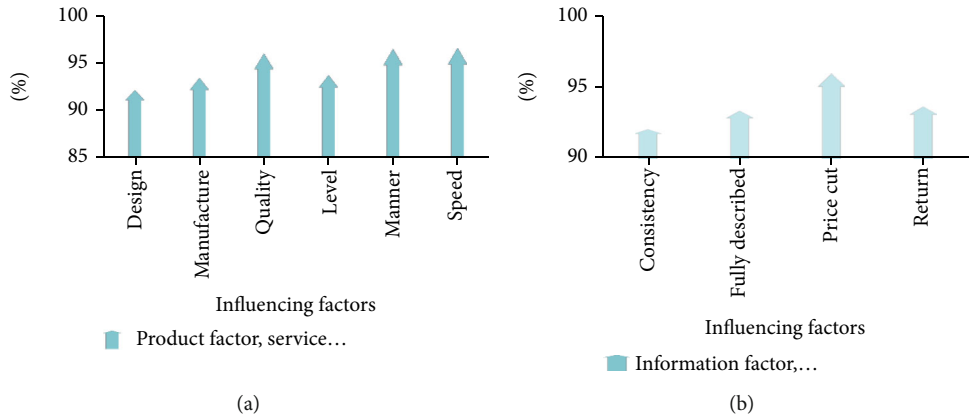

Figure 7: Regression analysis scoring reliability test results.

Table 2: Statistics of the total frequency of occurrence of each factor.

Influencing factors	Quantity	Frequency	Proportion
Product factor	2200	720	32.73%
Price factor	2200	569	25.86%
Service factor	2200	367	16.68%
Information factor	2200	296	13.45%
Shipping factor	2200	136	6.18%
Marketing strategy factors	2200	147	6.68%

lead to positive reviews. The frequency of mentioning product factors in positive reviews is quite different from that in the negative plane, and the number of mentions in negative reviews is much greater than that in positive reviews. It shows that product factors can easily lead to customer dissatisfaction, which will lead to negative reviews.

5.2. Two-Sample Z-Test. This study uses a single review as the unit of analysis. For each influencing factor, we performed a two-sample Z-test on the sample proportions of positive and negative reviews. A two-sample Z-test can be performed on means with known variance. It is used to test the null hypothesis that there is no difference between the two population means, not other hypotheses of one or both. In order to analyze emotional tendencies, the first step is to put forward hypotheses and verify the influencing factors. The hypotheses are shown in Table 3.

To verify K1-K6 in Table 3, a two-sample Z test was performed on the corresponding influencing factors. The results of the Z test are shown in Table 4.

The test results in Table 4 show that there are differences ($P < 0.05$) between positive and negative reviews of product quality, customer service, commodity price, and commodity information, rejecting hypotheses K1, K2, K3, K4, and K6. Among them, there were significant differences between positive and negative reviews on product quality, customer service, and commodity prices ($P < 0.01$

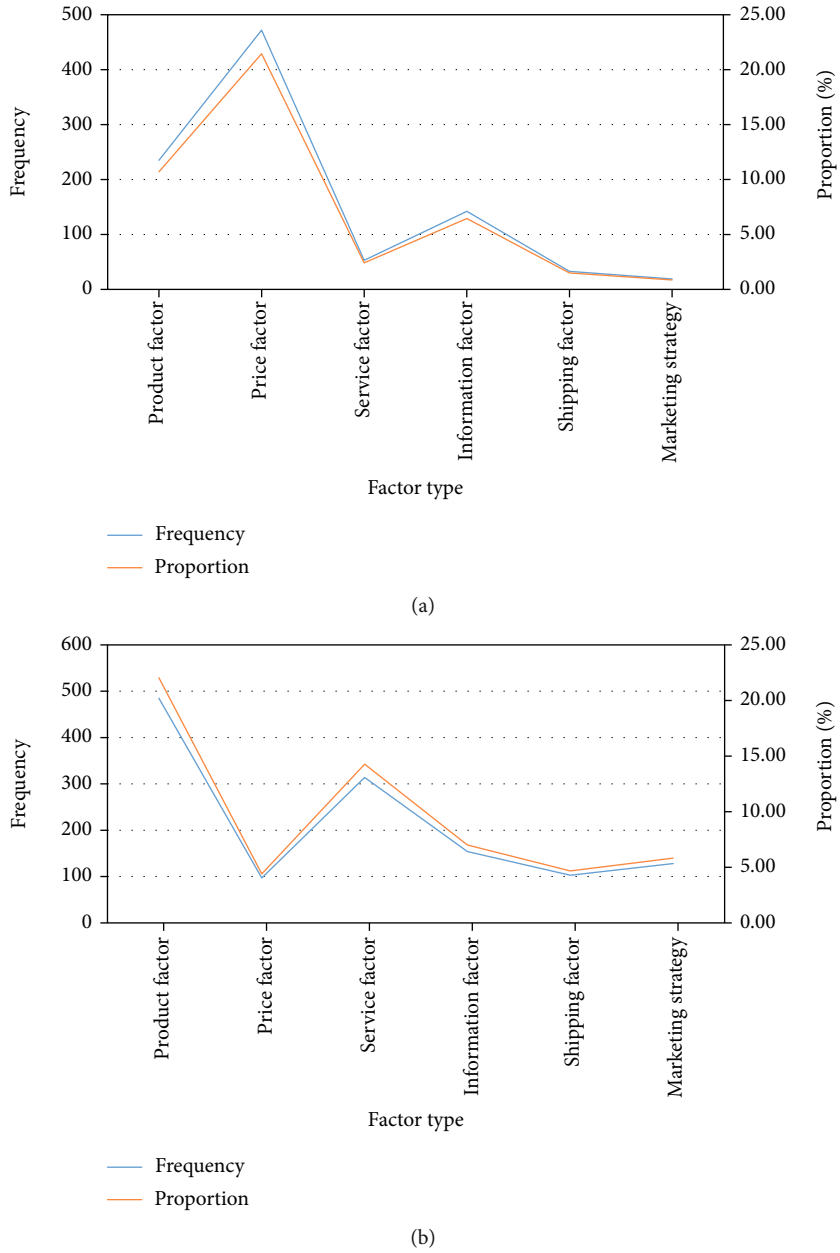

Figure 8: Positive and negative statistics of each influencing factor.

). There is little difference between positive and negative comments on logistics distribution and marketing strategies ($P > 0.05$), which supports K5. There is no significant difference between the mentioned frequency of logistics and distribution in the positive comments and the mentioned frequency in the negative plane. It shows that the difference between the probability of customer satisfaction and dissatisfaction caused by logistics distribution is not large.

5.3. Regression Results of Negative Emotional Influencing Factors. As shown in Figure 9, the regression coefficients of the influencing factors of negative emotional tendencies show that in product reviews, customers are more concerned about factors related to product quality. That is to say, merchants want to improve customer satisfaction, and they need to strictly control the quality of products. The second is the promotion and price reduction factor, that is, customers are more concerned about the rationality of prices and preferential strategies.

The regression analysis results of negative affective factors in Table 5 show that all 10 factors are significant. What is very significant is whether the description is comprehensive and whether the response in the service factor is timely.

In Table 5, X represents the correlation coefficient, and the coefficient of determination is also called the goodness

Table 3: Assumptions of influencing factors.

K1.	Frequency of mentions of product factors in positive versus negative reviews	No significant difference
K2.	How often the price factor is mentioned in positive versus negative reviews	No significant difference
K3.	Frequency of mentions of service factors in positive versus negative reviews	No significant difference
K4.	Frequency of mentions of informational factors in positive versus negative reviews	No significant difference
K5.	How often shipping factors are mentioned in positive versus negative reviews	No significant difference
K6.	The frequency of mentions of marketing strategy factors in positive and negative reviews	No significant difference

Table 4: Test results.

Influencing factors	Z	Significance (P value)
Product factor	-10.56	$P \le 0.01$
Price factor	17.73	$P \le 0.01$
Service factor	-14.53	$P \le 0.01$
Information factor	0.76	—
Shipping factor	-6.29	$P > 0.05$
Marketing strategy	-8.21	$P > 0.05$

of fit, which is the square of the correlation coefficient, so it is expressed as X^2. AR stands for the coefficient of determination, and its calculation formula is

$$\mathrm{AR} = 1 - \frac{(a-1)\left(1-X^2\right)}{a-i-1}. \tag{2}$$

a is the number of samples, i is the number of variables, and X^2 is the coefficient of determination.

The correlation coefficient, goodness of fit, and determination coefficient in Table 5 are all above 87%. It shows that the degree of fit of the secondary influencing factors of negative sentiment in the table is relatively high, and it is a factor that has a greater impact on the sales of merchants in product reviews.

5.4. Negative Emotional Reasons. In order to summarize the negative sentiment reasons, it is first necessary to conduct variance analysis on the influencing factors. The analysis of variance part includes degrees of freedom, error sum of squares, mean square error, F value, and P value. The analysis results are shown in the table.

Assuming that the degrees of freedom are expressed as Yz, the regression degrees of freedom (Yzr), the residual degrees of freedom (Yzc), and the total degrees of freedom (Yzs) are calculated, since

$$i = 10,\ j = 2200. \tag{3}$$

i is the number of samples, and j is the number of variables.

The regression degrees of freedom (Yzr) are

$$\mathrm{Yzr} = i = 10. \tag{4}$$

The residual degrees of freedom (Yzc) are

$$\mathrm{Yzc} = j - i - 1 = 2189. \tag{5}$$

The total degrees of freedom (Yzs) are

$$\mathrm{Yzs} = j - 1 = 2199. \tag{6}$$

Assuming that the sum of squared errors or variation is denoted as Wg, the regression variation (Wgr) representing the total deviation of the predicted value of the dependent variable from its mean value is

$$\mathrm{Wgr} = \sum_{n=1}^{j} \left(\widehat{Q}_n - \bar{Q}_n\right)^2. \tag{7}$$

The residual sum of squares (Wgc) that characterizes the total deviation of the dependent variable from its predicted value, also known as the residual sum of squares, is expressed as

$$\mathrm{Wgc} = \sum_{n=1}^{j} \left(Q_n - \bar{Q}_n\right)^2. \tag{8}$$

The larger the calculated value, the worse the fitting effect. The standard deviation of the above Q value is given by Wgc.

Then, it means that the total variation (Wgs) is

$$\mathrm{Wgs} = \sum_{n=1}^{j} \left(Q_n - \bar{Q}_n\right)^2. \tag{9}$$

There is

$$\mathrm{Wgr} + \mathrm{Wgc} = \mathrm{Wgs}. \tag{10}$$

The coefficient of determination (K^2) represents the proportion of the regression sum of squares in the total square, that is

$$K^2 = \frac{\mathrm{Wgr}}{\mathrm{Wgs}}. \tag{11}$$

The larger the value of the determination coefficient calculated by the above formula, the better the fitting effect.

Suppose the mean squared error is denoted by FG, the quotient was obtained by dividing the sum of squared errors

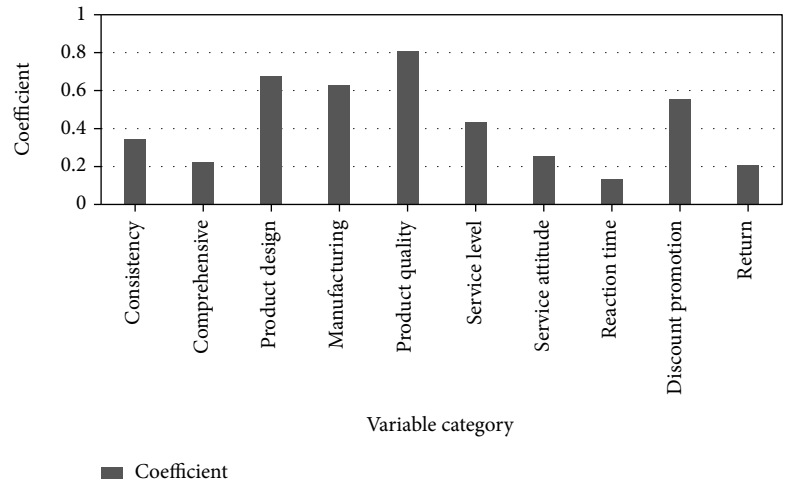

Figure 9: Regression results of influencing factors of negative sentiment.

Table 5: Regression analysis results of negative affective factors.

	Emotional tendencies The amount of data	Negative emotion 2200
Influencing factors	Variable	P value
Information factor	Consistency	$P \le 0.01$
	Comprehensive	$P \le 0.05$
Product factor	Product design	$P \le 0.01$
	Manufacturing	$P \le 0.01$
	Product quality	$P \le 0.01$
Service factor	Service level	$P \le 0.01$
	Service attitude	$P \le 0.01$
	Reaction time	$P \le 0.05$
Marketing strategy	Discount promotion	$P \le 0.01$
	Return	$P \le 0.01$
	Correlation coefficient (X)	0.934
	Goodness of fit (X^2)	0.871
	Coefficient of determination (AR)	0.87

by the corresponding degrees of freedom. Then, the regression mean square error FGr is

$$\mathrm{FGr} = \frac{\mathrm{Wgr}}{\mathrm{Yzr}}. \tag{12}$$

The residual mean square error FGc is expressed as

$$\mathrm{FGc} = \frac{\mathrm{Wgc}}{\mathrm{Yzc}}. \tag{13}$$

The smaller the value, the better the fitting effect.

For linear relationship judgment, the F value calculation formula for univariate linear regression is

$$F = \frac{K^2}{(1/(j-i-1))\left(1-K^2\right)}, \qquad F = \frac{\mathrm{Yzc} \bullet K^2}{1-K^2}. \tag{14}$$

The data in Table 6 corresponds to the degree of freedom Yz as the column, the first row is the regression degree of freedom, the second row is the residual degree of freedom, and the third row is also the last row of the total degree of freedom. The P value represents the rejection rate, the probability that the model is false. It can see that $1 - P$ is the

Table 6: ANOVA results.

	Yz	Mg	FG	F	P
Regression analysis	10	8880.92	634.35	933.55	0
Residual analysis	2189	1310.08	0.68	—	—
Total analysis	2199	10191	—	—	—

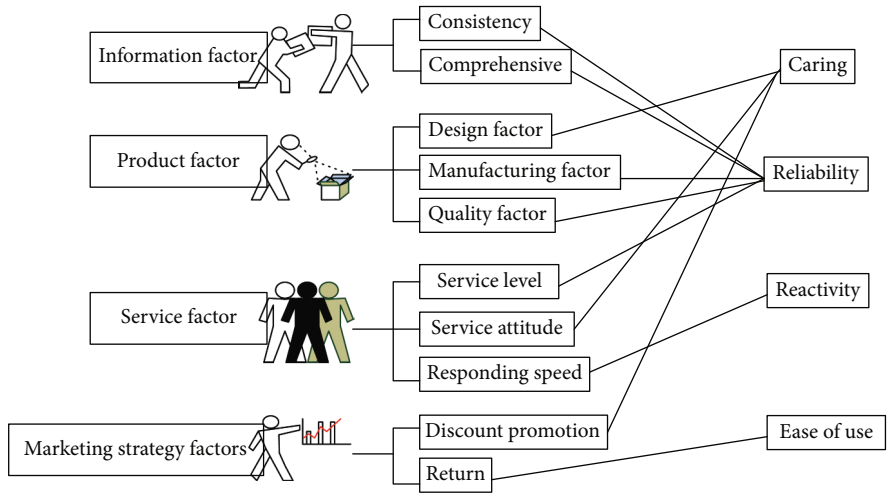

Figure 10: Schematic diagram of the attribution of negative emotional causes.

probability that the model is true. Therefore, the smaller the P value, the better.

From this, a regression model can be built

$$\begin{aligned}\text{negative emotio} = 0.7 &* \text{product design} + 0.6 \\ &* \text{Manufacturing} + 0.8 \\ &* \text{product quality} + 0.4 \\ &* \text{Service Level} + 0.3 \\ &* \text{Service attitude} + 0.13 \\ &* \text{responding speed} + 0.4 \\ &* \text{consistent description} + 0.2 \\ &* \text{fully comprehensive} + 0.6 \\ &* \text{Promotional price reduction} + 0.2 \\ &* \text{Return Policy}.\end{aligned} \tag{15}$$

Then, the 10 factors are summarized, and the 10 factors are attributed to the following four aspects. These aspects are based on the five dimensions of the SERVQUAL scale, combined with the characteristics of Internet businesses. And it made a negative emotional cause attribution Figure 10.

It can be seen from Figure 10 that among the reasons for the negative emotional factors of product reviews, reliability is one of the first reasons, followed by caring. Merchants need to provide comprehensive and correct product information, deliver products within the specified time, and ensure that the delivered products are free of defects and quality assurance, and the service level and attitude of employees need to be guaranteed. The humanization of product design, promotion strategy, and service attitude all need the psychological benefit of customers. By solving the above problems, the dissatisfaction factors of customers can be effectively solved, and the generation of product reviews with negative emotional tendencies can be reduced. That is, it can increase the sales volume of the product sideways.

6. Conclusion

This paper systematically analyzes the content of a large number of customer review texts and digs out the influencing factors of the emotional tendencies of Internet merchants' product reviews. It also extracts keywords and constructs a conceptual model of the influencing factors of emotional tendencies. This paper uses the two-sample Z test and regression analysis to explore the importance, reasons, and laws of the influencing factors of various emotional tendencies. And this paper further proves that reviews with negative emotional tendencies have a greater impact on consumers. Therefore, this paper focuses on the causes and analysis of negative emotions and gives some suggestions to Internet merchants. Among the negative affective factors, the factors related to the quality of the product are the main points that consumers pay attention to. That is to say, the product quality cannot be guaranteed, which will breed

negative emotions of consumers and affect the sales of products. The second is the guarantee of service attitude, which can also further enhance the goodwill of consumers and reduce negative emotional product reviews.

Data Availability

No data were used to support this study.

Conflicts of Interest

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

References

[1] A. Haddad, A. Ameen, and O. Isaac, "Factors that influence the net benefits of big data adoption within government agencies in the UAE," *International Journal of Control and Automation*, vol. 12, no. 6, pp. 841–860, 2019.

[2] T. Y. Wu and C. A. Lin, "Predicting the effects of eWOM and online brand messaging: source trust, bandwagon effect and innovation adoption factors," *Telematics and Informatics*, vol. 34, no. 2, pp. 470–480, 2017.

[3] K. Horie, M. Onoda, and T. Kaneko, "A proposal of review extraction method considering the knowledge amount of consumers and the purchase stage," *Total Quality Science*, vol. 4, no. 2, pp. 83–91, 2018.

[4] D. W. Mccloskey and S. Koch, "An examination of the data quality of online reviews," *Journal of Electronic Commerce in Organizations*, vol. 19, no. 1, pp. 24–42, 2021.

[5] M. J. Thomas, B. W. Wirtz, and J. C. Weyerer, "Influencing factors of online reviews: an empirical analysis of determinants of purchase intention," *International Journal of Electronic Business*, vol. 15, no. 1, pp. 43–71, 2019.

[6] Z. Xiang, Q. Du, and Y. Ma, "A comparative analysis of major online review platforms: implications for social media analytics in hospitality and tourism," *Tourism Management*, vol. 58, pp. 51–65, 2017.

[7] Y. J. Park and K. J. Kim, "Impact of semantic characteristics on perceived helpfulness of online reviews," *Journal of Intelligence and Information Systems*, vol. 23, no. 3, pp. 29–44, 2017.

[8] W. Shi, "Prsentiminer: a product review mining system for sentiment analysis of Chinese microblogging," *International Journal of Information and Management Sciences*, vol. 29, no. 2, pp. 171–189, 2018.

[9] X. Liang, J. Guo, Y. Sun, and X. Liu, "A method of product selection based on online reviews," *Mobile Information Systems*, vol. 2021, Article ID 9656315, 16 pages, 2021.

[10] M. Fayaz, A. Khan, J. U. Rahman, A. Alharbi, M. I. Uddin, and B. Alouffi, "Ensemble machine learning model for classification of spam product reviews," *Complexity*, vol. 2020, Article ID 8857570, 10 pages, 2020.

[11] S. Halder, M. Banik, and S. Ghosh, "Family of bound entangled states on the boundary of the Peres set," *Physical Review A*, vol. 99, no. 6, article 62329, 2019.

[12] Y. Sun, T. Hayashi, and Y. Ohsawa, "A latent topic analysis and visualization framework for category-level target promotion in the supermarket," *The Review of Socionetwork Strategies*, vol. 15, no. 2, pp. 429–453, 2021.

[13] A. E. Raftery, T. Gneiting, F. Balabdaoui, and M. Polakowski, "Using Bayesian model averaging to calibrate forecast ensembles," *Monthly Weather Review*, vol. 133, no. 5, pp. 1155–1174, 2005.

[14] J. Chakravarthy, "Ideological diversity in standard setting," *Review of Accounting Studies*, vol. 24, no. 1, pp. 113–155, 2019.

[15] G. Zhang and H. Qiu, "Competitive product identification and sales forecast based on consumer reviews," *Mathematical Problems in Engineering*, vol. 2021, Article ID 2370692, 15 pages, 2021.

[16] C. Tam and T. Oliveira, "Literature review of mobile banking and individual performance," *International Journal of Bank Marketing*, vol. 35, no. 7, pp. 1044–1067, 2017.

[17] M. Borowska, "Quantitative methods in the field of economic sciences," *VUZF Review*, vol. 5, no. 2, pp. 22–37, 2020.

[18] M. K. Dalal and M. A. Zaveri, "Semisupervised learning based opinion summarization and classification for online product reviews," *Applied Computational Intelligence and Soft Computing*, vol. 2013, Article ID 910706, 8 pages, 2013.

[19] S. S. Htay and K. T. Lynn, "Extracting product features and opinion words using pattern knowledge in customer reviews," *The Scientific World Journal*, vol. 2013, Article ID 394758, 5 pages, 2013.

[20] M. E. Alzahrani, T. H. H. Aldhyani, S. N. Alsubari, M. M. Althobaiti, and A. Fahad, "Developing an intelligent system with deep learning algorithms for sentiment analysis of E-commerce product reviews," *Computational Intelligence and Neuroscience*, vol. 2022, Article ID 3840071, 10 pages, 2022.

[21] I. Pavlidou, S. Papagiannidis, and E. Tsui, "Crowdsourcing: a systematic review of the literature using text mining," *Industrial Management & Data Systems*, vol. 120, no. 11, pp. 2041–2065, 2020.

[22] N. Basoglu, A. E. Ok, and T. U. Daim, "What will it take to adopt smart glasses: a consumer choice based review?," *Technology in Society*, vol. 50, pp. 50–56, 2017.

[23] V. Vaishnavi, M. Suresh, and P. Dutta, "A study on the influence of factors associated with organizational readiness for change in healthcare organizations using TISM," *International Journal*, vol. 26, no. 4, pp. 1290–1313, 2019.

[24] X. Zheng, G. Zhu, N. Metawa, and Q. Zhou, "Machine learning based customer meta-combination brand equity analysis for marketing behavior evaluation," *Information Processing and Management*, vol. 59, no. 1, article 102800, 2022.

[25] H. Wang, Z. Hong, and M. Hong, "Research on product recommendation based on matrix factorization models fusing user reviews," *Applied Soft Computing*, vol. 123, article 108971, 2022.

[26] S. Sinarti and U. Sari, "The influence of emotional intelligence on the accounting comprehension: gender based study," *Journal of Applied Managerial Accounting*, vol. 1, no. 1, pp. 30–36, 2017.

[27] J. Wang, Z. Li, and X. Sun, "Empirical analysis on the influence of business environment on foreign direct investment inflow based on the panel data on 26 countries," *International Journal of Sustainable Development and Planning*, vol. 15, no. 8, pp. 1223–1230, 2020.

[28] H. Xu, S. Zhang, G. Zhu, and H. Y. Zhu, "ALSEE: a framework for attribute-level sentiment element extraction towards product reviews," *Connection Science*, vol. 34, no. 1, pp. 205–223, 2022.

[29] G. Craciun and K. Moore, "Credibility of negative online product reviews: reviewer gender, reputation and emotion effects," *Computers in Human Behavior*, vol. 97, pp. 104–115, 2019.

[30] X. Chen, Y. Xue, H. Zhao, X. Lu, X. Hu, and Z. Ma, "A novel feature extraction methodology for sentiment analysis of product reviews," *Neural Computing and Applications*, vol. 31, no. 10, pp. 6625–6642, 2019.

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Research Article

Application of Internet Information Technology in College Music Education Teaching System

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The development of society has higher and higher requirements on the quality of talents, and the demand for talents with comprehensive literacy continues to rise. Using music education as a means to continuously improve the music aesthetic quality of the new generation of young people and establish music aesthetic concepts is an important entry point to improve the quality of the whole people. But the current colleges and universities basically still focus on the traditional education and teaching methods, largely ignoring the importance of music education. In order to improve the comprehensive quality of college students, this paper introduces Internet information technology into the study of music system. The experimental results show that the research on the application of Internet information technology in the music system of colleges and universities can save time and management costs to a great extent and increase the efficiency of educational resources by 3.58%. At the same time, it can implement dynamic music evaluation, reasonably arrange students' daily music training plans, improve students' comprehensive quality and music literacy, and integrate music education into students' lives, so as to increase the effect of music education to a great extent. Besides after the Internet information technology is applied to the music teaching system, the system can be linked with the network platform and resources, which greatly enriched teaching materials for music and information technology.

1. Introduction

With the continuous progress of Internet information technology, the educational methods of music are constantly changing, and the requirements of lifelong teaching, the requirement of lifelong education makes the traditional music teaching platform face huge challenges. Therefore, there is an urgent need to conduct research on the music information education and teaching system and Internet technology. Although the research results of the former two are very rich at present, few people have studied them, which makes it impossible to provide an important theoretical basis for the development of the music teaching system in colleges and universities. It is precisely because of this that the research on the application of Internet information technology in the music education and teaching system in colleges and universities is of great importance.

As an important artistic way of expressing emotion, music is of great significance for improving students' artistic literacy and comprehensive quality. Especially under the influence of the new educational concept, university education should not only enhance the practical ability and material ability of students to enter the society but also improve the comprehensive quality of students. In order to promote the all-round development of students, many people have carried out research on this. Sang believed that school music teaching should take aesthetic education as the core, gradually take correct art and music aesthetics as the learning path, and apply the knowledge learned to life and life [1]. On the basis of cloud computing technology, Zhang and Min broke the confinement of the traditional sports model and create an independent learning plan according to the basic principles of physical education teaching [2]. Gaobin et al. built a teaching evaluation system based on artificial intelligence fuzzy algorithm [3]. Since traditional teaching models and teaching concepts are considered unsuitable for the current environment, Juhe and Zhibin introduced the importance and application of multimedia computer-

assisted teaching in the development of physical education [4]. Zhang described the characteristics of leisure sports and described the research-based teaching reform of college sports and leisure sports [5]. Artes et al. used the educational teaching system to study the relationship between research performance and teaching quality in the context of the Spanish university system [6]. Xie proposed an optimization method for sports evaluation system and intelligent suggestion module design [7]. From this point of view, the research results of music teaching system have been very extensive, but few people have introduced Internet information technology into their research. In order to promote the development of music teaching, this paper combines the two to carry out research.

The application of the Internet greatly facilitates the dissemination of information and makes people's life and work more efficient. But the same is true for bad aspects, such as bad information. In order to give full play to the advantages of Internet information technology, many people in Shenyang have carried out research on this. Due to the limited range of motion of the robotic arms and the need to move the robot during operation, Braga used a da Vinci robot in the low anterior resection, using all three arms for the splenic flexure and pelvis [8]. Sun et al. mainly explored the nonartificial information terminal security technology based on the mobile network and analyzed and compared the current mainstream encryption algorithms of the mobile Internet [9]. Pan conducted advanced pattern analysis of the dissemination of national traditional movements based on information technology [10]. In order to reveal what kind of education about the use of safe Internet is provided in schools, Kaban reviewed and analyzed the textbooks of information technology and software courses in primary and secondary schools using the literature analysis method [11]. To investigate the impact of information technology and technological capabilities on Internet entrepreneurship and to compare the magnitude of their impact, Ayough et al. proposed a new model to explain the relationship between Internet entrepreneurship and information technology [12]. As young people who are almost constantly connected are vulnerable to pathological addiction to the Internet, Silajdi and Dudi explored the use of the Internet, social networks, and mobile phones by young people [13]. Since the whole idea and purpose of Internet information technology is to overturn the existing state or situation, Bajrami et al. believed that one of the most common ways of using Internet information technology is to transmit relevant information through advertisements of different products [14]. Although many people have researched the Internet information technology, few people have applied it to the music system for research. In order to use the Internet information technology more widely, this paper applies it to the system and conducts in-depth research.

The development of Internet information technology and its own advantages have made it constantly applied in different places and various education and teaching. But from the perspective of the current development status of Internet information technology, this technology has not been applied to the music education and teaching system of colleges and universities too much. As a result, it is difficult for the current college music system to borrow information technology to perfect and improve itself, and it is also difficult to meet the current society's music requirements for the system. Therefore, this paper conducts an in-depth study on the use of Internet information technology in the music education and teaching system in colleges and universities.

2. Specific Music Education System

2.1. Functional Modules of College Music Education System. The music education and teaching system studied in this paper is realized based on the technology of Internet informatization [15]. Since the system uses multimedia transmission technology and is developed in combination with the transmission protocol given to the network, it can provide a variety of services for college music education. In addition, the music education system studied in this paper is a functional module designed according to actual needs, and its specific functional modules are shown in Figure 1.

It can be seen from Figure 1 that the basic functional structure of the music education and teaching system in colleges and universities is divided into two parts, one part is the front end of the system, and the other part is the back end of the system. The front desk of the music education and teaching system in colleges and universities can only allow users who have registered an account on the platform to log in and use, but this user does not limit the user identity. In other words, the user logging in and using the music teaching system can be a music teacher, music students, or even nonmusic teachers or students. Only after entering the correct account and password can the user log in to the system, that is, the university music education system allows the user to use the front-end service. The front-end service objects of the system are mainly teachers and students, and its functions include five parts: virtual school management, music recognition, live broadcast, stage rehearsal, and personal design information management of basic nursing. The functions of the system background mainly include three functions: system management, user management, and multimedia information management. The functional design of the system foreground and system background can maintain the operation and use of the system in many aspects.

2.2. User Business Task Exchange Module. To do an in-depth study of the music education system, it is necessary to determine its main functional requirements first. And the research on the user's business transaction module is the key to determine the function of the music education system [16]. Through background investigation of the online music education system, this paper roughly divides users into three categories: administrators, students, and teachers, and the business exchanges among them are first shown in the virtual classroom. The basic business exchange of its users is shown in Figure 2.

As can be seen from Figure 2, the three types of users have very close business exchanges in the virtual classroom

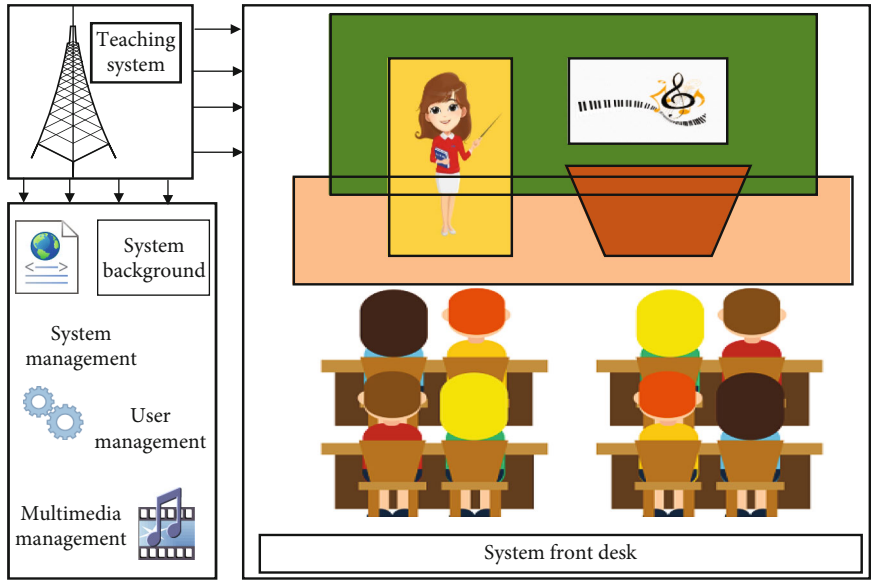

Figure 1: Functional modules of college music education system.

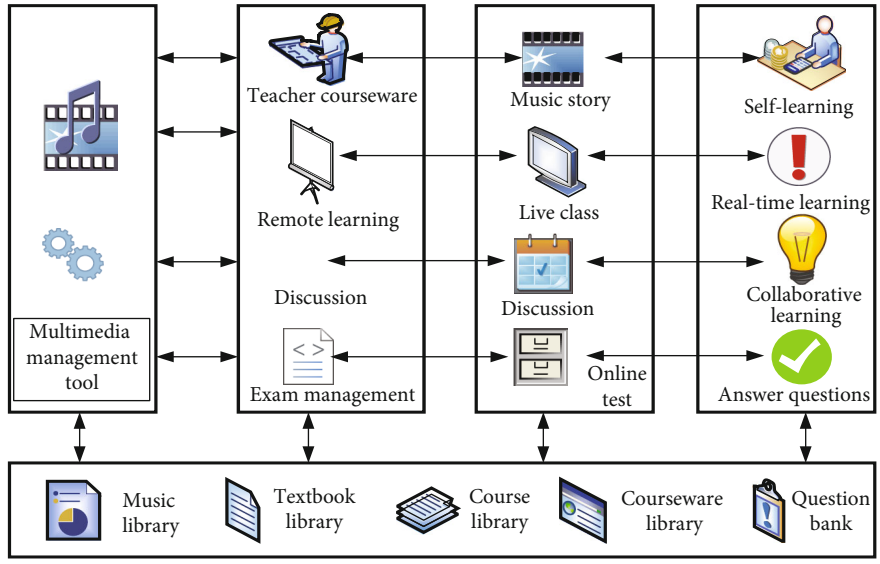

Figure 2: User business task exchange module.

of the music education and teaching system in colleges and universities. As far as the administrator is concerned, the activities of the program administrator mainly include the daily maintenance of the system. In addition, administrators also need to perform basic maintenance tasks on the music teaching system. As far as music teachers are concerned, as an important symbol in the music education and teaching system, teachers can not only manage educational activities in the program but also provide relevant functional content of the corresponding educational activities. When teachers conduct a music lesson, they need to fill in the relevant content and need to organize, integrate, delete, review, and recreate the virtual classrooms needed for educational work. As far as students are concerned, students are the main service target of the entire music education system. Students can conduct autonomous learning, autonomous testing, online training, and other activities in the music system studied in this paper. Among them, students can also view the materials released by the teacher and can repeat the courses that have been played. At the same time, it has completed the basic training activities arranged by the teacher in each class and conduct relevant tests. Of course, only after passing the exam can the study of this section be completed. In addition, the system will provide students with some practical exercises to help students improve their weaknesses through self-directed education.

2.3. Virtual Classroom Function Module. Virtual classrooms are an important part of college music programs and the preferred place for students to study music [17]. For

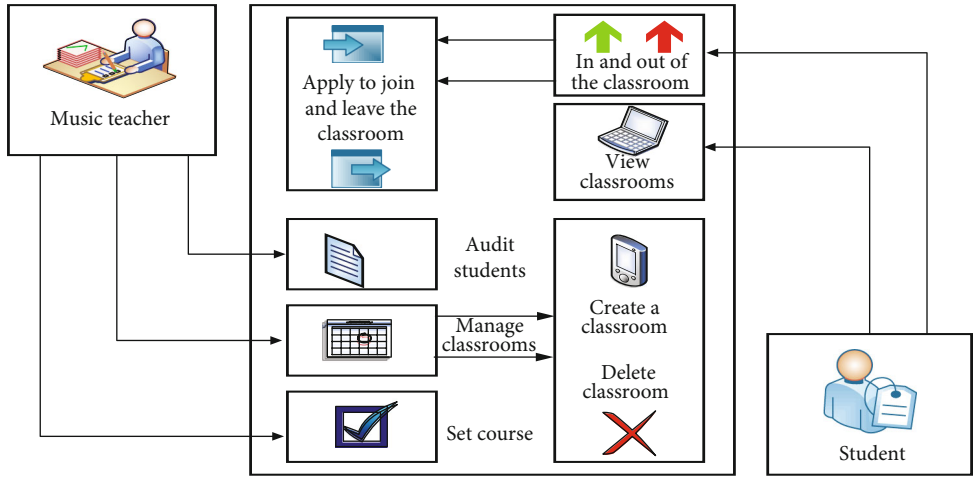

Figure 3: Functional module diagram of virtual classroom.

students, virtual school management can provide them with functions such as leaving the classroom, applying to join the classroom, and viewing the displayed classroom information. For teachers, the functions that can be used are creating virtual classrooms, configuring virtual classrooms, etc. In order to have a specific understanding of the music system, this paper explores and describes the work of creating a virtual classroom and the activities of students entering and leaving the classroom. Its virtual classroom management function is shown in Figure 3.

It can be seen from Figure 3 that students must first log in when using the virtual classroom. Only when the student's account and password are entered correctly, the system will allow students to access. After entering the system, students should select a suitable virtual classroom and then apply for permission to join, and teachers and supervisors will make plans for the use of virtual classrooms. Each virtual classroom has a teacher, because the virtual classroom is the responsibility of the teacher, but in the background of the system, the administrator has the right to block some classrooms that cannot be used normally. After opening a virtual classroom, teacher users not only need to fill in the corresponding virtual classroom information but also prepare relevant class materials. After the virtual classroom application is completed, the administrator will review it, and after the application is approved, the administrator will announce the class so that students can choose educational activities. Classroom management functions include creating and deleting classrooms and adjusting classroom volume, while course functions are selected and used by classroom users. The student review process means that once the virtual classroom starts, students can freely choose music courses. After that, the user's teacher will check the student's profile information and give permission to enter the classroom. Only after the student has obtained the access permission can they enter the classroom. Classroom entry and exit services are used by students who are responsible for student requests to enter and exit the virtual classroom. For the virtual classroom viewing function, students who have not selected a virtual classroom, or students who have already registered for a classroom, can use it to view virtual classroom information.

2.4. Performance Appreciation Module. The performance appreciation module is shared by teachers and students, and its content takes into account the basic online music playback function of the system studied in this paper [18]. In the college music education teaching management system studied in this paper, the performance appreciation module is a module that is used more frequently. This module can be provided to all users of the music system studied in this paper, so that more people can receive music education. The specific performance function module is shown in Figure 4.

As can be seen from Figure 4, the performance playback module provides services such as music storage, playlists, playlists, and playlists. Users can edit playlists to select their favorite music from a massive data set and play it at any time. In addition, the users of the system studied in this paper can realize the collection of music library and the online play of music. There are three main play commands: random play, single loop, and sequential play. Through the performance and playback module, users can better participate in music learning while improving user experience, so as to deepen the interaction between students and teachers. Since the user group of the system studied in this paper is all users who want to learn music, the only task performed by the program administrator is to add, delete, and edit tracks in the music system. At the same time, it allows student users to filter out the tracks they want in a custom list. In addition, the program can also provide electronic music playback, listening, sharing, downloading, and other functions for all users of the system. The music maintenance service is only used and performed by system administrators, and the main task is to perform basic tasks on songs, such as adding, deleting, checking and changing tracks, and updating or updating data. Created list is a playlist developed for system users according to user needs. Music playback is the most important and basic function in the system studied in this paper, and the upload management

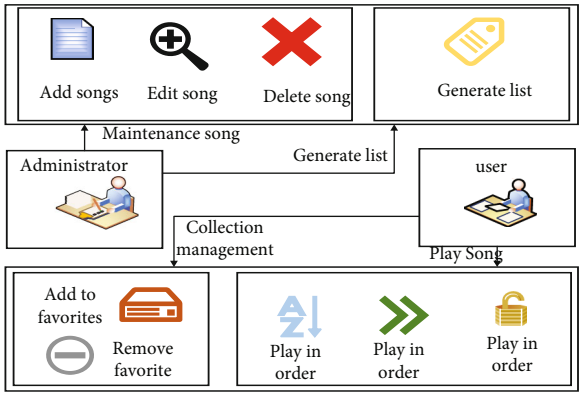

Figure 4: Functional block diagram of performance appreciation.

function is a function that can provide music collection for all users of the system.

2.5. Live Classroom Function Module. The live classroom function module is one of the most used modules in the current music education system [19]. Because it can avoid the limitations of traditional performance, realize one-to-one service between teachers and students, and promote interaction and communication between teachers and students, students' musical literacy is cultivated, so that their overall quality is improved. In order to make use of the features of the live classroom function module at a deeper level, this paper conducts a detailed study on it, and its specific function module is shown in Figure 5.

As can be seen from Figure 5, the functional modules of the live classroom mainly include functions such as publishing live broadcasts, online live broadcasts, live broadcast recording, answering questions, watching live broadcasts, and asking questions. Among them, the online live broadcast also includes three small functions: video adjustment, audio adjustment, and progress control. Before teachers can schedule live classes, they must first send a live video request to the administrator. After receiving the application sent by the teacher, the administrator will schedule the application for live broadcast in a unified manner, so as to prevent the overlapping of the time of the live broadcast class. After the final review is completed, the administrator will publish the live class on the announcement page and notify the relevant students to attend the class within the specified time frame. In the online live broadcast module, in addition to the basic needs of providing live broadcast services for teachers, it should also have the operation functions of each user. Using these services, users can realize the function of adjusting live video. The live recording service is provided by the system, which can automatically record the teacher's live broadcast during the live broadcast. Then the administrator can also organize the recorded videos and upload them online for use by some students who are not compatible with live videos. In addition, during the live broadcast, teachers can also discuss by leaving messages or talking with other students in the class to increase the effectiveness of problem solving and enhance the communication between teachers and students.

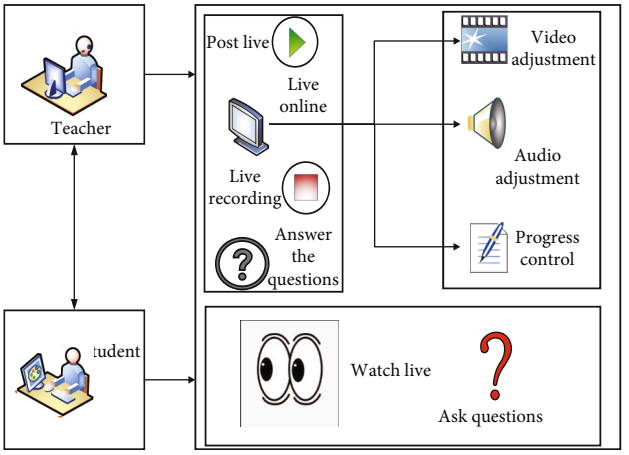

Figure 5: Functional module diagram of live classroom.

3. Application Algorithms of Internet Information Technology

3.1. Information Gain. This method can use the amount of information that the attribute can bring to the customized system to measure the importance of the attribute [20], and its calculation formula is:

$$H(x) = -\sum_{i=1}^{n} \log p(x_i). \tag{1}$$

3.2. Mutual Information. Mutual information measures the relative degrees of freedom between certain categories of information [21], and its calculation formula is:

$$I(t,c) \approx \lg \frac{\mathrm{AN}}{(A+C)(A+B)}. \tag{2}$$

Among them, A is the number of documents with feature t in category c, B is the number of documents with feature t in other categories, C is the number of documents in category c without feature t, and N is the total number of documents in the training set.

3.3. Chi-Square Statistics. The chi-square statistic can be used to test the independence or determine the association between categorical variables. If the value associated with the chi-square statistic is less than a given level, it is determined that the two variables are not independent of each other. Its calculation formula is:

$$x^2 = \frac{N(AC-BC)^2}{(A+C)(B+C)(A+B)}. \tag{3}$$

3.4. Boolean Weights. Boolean weight is a simple weight calculation method, also called binary weight. Its calculation formula is:

$$w_{ij} = \begin{cases} 1, tf_{ij>0} \\ 0, tf_{ij\le 0}. \end{cases} \tag{4}$$

3.5. Characteristic Proportion. Characteristic proportion is:

$$p_{ij} = \frac{t_{ij}}{\sum_{i=1}^{m} t_{ij}}. \tag{5}$$

3.6. Information Entropy. Information entropy is:

$$\begin{aligned} e_j &= -k \sum_{i=1}^{m} p_{ij}, \\ k &= \frac{1}{\ln m}. \end{aligned} \tag{6}$$

3.7. Feature Entropy Weight. Feature entropy weight is:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)}. \tag{7}$$

3.8. Comprehensive Weights. Comprehensive weights are:

$$\beta_j = \frac{\alpha_i w_i}{\sum_{i=1}^{m} \alpha_i w_i}. \tag{8}$$

3.9. Word Frequency. Word frequency is:

$$tf_{ij} = \frac{n_{ij}}{\sum_k n_{kj}}. \tag{9}$$

3.10. Reverse File Frequency. Reverse file frequency is:

$$df_i = \log \frac{|D|}{|(j \in d_j)|}. \tag{10}$$

Among them, $|D|$ is the total number of data in the database.

3.11. Correlation Probability. Correlation probability is:

$$p(d_i, d_q) = \sum \log \frac{p_i(1 - q_i)}{q_i(1 - p_i)}. \tag{11}$$

Among them, f is the total number of training texts, and r is the number of relevant documents in the centralized data query.

3.12. Posterior probability. Posterior probability is:

$$P(C_i|X) = \frac{P(C_i)P(X|C_i)}{P(X)}. \tag{12}$$

Among them, $P(X)$ is a constant for all classes.

3.13. Structural Semantic Entropy. Structural semantic entropy is:

$$E(S) = -\sum_{i=1}^{m} \log(p_i). \tag{13}$$

p_i is the probability of any leaf node.

3.14. Structure Information Entropy. Structure information entropy is:

$$H(X) = -\sum_{i=1}^{n} p(x_i). \tag{14}$$

3.15. Sum of Hyperlinks. Sum of hyperlinks is:

$$R(u) c \sum \frac{R(v)}{N_v}. \tag{15}$$

Among them, $R(u)$ is the hyperlink value of web page u.

3.16. Date Weight. Date weight is:

$$W_t = \frac{C_T D}{T}. \tag{16}$$

Among them, W_t is the date weight of the web page t, C is the search time of the search, and D is a constant.

3.17. Data Mining Algorithms. Data mining algorithms are:

$$E(X) = (1 - c) + c \sum_{i=l}^{n} E(T_i). \tag{17}$$

3.18. Correlation Function. Correlation function is:

$$p_q(j) = \frac{R_q(j)}{\sum_{k \in W} R_q(k)}. \tag{18}$$

W is a collection of web pages for the entire network.

3.19. Similarity. Similarity is:

$$sim(Q, D) = \frac{\sum (U_{iq}, U_{ij})}{\sqrt{\left(\sum U_{iq}^2\right) \times \left(\sum U_{ij}^2\right)}}. \tag{19}$$

4. Music Teaching System

4.1. Questionnaire Method. Questionnaire query analysis is a process in which researchers design the content of surveys and research into questions, then receive answers in the form of questionnaires, and organize and record documents. This article allows students from different schools to experience different music teaching systems, and then asks students and teachers to fill out many relevant questions in the form of questionnaires, so as to obtain the corresponding

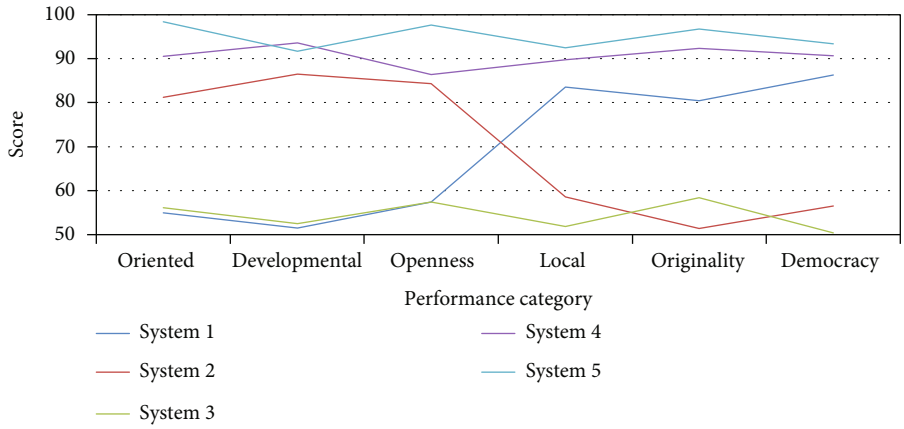

Figure 6: Comparative analysis of performance between different music systems.

results and data, then to facilitate the analysis of the content of this paper.

4.2. Literature Research Method. In order to formulate a music curriculum suitable for students in different regions or different universities, this paper conducts detailed research and specific explanations of relevant documents. In order to better study the music education system, this article has consulted a lot of relevant documents.

4.3. Data Source Method. For the convenience of research, the different colleges and universities are named as school 1, school 2, school 3, and school 4, respectively. The different music education systems are named system 1, system 2, system 3, system 4, and system 5. System 5 is the music education system under the information technology studied in this paper. In order to get specific data, this paper studies and analyzes between different systems.

5. Experiment of Music Teaching System

5.1. Comparative Analysis of Performance between Different Music Systems. Different colleges and universities use different music systems, and these different music education and teaching systems also have different performances, which also determines that different music systems have their own usage restrictions. In order to conduct a detailed study of the application of information technology in the music education system, this paper compares and analyzes the performance of different music systems; the specific data is shown in Figure 6.

As can be seen from Figure 6, the music education system is mainly compared from six aspects: orientation, development, openness, locality, originality, and democracy. In terms of orientation, system 1 and system 3 scored in the 50-60 range. Compared with other systems, the orientation of these two systems is relatively low, indicating that these two systems cannot provide orientation services for students well. In terms of development, the score value of system 4 is about 2 points higher than that of system 5, indicating that the development of system 4 is better than that of system 5. In terms of openness, the scores of system 2, system 4, and system 5 are higher than those of the other two systems, indicating that these three systems not only provide teaching services for music majors but also provide services for music and nonmusic majors. In terms of locality, the scores of system 2 and system 3 are at least 20 points lower than the other three systems, indicating that these two systems have few local characteristics and are less inclusive of music. In terms of originality, the scores of system 1, system 4, and system 5 are all above 80 points, indicating that the innovation degree of these three systems is relatively low, and they are more inclined to the traditional model. In terms of democracy, the score value of system 2 is higher than that of system 3, indicating that system 2 can allow users to make changes and suggestions within a relatively small range. On the whole, the performance of System 5 is relatively high, but it still needs to be improved in terms of development.

5.2. Comparison of Advantages between Different Systems. Different music education and teaching systems can be used by different colleges and universities, which shows that these music education and teaching systems have unusual advantages. In order to continuously learn from and develop the music teaching system under the Internet information technology, this paper compares and analyzes the advantages of different systems, so as to understand the difference between the music education and teaching system studied in this paper and other systems. Its specific data is shown in Figure 7.

As can be seen from Figure 7, this paper mainly compares and analyzes the advantages between different systems from six aspects: accuracy, stability, compatibility, scalability, code reuse, and convenience. In terms of accuracy, the score values of system 1 and system 3 only fluctuate around 50 points, indicating that the accuracy of the recommended music teaching of these two systems is lower than that of the other three systems. In terms of stability, the scores of system 2, system 4, and system 5 are relatively high compared to the other two systems, indicating that these three systems are not prone to problems during the use of music majors in colleges and universities and can ensure their stable development. In terms of compatibility, the scores of system 3 and

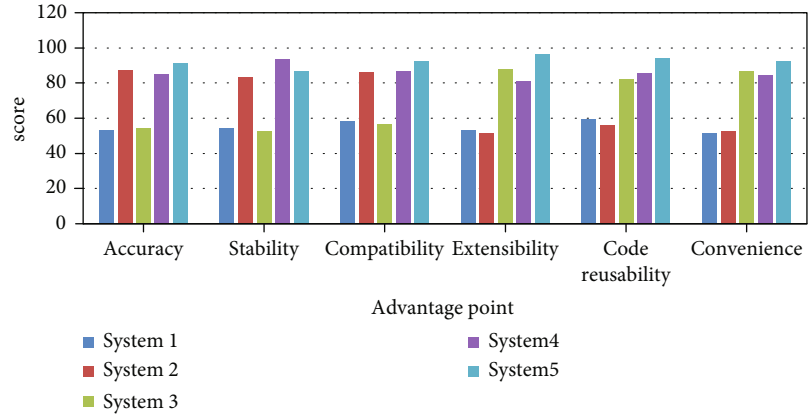

Figure 7: Comparison of advantages between different systems.

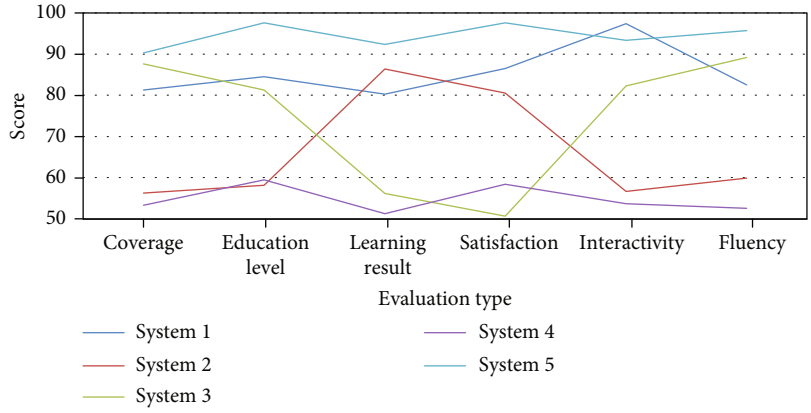

Figure 8: Students' evaluation of different systems.

system 5 are between 80 and 90 points, which is about 20 points higher than that of system 1 and system 3, indicating that these two systems can allow multiple types of music at the same time. In terms of scalability, the scores of System 3 and system 5 are relatively high compared to other music education and teaching systems, indicating that these two systems can continuously expand music types during use. In terms of code reusability and convenience, the scores of system 1 and system 2 are the lowest among all systems, indicating that these two systems have relatively low practical significance and are not suitable for large-scale use. On the whole, system 5 has outstanding advantages in all education systems.

5.3. Students' Evaluation of Different Systems. The music education system is used by music teachers to teach students about music; the main body of the music teaching system is the students. Therefore, in order to continuously promote the continuous development of the music education and teaching system in colleges and universities, it is necessary to understand the students' evaluation of the use of the system. In order to conduct a detailed study of the college music system under the information technology, the students' evaluation of different systems was first studied. The specific data is shown in Figure 8.

It can be seen from Figure 8 that students who use the music education teaching system in colleges and universities evaluate different systems from six aspects: coverage, educational level, learning effect, satisfaction, interactivity, and fluency. In terms of coverage, the scores of system 2 and system 4 are the lowest among all systems, with an average of only about 55 points, indicating that the coverage of students in these two systems is relatively low and cannot be popularized to students outside the music major. In terms of education level, the scores of system 1, system 3, and system 5 are much higher than the other two systems, indicating that these three systems include different levels of music education to a large extent. In terms of learning effect, the scores of system 3 and system 4 are relatively low, only about 60 points, indicating that students can obtain less learning results in this system. In terms of satisfaction, the scores of system 1 and system 5 are relatively high, indicating that students' satisfaction with these two systems is relatively high. In terms of interactivity, the scores of system 2 and system 3 are at least about 30 points lower than the other three systems, indicating that students do not have in-depth communication with teachers in these two systems. In terms of fluency, the scores of system 1, system 4, and system 5 are relatively high among all educational systems, indicating that students are difficult to encounter the phenomenon of

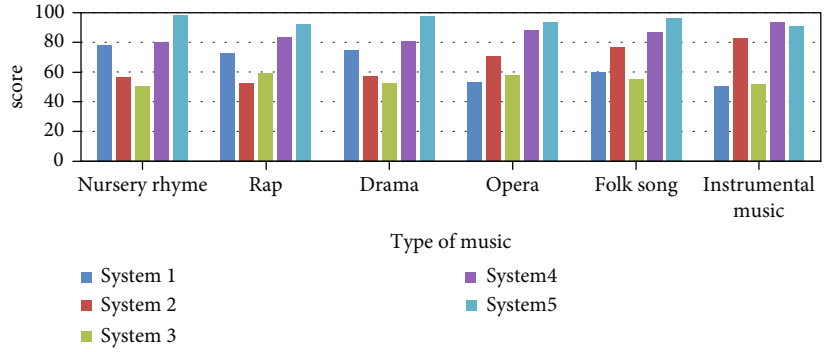

Figure 9: Teaching effects of different systems on different music.

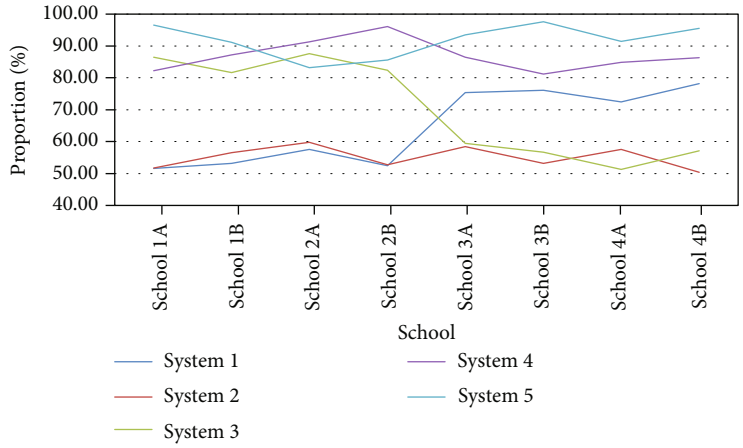

Figure 10: Learning efficiency of different students in different systems.

lag when using these three systems. Overall, system 5 is rated the highest, but not as interactive as system 1.

5.4. The Teaching Effect of Different Systems on Different Music. The most fundamental purpose of the music education system is to create and use the different types of music knowledge to the students. However, because teachers have different teaching effects on different music teaching systems in different music teaching systems, in this paper, the purpose of researching the teaching effect of different systems on different music is to continuously improve and develop the music system in colleges and universities studied in this paper. The specific data are shown in Figure 9.

As can be seen from Figure 9, the types of music mainly include six aspects: nursery rhymes, rap, opera, opera, folk songs, and instrumental music. From the perspective of nursery rhymes, the scores of system 2 and system 3 are relatively low, indicating that nursery rhyme music is not suitable for teaching in these two systems. In terms of rap, the scores of system 1, system 4, and system 5 are relatively high among all teaching systems, indicating that rap-type music is more suitable for teaching in these three systems. In terms of opera, the scores of system 2, system 4, and system 5 are relatively high compared to other systems, indicating that the teaching effect of opera-type music is better in these three systems. In terms of folk songs, the scores of system 1 and system 3 are the lowest among all systems, indicating that folk songs are not suitable for teaching in these two systems. In terms of instrumental music, the score value of system 4 is higher than that of system 5, indicating that the teaching effect of instrumental music on system 4 is better than that of system 5. On the whole, various types of music can obtain good teaching effect on the system 5 and enhance the effect of music teaching.

5.5. Learning Efficiency of Different Students in Different Systems. Judging whether a music education system is excellent depends on whether the system provides good services for teachers and students. In this paper, the purpose of in-depth research on the learning efficiency of different students in different systems is to judge whether it is correct to apply Internet information technology to college education and teaching systems. The specific data is shown in Figure 10.

As can be seen from Figure 10, this paper names students from different schools, including professional music students and nonmajor students, as class A and class B, respectively. In school 1, the learning efficiency of class A students in system 1 and system 2 is the lowest, only about half of the normal learning efficiency, indicating that these two systems are not suitable for class A students to study music; the learning efficiency of class B students in system

3, system 4, and system 5 is the highest among all systems, indicating that students can gain a lot of music knowledge in these three systems. In school 2, the learning efficiency of class A students and class B students in system 1 and system 2 is the lowest, only about 52%. The learning efficiency of these two types of students in system 3, system 4, and system 5 is the highest among all music teaching systems, indicating that students in school 2 are more suitable for using system 3, system 4, and system 5 for music learning. In school 3, the learning efficiency of class A and class B students in system 2 and system 3 is relatively low compared to other teaching systems, indicating that the A and B students of this school are more suitable for learning music in the system 1, system 4, and system 5. In school 4, the learning effect of A and B students in system 1 is much higher than that of system 2 and system 3, but far lower than the learning efficiency in system 4 and system 5, indicating that system 1 can enhance the learning effect of students in this school to a certain extent. On the whole, the learning efficiency of different students in different colleges and universities in system 5 is much higher than that of other music education systems, indicating that system 5 is a system that is more in line with the current needs of college music education.

6. Experiment Results of Music Teaching System

With the continuous improvement of humanistic quality, music education has become the focus of attention. The music education system has also become an important tool for music teaching in most schools in recent years, but there are still various problems in the music education and teaching system used by most colleges and universities at present. The purpose of this paper is to study the use of information technology in the music education system in detail to avoid these problems and make the development of music education to a higher level.

(1) The performance of different music systems is compared and analyzed. The research results show that the two systems are system 1 and system 3, which cannot provide guidance services for students very well. System 4 is well developed and has great prospects for development. The openness score of system 2, system 4, and system 5 is the highest among all music teaching systems and can provide services for all students who want to learn music. Both system 2 and system 3 lack multiple types of music in the service for students. System 1, system 4, and system 5 are relatively low in originality and are easily eliminated during use. On the whole, the performance of system 5 is relatively high in all aspects except for development

(2) The advantages between different music system systems are compared and analyzed. The results of the study show that the accuracy of system 1 and system 3 is relatively low, because their score values only fluctuate around 50 points. The stability of system 2, system 4 and system 5 is relatively high among all systems, which can ensure the stable development of school music education. The compatibility of system 3 and system 5 is relatively high, allowing multiple types of music to be taught simultaneously. System 3 and system 5 have high scalability evaluation and can continue to develop to meet the school's music requirements. On the whole, the advantages of system 5 are very prominent

(3) Students' evaluations of different systems are researched and analyzed. The research results show that in terms of coverage, system 2 and system 4 cannot be popularized to students outside the music major, and the coverage rate of students is relatively low. System 1, system 3, and system 5 include different levels of music education to a large extent, so that students of all levels can learn music knowledge in these systems. The learning outcomes that students get in system 3 and system 4 are less, because the grades of these two systems are relatively low. Students cannot get in-depth communication with teachers in the two systems of system 2 and system 3. On the whole, the students' evaluation of system 5 is the highest, indicating that system 5 has great use value

(4) The teaching effect of different systems on different music was researched and analyzed. The research results show that the system 2 and system 3 are not suitable for the teaching of nursery rhyme type music; the students are more suitable for the rap-type music learning in system 1, system 4, and system 5. In system 2 and system 3, the effect of opera teaching is relatively poor; when students learn opera and folk music in system 1 and system 3, the learning effect is relatively poor. On the whole, various types of music can obtain good teaching effect on the system 5

(5) A study was conducted on the learning efficiency of different students in different systems. The results of the study show that school 1, system 1, and system 2 are not very suitable for A and B students to study music. In school 2, A and B students are more suitable to use system 3, system 4, and system 5 to study music. In school 3, students of class A and class B are more suitable for learning music in system 1, system 4, and system 5. In school 4, A and B students can improve their learning efficiency in system 1. Overall, system 5 is a system suitable for music education in all schools

7. Conclusion

The music education system is a system used by most schools for music education, but the use of music systems in different schools is different. However, the current music education systems used by various schools have their own

defects, which are not suitable for the long-term and stable use of music education. The purpose of this paper to introduce information technology into the music education system is to solve this problem. In addition, the relevant knowledge and functional technology of the online education system are mainly used in the system research, and the management of the relevant knowledge and work technology of the online network teaching system is understood. In order to obtain specific data, this paper investigates many teaching-related institutions and conducts a questionnaire survey on some teachers and students in different universities to determine the main research content and then go to the library to learn relevant knowledge and obtain materials on the Internet. Then, by going to the library to learn relevant knowledge and obtaining materials on the Internet, finally, there is a deep understanding of the current school teaching system, especially the online music teaching system. The music education system under information technology is a system that combines the needs of the current school music curriculum. Its systematic research is beneficial to enhance the interaction between teachers and students and can also provide various functions and services for network teaching. Of course, there are still some shortcomings in this article, which will be improved and developed continuously in the future development process.

Data Availability

No data were used to support this study.

Conflicts of Interest

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

References

[1] F. Sang and Y. Xu, "Research on the current situation and improvement strategies of aesthetic education in music classrooms in primary and secondary schools in China," *Modern Economics & Management Forum*, vol. 3, no. 1, pp. 14–19, 2022.

[2] Z. Zhang and H. Min, "Analysis on the construction of personalized physical education teaching system based on a cloud computing platform," *Wireless Communications and Mobile Computing*, vol. 2020, Article ID 8854811, 8 pages, 2020.

[3] C. H. N. Gaobin and Z. Z. Liu, "An artificial intelligence fuzzy system for improvement of physical education teaching method," *Journal of Intelligent Fuzzy Systems*, vol. 40, no. 2, pp. 3595–3604, 2021.

[4] W. Juhe and W. Zhibin, "Research on college physical education teaching mode based on multimedia teaching system," *Agro Food Industry Hi-Tech*, vol. 28, no. 1, pp. 353–356, 2017.

[5] W. Zhang, "Research on the reform of college physical education teaching system based on lifelong sport education," *Revista de la Facultad de Ingenieria*, vol. 32, no. 9, pp. 610–616, 2017.

[6] J. Artes, F. Pedraja-Chaparro, and M. D. M. Salinas-Jimenez, "Research performance and teaching quality in the Spanish higher education system: evidence from a medium-sized university," *Research Policy*, vol. 46, no. 1, pp. 19–29, 2017.

[7] X. Xie, "An optimization method for physical education teaching evaluation system analysis and intelligent assessment system design," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 16, pp. 62–67, 2017.

[8] S. S. Braga, "Internet and representative institutions in Brazil: information technology in Brazilian houses of representatives," *American Physical Education Review*, vol. 8, no. 2, pp. 101-102, 2018.

[9] N. Sun, T. Li, G. Song, and H. Xia, "Network security technology of intelligent information terminal based on mobile Internet of Things," *Mobile Information Systems*, vol. 2021, Article ID 6676946, 9 pages, 2021.

[10] J. Pan, "An advanced mode analysis for spread and development of national traditional sports based on internet information technology," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 18, pp. 420–425, 2017.

[11] A. Kaban, "Secure internet use in information technologies and software course textbooks at primary and secondary schools," *Athens Journal of Education*, vol. 8, no. 1, pp. 37–52, 2020.

[12] A. Ayough, A. Alemtabriz, and M. Tavanaei, "Investigating the impact of technological distinctive competencies and information technology capabilities on internet entrepreneurship by means of innovation capability," *AMC Indian Journal of Entrepreneurship*, vol. 3, no. 1, pp. 27–41, 2020.

[13] L. Silajdi and A. Dudi, "Youth and addiction to information and communications technology: internet, social networks and mobile phones," *CM Communication and Media*, vol. 15, no. 47, pp. 57–84, 2020.

[14] D. Bajrami, A. Iseni, and A. Topko, "Subversion -the secret power of the message enlaced with the power of the internet and information technology," *Khazar Journal of Humanities and Social Sciences*, vol. 22, no. 3, pp. 60–70, 2019.

[15] B. Ray, "Designing hybrid energy storage systems: a tool for teaching system-level modeling and simulation," *Journal of Engineering Technology*, vol. 34, no. 1, pp. 18–27, 2017.

[16] M. Milovanović and G. Medić-Simić, "Aesthetical criterion in art and science," *Neural Computing and Applications*, vol. 33, no. 6, pp. 2137–2156, 2021.

[17] M. Radovan and N. Kristl, "Acceptance of technology and its impact on teachers' activities in virtual classroom: integrating UTAUT and CoI into a combined model," *The Turkish Online Journal of Educational Technology*, vol. 16, no. 3, pp. 11–22, 2017.

[18] M. Zareapoor, P. Shamsolmoali, D. K. Jain, H. Wang, and J. Yang, "Kernelized support vector machine with deep learning: an efficient approach for extreme multiclass dataset," *Pattern Recognition Letters*, vol. 115, pp. 4–13, 2018.

[19] S. M. Truman and P. J. Truman, "An investigation of the situated learnability effects of single- and dual-modal systems in education: a report of music-oriented learning environment and science computer-assisted teaching studies," *British Journal of Educational Technology*, vol. 37, no. 1, pp. 131–142, 2006.

[20] A. A. Frolov, D. Husek, and P. Y. Polyakov, "Comparison of seven methods for Boolean factor analysis and their evaluation by information gain," *IEEE Transactions on Neural Networks and Learning Systems*, vol. 27, no. 3, pp. 538–550, 2016.

[21] Z. Wang and D. Lyu, "Design and realization of a fuzzy comprehensive evaluation system for music teaching in higher education," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 22, pp. 59–72, 2021.

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Retraction

Retracted: Exploration of Regional Public Digital Culture Service Mode Based on Artificial Intelligence Technology

Wireless Communications and Mobile Computing

Received 31 October 2023; Accepted 31 October 2023; Published 1 November 2023

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

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

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

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

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

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

References

[1] Q. Yin and Y. Dong, "Exploration of Regional Public Digital Culture Service Mode Based on Artificial Intelligence Technology," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 1852502, 11 pages, 2022.

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Research Article

Exploration of Regional Public Digital Culture Service Mode Based on Artificial Intelligence Technology

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In order to improve the development of China's public cultural service supply field, this paper introduces the public culture of weather services with the support of network intelligence services and smart devices. This article examines the purpose of public cultural cloud services to identify current public service public culture and future development models; The results show that the average consistency indexes determined by the weight of evaluation indexes based on AHP are 0, 0, 0.514, 0.894, 1.118, 1.248, 1.344, 1.421, and 1.461, respectively. Their importance order is judged according to the degree of relative importance. According to the hierarchy and diversity of users' needs, a "multiple" development model of public digital culture cloud service is constructed. This data provides a measure of resistance to innovations in public cloud culture, data advocacy to support public climate change in four areas: the reform of service strategies, the integration of public culture, the development of specialized resources, and the development of service teams and customer capabilities.

1. Introduction

In recent years, China's public service culture has been constantly improving, and the overall level of China's public service culture has been increasing, including government policies and the involvement of relations. At the same time, the development of information technology and the use of technology have provided strong support to improve public service ethics. The concept of developing a smart city based on intelligent technology is the goal of research in China's public service culture. The emergence of the concept of smart city has a direct impact on the provision of public service culture in China in terms of technology, citizenship, organization, and governance. At the same time, it promotes innovation and improvement of public digital culture standards. The rapid development of science, technology, and information technology not only promotes the improvement of all segments of the human race but also promotes the rapid development of public service culture. Over the past two years, China has increased its resources in public service culture. Digital cultural services, an important type of public cultural services, also face many challenges in the current development environment, such as the distribution of relative digital resources and without the involvement of civil society organizations. These issues have a significant impact on the quality of public digital culture services, resulting in poor resource utilization and poor public services. The emergence of information technology based on cloud computing and the mass media network provides further support for improving the consensus of allocating funds to public cultures [1]. Based on this, we hope to support key technologies as network services, starting with the concept, features, and needs of digital cloud services to the public, and promote the improvement of the health of public culture with artificial intelligence technology.

2. Literature Review

Tang and others believe that big data has an impact on library information consulting services, mainly in data storage, data processing, information security, big data concept, and talent [2]; Li and others believe that information retrieval efficiency is the key to the effect of information service. Only by providing a certain retrieval efficiency can the

library meet the needs of users. However, the real collection and virtual collection together constitute the scale of big data, and meeting the needs of users is an arduous task [3]. Based on the analysis of the characteristics of information in the era of big data and the changes in readers' needs, Liu and others believe that the traditional service mode of the library has been impacted and put forward suggestions on building a cloud service platform, building a mobile library, using new technologies to carry out information services, and analyzing library services with big data to create a new mode of library information services [4]; Ding and others believe that big data has prompted readers to have personalized needs [5].

Yuan and others studied and constructed the intelligent service mode of regional sharing platform by analyzing the intelligent service cycle mechanism, intelligent service system module composition, and intelligent service type of sharing platform, including system intelligent service and expert team support service [6]. By analyzing the development law of regional science and technology resource sharing platform, Leguina and others revealed the innovation mechanism of service mode of regional science and technology resource sharing platform. On this basis, they designed the resource leading mode of regional sharing platform, the demand traction mode of regional sharing platform, and the intelligent service mode of regional sharing platform [7]; Cui and others took the construction of science and technology literature and information resources in Western Hunan as the starting point, found out the restrictive factors of coconstruction and sharing of science and technology literature and information resources in Western Hunan through investigation, and constructed the information service mode of coconstruction and sharing of science and technology literature and information resources in Western Hunan [8]. By analyzing the innovation activities of strategic emerging industry clusters in different innovation stages, Remencová and others constructed the standardization and integration mode of regional sharing platform o2o service. Based on the analysis of the factors restricting resource sharing, such as the blocked channels of scientific and technological resource sharing and the vacancy of macro harmonious management, this paper puts forward the service mode of "principal-agent," which solves the problem of closure and blockade of scientific and technological resource sharing [9].

In terms of the research on the public cultural service system, Wu and others summarized the evolution process of the development of Chinese public culture, analyzed in detail the changes of the organizational system of public cultural institutions, and believed that the organizational system of Chinese public cultural services is gradually evolving into the mode of coordinated development of the government, public cultural institutions, and the third party [10]; Qu and others studied the important role of free opening in the development of national public cultural services and believed that free opening will be the main direction of the development of public cultural services [11]; Chen and others selected several western countries with characteristics to analyze the evolution process of these countries in terms of service system, the service responsibilities of governments and cultural institutions, and the guarantee mechanism implemented by these countries in promoting the development of public cultural services [12].

Liu and others' representative views on the integration of public digital cultural resources mainly include pointing out that public cultural institutions should carry out service activities according to the needs of users, provide users with a resource environment covering various knowledge fields, and effectively attract new users through joint construction and sharing among institutions [13]; Wang proposed that search engines should arrange and combine public digital cultural resources according to users' retrieval information to provide resources and services that best meet users' needs [14]. Santiago pointed out in cloud storage research that cloud storage has surpassed physical media to become a dominant means of communication and a way to share digital content, and its advantages in music, documents, photos, and videos are more obvious [15].

According to the present research, this paper describes the meaning and status of public cloud culture. This paper examines the motivation for innovation in public digital cloud services from four perspectives: political, business, social, scientific, and technological, and examines the demand for public digital weather services. Based on the definitions of cloud service and cloud manufacturing service, combined with the characteristics of public digital culture service, this paper interprets the new connotation and characteristics of public digital culture cloud service and studies the architecture of public digital culture cloud service innovation. This paper studies the constituent elements of public digital culture cloud service system from five aspects: service participants, service concept, service resources and service content, service mode, service support technology, and means, constructs the structure of public digital culture cloud service system, and analyzes the system structure and function. From the perspective of optimal allocation of public digital culture cloud resources, this paper analyzes the innovation process of public digital culture cloud services in four aspects: cloud resource standardization, cloud resource integration, cloud resource combination optimization, and cloud service innovation, and constructs a "multiple" development model of public digital culture cloud services. Based on the collection of typical cases of public digital culture service model, this paper summarizes the characteristics of the existing service model.

3. Artificial Intelligence Semantic Network Service and Intelligent Key Technology

3.1. Introduction to Web Services. Openness is one of the development trends of network services. Only through open interfaces can different types of services interoperate or access each other. Therefore, the semantic web service in this paper adopts service-oriented architecture mode, and web service technology is the main implementation technology of service-oriented architecture mode. The semantic web service in this paper exists in the form of web service. The difference between semantic web service and traditional web service is that semantic web service is a web service

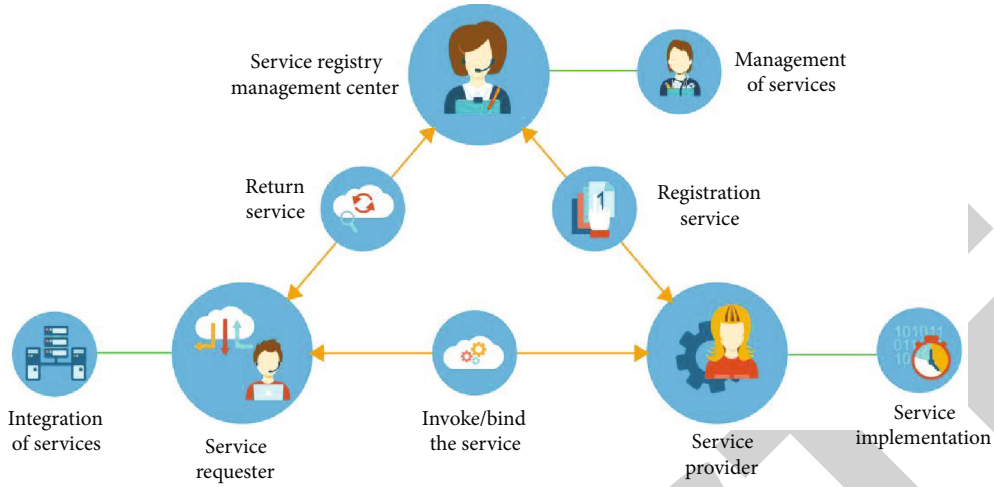

Figure 1: Schematic diagram of service-oriented architecture.

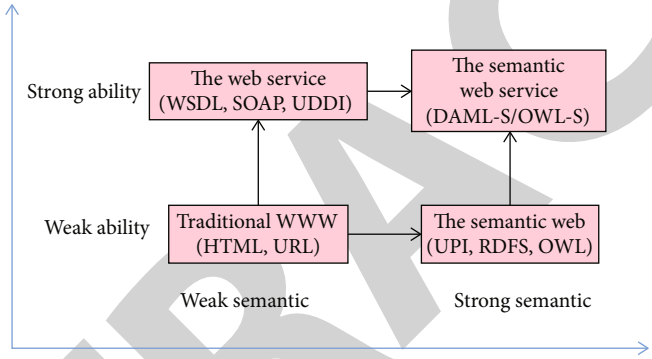

Figure 2: Development trend of traditional WWW and web services.

Table 1: Differences between web services and semantic web services.

Comparison item	Web	Semantic web services
Service	Ordinary	Complex
Service description	Based on vocabulary	Based on ontology
Data exchange	Based on grammar	Based on semantics

represented by ontology. Web service is the basic unit of semantic web service. This paper adopts the service architecture mode shown in Figure 1 [16, 17].

The service provider provides three kinds of functions: service request, service provider registration, and service provider management. The service requester goes to the service registration management center to find the corresponding service according to the service request description information, and then, the service description information obtained through service discovery is bound to the specific service provider. The service requester will be responsible for the integration of various services.

3.2. Semantic Web Services and OWL-S Language

3.2.1. Semantic Web Services. The proposal of the concept makes a new research trend in the field of web services. The service integrating semantic technology, namely, semantic web service, is different from traditional web service. Semantic web service is a web service that exists completely in the form of ontology. It is an ontology about services. It has clear semantics that can be understood by machines. It allows users or software agents to automatically locate, select, use, combine, and monitor web-based services and can use software agents for analysis and identification. It will promote the interoperability of network services to the direction of intelligence, so as to provide a technical guarantee for the seamless integration of self-organizing and intelligent services. Semantic web services are the future development trend of web services, as shown in Figure 2.

At the same time, this paper also compares the differences between web services and semantic web services, as shown in Table 1.

3.2.2. Semantic Web Service Description Language OWL-S. In order to meet the above tasks, OWL-S gives a set of ontologies to describe semantic web services, through which semantic web services can be understood by machines. OWL-S consists of three parts, as shown in Figure 3.

The properties of Prifile can be divided into two categories: functional properties and nonfunctional properties. The functional attributes of a service include the input and

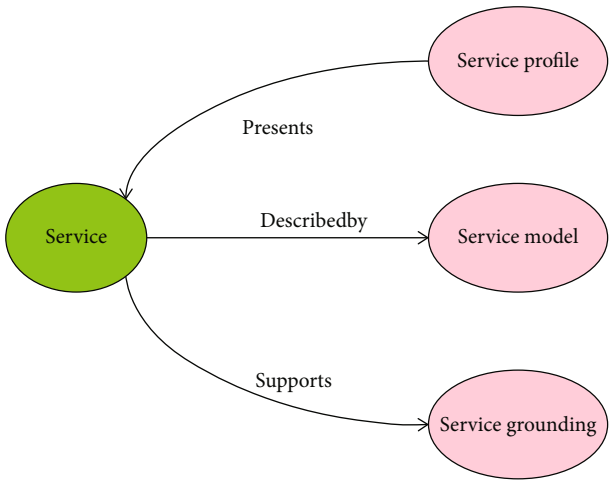

Figure 3: OWL-S top-level service ontology structure.

output of the service, the preconditions for service execution, and the expected effect of service execution. Nonfunctional attributes are a set of attributes used to describe the characteristics of the service, including the type of service, the provider information of the service, and the service quality. A list of service parameters with unlimited length. It can contain any type of information, which may include the maximum response time of the service and the location and availability of the service.

3.3. Definition of Semantic Web Services. Firstly, we give the mathematical model of network service. The process of associating semantic web services with OWL-S is to establish the relationship between semantic web services [18].

3.3.1. Define Service Model NS. The network service model NS is an abstraction of various network services, which can be expressed as

$$\mathrm{NS} = \{\mathrm{NF}, \mathrm{PuF}, \mathrm{PrF}\}, \tag{1}$$

where

$$\mathrm{NF} = \{\mathrm{NFI}, \mathrm{NFO}, \mathrm{NFP}, \mathrm{NFE}\}. \tag{2}$$

The above formula is a collection, indicating that the functions of network services belong to win. Functional attributes refer to the attributes closely related to the realization of network service functions. The most commonly used are the input and output of services and the execution results of preconditions [19, 20].

$$\mathrm{PuF} = \{\mathrm{NSC}, \mathrm{NSN}, \mathrm{NSP}\}. \tag{3}$$

The common characteristics of some public services on the network [21]

$$\mathrm{PrF} = \{\mathrm{SY}, \mathrm{SCh}, \mathrm{SNW}, \mathrm{SQoS}\}. \tag{4}$$

The above formula is a set, which represents the private characteristics of network services. Private characteristics refer to the characteristics closely related to the network, such as service terminal, network system, and billing mode [22].

3.3.2. A Mathematical Model Describing the Specification OWL-S. The service class in OWL-S is used to represent a service. Specifically, a complete service is described from three perspectives through service profile class, service model class, and service grounding class. However, in practical application, OWL-S can be expressed as

$$\mathrm{OWLS} = \{\mathrm{Profile}, \mathrm{Process}, \mathrm{Grounding}\}. \tag{5}$$

The semantics of web services is to use ontology-based semantic description specification OWL-S to represent existing web services and introduce semantic information into web services [23]. From the perspective of set mapping, semantic representation is to establish a mapping H between sets NS and OWL-S:

$$H = \left\{h | x \underset{\longrightarrow}{h} y, \forall x \in \mathrm{NS}, \exists y \in \mathrm{OWLS}\right\}. \tag{6}$$

H makes any element x in the set NS correspond to at least one element y in the set OWL-S, so as to accurately describe the network service [24].

The mapping between combined NS and OWL-S is as follows:

$$H_1 = \left\{h_1 | \mathrm{NF} \underset{\longrightarrow}{h_1} \mathrm{FA}, \mathrm{NF} \subset \mathrm{NS}, \mathrm{FA} \subset \mathrm{Profile}\right\}. \tag{7}$$

The functional attributes of the network service can be described by the functional attributes of the profile class of OWL-S. There are the following mappings:

$$H_2 = \left\{h_2 | \mathrm{NF} \underset{\longrightarrow}{h_2} \mathrm{Process}, \mathrm{NF} \subset \mathrm{NS}, \mathrm{Process} \subset \mathrm{OWLS}\right\}. \tag{8}$$

That is, the public characteristics of network services can be described by the nonfunctional attributes of profile class.

This paper extends OWL-S by adding new attributes to the profile class. The mathematical model of the new profile is

$$\mathrm{NP} = \{\mathrm{FA}, \mathrm{NFA}\}, \tag{9}$$

where

$$\mathrm{NFA} = \{\mathrm{SC}, \mathrm{SN}, \mathrm{SP}, \mathrm{PrD}\}, \tag{10}$$

$$\mathrm{PrD} = \{\mathrm{STD}, \mathrm{SChD}, \mathrm{SNWD}, \mathrm{SQoSD}\}. \tag{11}$$

It can be seen from formulas (10) and (11) that by adding private feature description PrD in the nonfunctional attribute NFA of OWL-S, that is, terminal, network billing, network information, QoS, and other information, the existing OWL-S can support the features in network services, so as to achieve the purpose of accurately

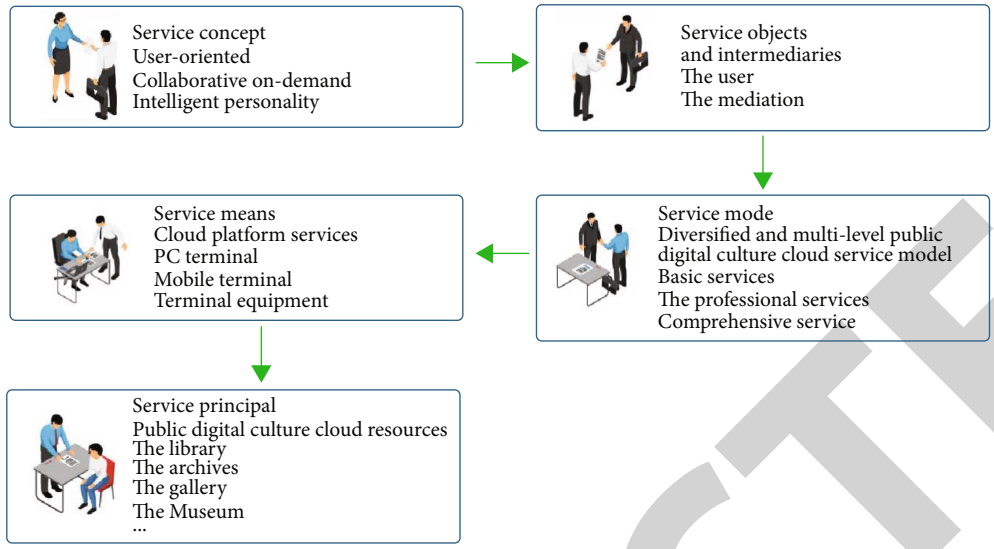

Figure 4: Public digital culture cloud service system structure.

describing network services. In practical application, the private characteristics of network services can continue to increase according to specific conditions.

3.4. Heuristic Semantic Web Services Based on Iteration. In this paper, the service type attribute SCS is separated from the nonfunctional attribute because the service type has a great impact on service discovery. If the service type matching degree is low, it is unlikely to eventually become a service that meets the requirements. This leads to

$$\mathrm{MS} = \begin{pmatrix} \mathrm{SCS}_1 & \cdots & \mathrm{SCS}_n \\ \mathrm{FAS}_1 & \cdots & \mathrm{FAS}_n \\ \mathrm{NFAS}_1 & \cdots & \mathrm{NFAS}_n \end{pmatrix}. \tag{12}$$

Also, due to

$$\mathrm{MS} = \begin{pmatrix} \mathrm{SCS} \\ \mathrm{FAS} \\ \mathrm{NFAS} \end{pmatrix} = \begin{pmatrix} \mathrm{SCS}_1 & \cdots & \mathrm{SCS}_n \\ \mathrm{FAS}_1 & \cdots & \mathrm{FAS}_n \\ \mathrm{NFAS}_1 & \cdots & \mathrm{NFAS}_n \end{pmatrix}, \tag{13}$$

where

$$\begin{aligned} \mathrm{SCS} &= (\mathrm{SCS}_1, \mathrm{SCS}_2, \cdots, \mathrm{SCS}_n), \\ \mathrm{FAS} &= (\mathrm{FAS}_1, \mathrm{FAS}_2, \cdots, \mathrm{FAS}_n), \\ \mathrm{NFAS} &= (\mathrm{NFAS}_1, \mathrm{NFAS}_2, \cdots, \mathrm{NFAS}_n). \end{aligned} \tag{14}$$

It can be seen from the above that the matching space MS can be divided into three subspaces: service type subspace (SCS), functional attribute subspace (FAS), and nonfunctional attribute subspace (NFAS). The discovery algorithm proposed in this paper is based on these three subspaces; that is, the discovery problem in the whole matching space is decomposed into the discovery problem in three subspaces. In addition, when calculating the value of the heuristic function, we need to consider not only the similar value for the current sub-subspace but also the similar value for the previous sub-subspace. This is because if the similar value of the subsite is too small, the similar value for the next subsite will be lower; for example, in the service contract, we only consider the approximate value of the current sub-subspace, the effect of the degree of adjustment of the previous subspace on the degree of adjustment of the current subspace.

Therefore, the expression of the heuristic function based on iteration is as follows:

$$f_{\mathrm{AS}_i}(t) = \frac{\mathrm{sgn}\left[\prod_{k=1}^{n} \mathrm{match}_{(k)}(\mathrm{RS}, \mathrm{AS}_i) - t\right] + 1}{2}, \tag{15}$$

where

$$n = \{0, 1, 2\}. \tag{16}$$

The above formula represents three subspaces, respectively. $\mathrm{match}_{(k)}(\mathrm{RS}, \mathrm{AS}_i)$ is defined as the matching degree of requesting service and publishing service. The interval $[t, 1]$ is called the matching interval, and t is the lower bound of the interval $[t, 1]$. Heuristic function is the focus of this chapter. Through heuristic function, the services that do not meet the requirements cannot enter the next matching space, reduce the number of services participating in matching, and improve the efficiency of service discovery.

4. Construction of Regional Public Digital Culture Service Model

4.1. Structure of Public Digital Culture Cloud Service System

4.1.1. System Architecture. Through the analysis of the constituent elements of the public digital culture cloud service

Table 2: Digital resources of major public cultural institutions.

Organization type	Library	Museum	Archives center	Art gallery
Mechanism function	Collect, sort out, and collect books and periodicals for reading and reference	Solicit, collect, display, and study objects representing natural and human cultural heritage	Collect and keep archives and be responsible for receiving, collecting, managing, and utilizing archives	Preserve and display works of art
Resource type	Books, periodicals, pictures, web pages, videos, etc.	Images, calligraphy and painting works, sculptures, videos, static 3D, live 3D, etc.	Text, video, pictures, etc.	Text, pictures, dynamic artistic activities, etc.
Metadata format	Marc, XML, DC, RDF, etc.	CDWA, DC, VRA, CIMI, RDA, etc.	EAD, EAC, TEI, etc.	NAMO CDOI, etc.

Table 3: Relative importance level.

Serial number	Degree of importance when comparing with each other	a_{ij} assignment
1	Element i is as important as element j	1
2	Element i is slightly more important than element j	3
3	Element i is obviously more important than element j	5
4	Element i is very important compared with element j	7
5	Element i is extremely important compared with element j	9
6	In the middle of the above level	2, 4, 6, 8

system, this paper designs a schematic structure of the public digital culture cloud service system, as shown in Figure 4.

The service subject of public digital culture cloud service system is composed of public cultural institutions such as libraries, archives, museums, and art galleries. The resources of public cultural institutions are encapsulated through cloud computing technology to form public digital culture cloud resources, realize the unified scheduling of resources and services, and provide resource basis for public cultural institutions to provide on-demand and agile intelligent services. Service means mainly include cloud service platform and various terminal devices.

4.1.2. Basic Functions of the System. Public digital culture cloud service runs through the whole process of resource collection, resource management, and resource service. Combined with the basic functions of public digital culture service, the functions of public digital culture cloud service system mainly include three parts: cloud resource integration and sharing function, cloud service function, and cloud platform management function.

4.1.3. Public Digital Culture Cloud Service Innovation Process. The innovation process of public digital culture cloud service can be seen as a process of driving resources according to user needs to form a shared service chain and realize the optimal allocation of cloud resources and service efficiency. The whole process of optimal allocation of resources or supply-demand matching needs to go through gradual stages such as virtualization, service, and combination optimization and finally realize innovative services. Among them, virtualization refers to the standardized modeling of decentralized and heterogeneous public digital culture cloud resources to form a cloud resource pool, so as to realize the effective aggregation and sharing of resources. Service-oriented refers to the construction of cloud resource service chain based on the aggregation of cloud resources, so as to realize the on-demand matching of cloud resource services. Portfolio optimization refers to using the service portfolio optimization algorithm to select the best cloud service according to the demand attributes of the cloud service demander, so as to improve the matching degree between user needs and public digital cultural resources.

Table 4: Average consistency index.

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.514	0.894	1.118	1.248	1.344	1.421	1.461

4.1.4. Virtual Modeling of Public Digital Culture Cloud Resources. The virtualization modeling of public digital culture cloud resources is the premise and foundation for the standardized description of public digital culture cloud resources and the subsequent sharing and service of cloud resources. Different public cultural institutions have great differences in service content, resource type, metadata format, etc., as shown in Table 2.

On the one hand, it is necessary to effectively integrate the existing public digital cultural resources in the organization by using the existing technical means such as metadata warehousing to facilitate integration and sharing. On the other hand, under the cloud service mode, service providers (service subjects) are no longer limited to public cultural institutions, but also include some organizations and individuals. The public digital culture cloud resources owned

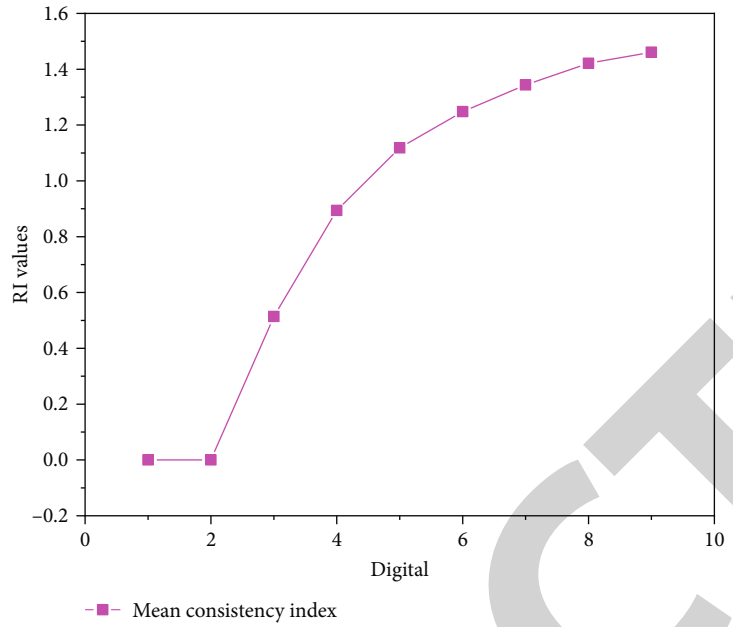

Figure 5: Average consistency index.

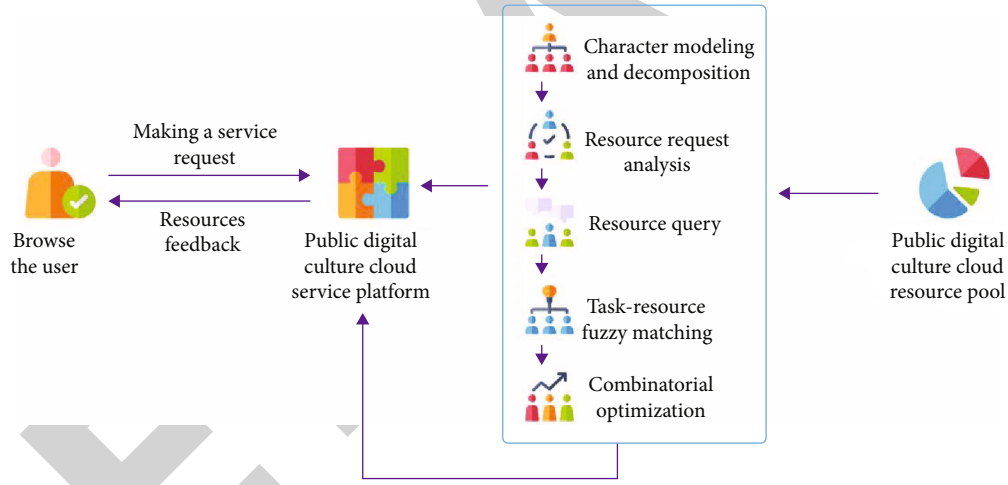

Figure 6: Cloud service model for basic public digital culture needs.

by each service subject have typical characteristics such as distribution, heterogeneity, diversity, autonomy, and mass. Therefore, it is necessary to classify these cloud resources scientifically and reasonably and extract the attribute characteristics of various cloud resources in terms of function, value, and association, so as to build a general multidimensional information description model of cloud resources.

4.2. Regional Public Digital Culture Cloud Service Platform Model

4.2.1. Determination of Evaluation Index Weight Based on AHP. The weight can reflect the relative importance of each evaluation index. There are many methods to determine the index weight of the operation effect of cloud service mode of regional sharing platform. This paper selects analytic hierarchy process to determine the index weight. Analytic hierarchy process transforms the weight judgment of multiple different factors into comparing different factors. This method uses the numbers 1-9 and their reciprocal as the evaluation scale to construct the judgment matrix of pairwise comparison. At the same time, different indexes are compared in pairs, and their importance order is judged according to the degree of relative importance, as shown in Table 3; Table 4 is the average consistency index, and Figure 5 is the discount diagram of average consistency index.

Pass the index consistency test; otherwise, it is necessary to redeploy the original judgment matrix and return to the first step.

4.2.2. Construction of Comprehensive Evaluation Model. When we evaluate something, because its boundary is not

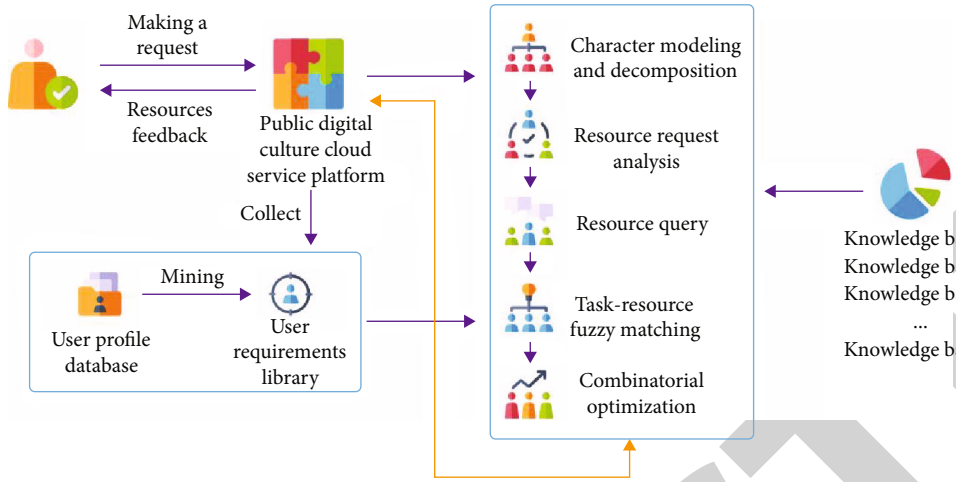

Figure 7: Cloud service model for professional public digital culture needs.

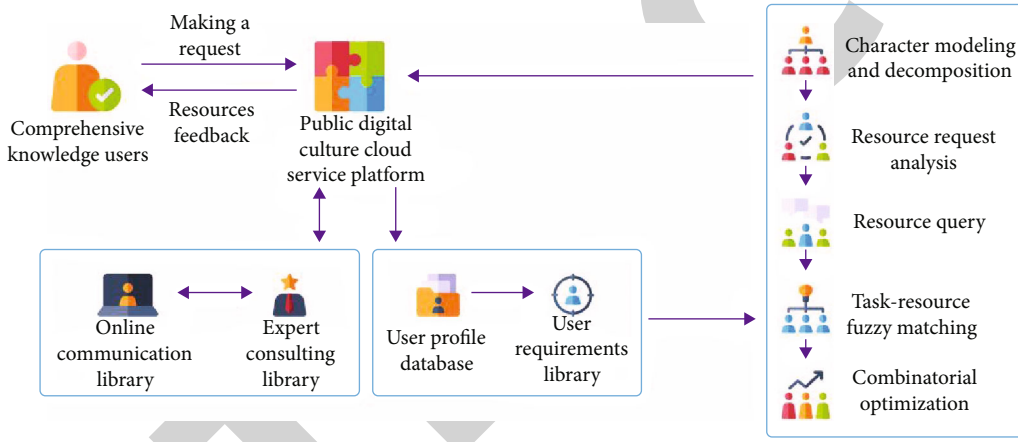

Figure 8: Cloud service model for comprehensive public digital culture needs.

very clear and has a certain fuzziness, it is difficult to give a clear judgment such as "yes" or "no." However, the fuzzy comprehensive evaluation model based on fuzzy mathematics theory can make up for this disadvantage. Therefore, we can implement fuzzy comprehensive evaluation for more complex problems. The fuzzy comprehensive evaluation of the operation effect of the cloud service mode of the regional sharing platform is calculated according to the membership matrix and its weight of the evaluation index, but it is sufficient in the comprehensive evaluation degree and the use of the information of the index evaluation matrix. It is fully reflected in the weight, the degree of comprehensive evaluation, and the use of index evaluation matrix. Firstly, this paper analyzes the influencing factors of the operation effect of cloud service mode of regional sharing platform, including demand integration, resource integration, operation management, and service effect. Based on this, a design model of the cloud-based measurement system was provided, and a cloud-based measurement system was developed. Finally, the weight of the metric was determined by hierarchical analytical procedures, creating an unambiguous measure of the performance of the cloud computing service.

4.3. Construction of "Multiple" Mode of Public Digital Culture Cloud Service

4.3.1. "Multilevel" User Needs of Public Digital Culture Cloud Services. Simple browsing type: the main purpose of this kind of users to obtain public digital cultural resources is to enrich their amateur cultural life. They have no strong desire to learn, but simply browse some learning and entertainment materials, such as public digital cultural news, opera resource library, and multimedia resources. They do not have high requirements for the professionalism of public digital cultural resources and mainly hold the mentality of easy entertainment. They have a wide range of interests and curiosity. They may be interested in any form of public digital cultural resources. Novel public digital cultural resources and diversified communication forms can attract their attention.

Table 5: Summary of digital cloud public service modes.

Service mode	Cloud service model for basic public digital culture needs	Cloud service model for professional public digital culture needs	Cloud service model for comprehensive public digital culture needs
Service object	Simple information browsing users	Specific user groups	Comprehensive knowledge user
Service objectives	Meet basic needs	Meet the needs of learning and tasks	Get diversified solutions
Service resources	Novel and peculiar	Pay attention to professionalism and have a deep range of resources	It emphasizes the collaborative interaction of resources and has a wide range of resources
Service content	Book resources, archives resources, art resources, and other public digital culture cloud resources	User characteristic information base, user demand base, and professional knowledge base	Expert consultation database, online communication database, user characteristic information database, user demand database, and various public digital culture cloud resources
Service mode	Routine service, simple requirements	Professional service and strong pertinence	Comprehensive service and complex process

Professional learning: this is the psychology of most users to use public digital cultural resources. Their purpose of using public digital cultural resources is directly related to their own learning and tasks. Such users pay more attention to the authenticity and originality of public digital cultural resources and have a clear positioning for their public digital cultural needs. They also need to obtain all public digital cultural resources in the target field to meet their learning needs and have an accurate grasp of the public digital cultural resources they want to retrieve with clear goals.

Comprehensive knowledge type: with the development of network technology and the popularization of terminal equipment, users have more and more means to obtain public digital cultural resources. Users' needs are comprehensive and systematic. They want to understand multichannel and multidirectional public digital cultural resources. Such users are often good at a certain field. They need more solutions to problems and require the retrieved public digital culture resources to be concise, complete, accurate, and comprehensive. Their expectations for public digital culture resources are often not limited to the resources themselves, but also include the interaction and communication between experts and peers, and expect the support and help of experts.

4.3.2. "Multiple" Mode of Public Digital Culture Cloud Service Based on User Needs. Cloud service model for basic public digital culture needs: building an open and integrated cloud service model for basic public digital culture needs is a basic service model provided by public digital culture cloud services. The purpose of the service is to ensure the integrated sharing and barrier-free access of public digital culture resources. The service object is users who browse simple information on the Internet. Such users browse public digital cultural resources mainly to meet their basic needs without specific purposes, as shown in Figure 6.

The cloud service model for professional public digital culture needs is mainly for users with specific public digital culture needs. This kind of users' demand for resources has two characteristics: on the one hand, the scope of public digital culture resources required is narrow and targeted; on the other hand, due to the influence of cultural background and learning skills, the resources and services that such users want to obtain are deep and professional. The cloud service model for professional public digital culture needs is shown in Figure 7.

The cloud service model for comprehensive public digital culture needs has two characteristics: on the one hand, the public digital culture resources users want to obtain are the optimal resources optimized by system combination, rather than the raw resources without processing; on the other hand, users not only hope to obtain the most professional public digital cultural resources but also the most comprehensive. It is a comprehensive public digital cultural resource obtained by combining multiple knowledge subjects. The cloud service model for the needs of comprehensive public digital culture is shown in Figure 8.

4.3.3. Summary of Three Service Modes of Public Digital Culture Cloud Service. The cloud service mode for basic public digital culture needs, the cloud service mode for professional public digital culture needs, and the cloud service mode for comprehensive public digital culture needs are three modes of public digital culture cloud services. The development of these three service modes is progressive at all levels. Public cultural institutions should provide public digital culture cloud services in combination with their own actual situation in the construction process. Among them, barrier-free access and sharing of public digital culture resources is the basis for the development of cloud services for basic public digital culture needs, and it is also the premise and guarantee for the realization of the other two cloud service modes. The continuous expansion and deepening of the cloud service model for the needs of professional public digital culture also constitute the cornerstone of the development of the cloud service model for the needs of comprehensive public digital culture. The following summarizes the

above three service modes from the aspects of service objects, service objectives, service resources, service contents, and service methods, as shown in Table 5.

5. Conclusion

The continuous advancement of information and the rapid development of digital technology will not only improve the public service digital culture but also affect the services existing in public culture. New technologies such as cloud computing have provided support to improve public digital culture services and create new models of public weather practices. This article examines the fundamental concepts of digital weather cloud services in three areas: the definition and characteristics of digital weather public service, the new process of public service, digital culture weather, and public services digital culture cloud was planned to strike, rapid innovation of public cloud culture. This article describes the meaning and status of public cloud culture services, examines the motivation for innovation in public digital cloud services through political, economic, social, scientific, and technological, and assesses the needs of the public culture. Based on the definitions of cloud service and cloud manufacturing service, combined with the characteristics of public digital culture service, this paper interprets the new connotation and characteristics of public digital culture cloud service and studies the architecture of public digital culture cloud service innovation. This paper studies the constituent elements of public digital culture cloud service system from five aspects: service participants, service concept, service resources and service content, service mode, service support technology, and means, constructs the structure of public digital culture cloud service system, and analyzes the system structure and function. From the perspective of optimizing the allocation of public digital culture cloud resources, this paper analyzes the innovation process of public digital culture cloud services in four aspects: cloud resource standardization, cloud resource integration, cloud resource combination optimization, and cloud service innovation, and constructs a "multiple" development model of public digital culture cloud services. Based on the collection of typical cases of public digital culture service mode, this paper summarizes the characteristics of the existing service mode and analyzes the goal of public digital culture cloud service in view of the bottleneck of current public digital culture service and future development trend. According to the hierarchy and diversity of users' needs, this paper constructs the "multiple" development model of public digital culture cloud service and puts forward the countermeasures for the innovation of public digital culture cloud service. This paper puts forward the countermeasures to promote the innovation of public digital culture cloud service from four aspects: the innovation of service concept, the integration of public digital culture resources, the construction of characteristic resource database, and the cultivation of service team and user ability.

Data Availability

No data were used to support this study.

Conflicts of Interest

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

References

[1] J. He and X. Yin, "Development mode of internet economy based on artificial intelligence technology," *Journal of Physics: Conference Series*, vol. 1881, no. 2, article 022062, 2021.

[2] J. Tang and L. Hai, "Construction and exploration of an intelligent evaluation system for educational app through artificial intelligence technology," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 16, no. 5, p. 17, 2021.

[3] G. Li, A. Liu, E. T. Kabadayi, N. C. Aksoy, N. Yazici, and A. K. Alan, "Airbnb as a sharing economy-enabled digital service platform: the power of motivational factors and the moderating role of experience," *Tourism Economics*, vol. 28, no. 3, pp. 748–771, 2022.

[4] Y. Liu, Z. Wang, Y. Pan, and Y. Zuo, "Research on intelligent monitoring and early warning of electric power safety based on artificial intelligence technology," *Journal of Physics: Conference Series*, vol. 1748, no. 5, article 052046, 2021.

[5] Y. Ding, "Performance analysis of public management teaching practice training based on artificial intelligence technology," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 5, pp. 1–14, 2020.

[6] X. Yuan, "Design of college English teaching information platform based on artificial intelligence technology," *Journal of Physics Conference Series*, vol. 1852, no. 2, article 022031, 2021.

[7] A. Leguina, S. Mihelj, and J. Downey, "Public libraries as reserves of cultural and digital capital: addressing inequality through digitalization," *Library & Information Science Research*, vol. 43, no. 3, article 101103, 2021.

[8] L. Cui, "A preliminary study on the management strategy of university personnel files based on artificial intelligence technology," *Journal of Electronic Research and Application*, vol. 5, no. 2, pp. 1–4, 2021.

[9] T. Remencová and A. N. Sedláková, "Modernization of digital technologies at regional airports and its potential impact on the cost reduction," *Transportation Research Procedia*, vol. 55, no. 6, pp. 18–25, 2021.

[10] Y. Wu, "A method of character verification code recognition in network based on artificial intelligence technology," *International Journal of Information and Communication Technology*, vol. 16, no. 4, p. 325, 2020.

[11] Y. X. Qu and M. F. Wang, "A study on the design of children intelligent guardianship product based on artificial intelligence technology," *E3S Web of Conferences*, vol. 179, no. 6, p. 02050, 2020.

[12] K. Ch En, Y. Zu, and Y. Cui, "Design and implementation of bilingual digital reader based on artificial intelligence and big data technology," *Journal of Computational Methods in Sciences and Engineering*, vol. 20, no. 2, pp. 1–19, 2020.

[13] Y. Liu, G. Lu, J. Chen, and Q. Zhu, "Exploration of internal and external factors of swimmers' performance based on biofluid mechanics and computer simulation," *International Journal of Environmental Research and Public Health*, vol. 18, no. 12, p. 6471, 2021.

[14] B. Wang, "Digital design of smart museum based on artificial intelligence," *Mobile Information Systems*, vol. 2021, no. 6, Article ID 4894131, p. 13, 2021.

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Retraction

Retracted: The Application and Development Trend of Youth Sports Simulation Based on Computer Vision

Wireless Communications and Mobile Computing

Received 17 October 2023; Accepted 17 October 2023; Published 18 October 2023

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

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

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

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

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

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

References

[1] T. Zhou and Y. Wang, "The Application and Development Trend of Youth Sports Simulation Based on Computer Vision," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 8500869, 9 pages, 2022.

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Research Article

The Application and Development Trend of Youth Sports Simulation Based on Computer Vision

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Based on computer vision technology, this paper presents a human motion analysis and target tracking technology based on computer vision. In terms of moving target detection, the current moving target detection technology is summarized, and some experimental results of the algorithm are given. The background difference method under monocular camera is emphatically analyzed. The preliminary human contour is obtained by the background difference method. In order to obtain a smoother target contour, the mathematical morphology is used to remove the noise, and the judgment algorithm of the size of the image connected domain is added. A specific threshold is set to remove the connected domain of the noise block less than the threshold. In the aspect of human motion recognition, this paper selects human motion features, including minimum external rectangle aspect ratio, rectangularity, circularity, and moment invariant. The criteria for selecting human motion features are strong noise resistance and obvious distinction. Then, the three types of human motion images are classified and recognized. After cross-validation and parameter optimization, the recognition accuracy is significantly improved. The experimental results show that the video sequence collected in the field has a total of 376 frames, and the frame rate is 10 frames/s. Due to the small traffic, the mean shift algorithm based on adaptive feature fusion is used to track the target every 2-3 frames. And set the inverse X direction as the direction of entering the scene and the X direction as the direction of moving out of the scene so that the allowable error of the distance between the detection and tracking results is 10. The weight of each feature is dynamically updated by the similarity between the candidate model and the target model, which solves the problem that the mean shift algorithm is not robust enough when similar objects are occluded and interfered and achieves more accurate tracking.

1. Introduction

In today's life, as people's way of life is better, people today need more sports. Sport has become an integral part of human life. For teens, exercise helps them improve their physical and mental well-being. According to the future and development expectations of the country, the development of physical and mental health of young people has always been the goal of scientific research. Education and sports and physical education have helped to improve the mental and physical health of young people [1]. As science and technology develop in the past, more and more new technologies are being used in research games. For example, the main goal of computer vision science is to give the computer a human-like ability to make the computer see the environment, understand the content of thought, and do the necessary. At the same time, the combination of computer vision technology and sports can further improve the simulation effect of sports, help sports get rid of the defects of weather, venues, equipment, funds, and so on, and maximize the effect of sports [2]. Therefore, this paper proposes a human motion analysis and target tracking technology

based on computer vision, in order to better integrate computer vision technology into the application of youth sports simulation.

Object tracking is to create a corresponding matching problem between successive image frames based on position, speed, shape, texture, color, and other related features. At present, as far as the tracking object is human, it can track the body parts such as hands, faces, heads, legs, and the whole human body. In terms of tracking angle, there are single angle of view corresponding to a single camera, multiangle of view corresponding to multiple cameras, and omnidirectional angle of view [3]. According to the different numbers of tracking targets, it can be divided into single moving target and multimoving target. Of course, it can also be classified by tracking target category (rigid body, nonrigid body, etc.) and camera state (moving or fixed). The recognition and analysis of human motion have always been a complex research topic. So far, human motion analysis has gradually moved from theoretical research to practical application [4]. For example, tracking the markers attached to clothes has been widely used, but the markers attached to clothes will be deformed due to movement and prone to dislocation. In this paper, human motion recognition is based on the research of nonattached markers. There are still many difficulties in video analysis of human motion characteristics.

There are different ways of human motion analysis in different fields and different objectives in practical applications, so there are different classification methods for human motion analysis. According to the number of cameras used, there are two kinds of methods: monocular camera based and multicamera based: as the name suggests, monocular camera uses a single camera to obtain images and analyze and process the obtained video. Multicamera is to use multiple cameras to acquire and process video. The advantage of multicamera is that it is conducive to obtain depth information, but the implementation is more complex, so in most cases, monocular camera is used to obtain video [5].

Region-based human motion analysis method is widely used at present, which can be divided into two parts: the analysis based on the whole human body and the analysis based on the local human body. The former does not need to accurately establish the human model and initialize the model, but only needs to calculate the area of the foreground and set the constraints of the geometric structure. For the analysis based on the local part of the human body, the foreground needs to be more accurate. Through the analysis of different parts of the human body (such as hands, head, and limbs), the representation is classified and constructed. If a new area appears, the representation will be generated, and if the corresponding area disappears, the representation will be deleted. The difficulty of region-based human motion analysis lies in how to deal with shadow region and object occlusion. If the human motion is predicted by the filter, the tracking can be completed under the premise of occlusion [6].

The research direction of Artificial Intelligence Research Institute is mainly artificial animation, which uses manual annotation of human feature points in the first frame to accurately estimate the occluded position. The Computer Institute of the Chinese Academy of Sciences is dedicated to the study of gesture recognition. The experimenter wears a special glove with a sensor. The researcher obtains data from the sensor to analyze gestures. In addition, the Institute of Computer Science of the Chinese Academy of Sciences has also extended its research to sports training, analyzing the training actions of national diving team athletes and performing three-dimensional reconstruction. From the development trend of human motion analysis at home and abroad, the types of sports analyzed are transiting from simple periodic sports (such as walking and running) to complex sports (such as gymnastics). The viewpoint of the analysis is transited from monocular vision to binocular or even multiocular vision. The tracking process transits from manual annotation to automatic annotation [7].

2. Analysis of Human Sports Based on Computer Vision

2.1. Human Moving Target Detection Technology. The objective search engine is divided into two parts: static image objective detection technology and dynamic sequence target search machine. The technology of capturing objects from images was also developed early on. Applications typically include the starting method, the image comparison method, the edge view, and the standard segmentation method. Static image object detection method only uses the spatial information of the image, but does not use the interframe correlation information in the video, which cannot meet the real-time contour extraction. Dynamic sequence object detection technology uses motion information from video to extract moving objects [8].

2.1.1. Frame Division Difference Method. The different process is called time difference method and the simple difference method and is the simplest way to identify the transition images of the two frames. While the subject and the camera are still there, the video image has the same background. Comparing two images at different times can affect the movement of the object. The adjacent differences are shown in

$$P(x,y) = \begin{cases} 255, & \text{if } |I_i(x,y) - I_{i-1}(x,y)| > T, \\ 0, & \text{if } |I_i(x,y) - I_{i-1}(x,y)| \le T. \end{cases} \quad (1)$$

A schematic of the difference in variance is shown in Figure 1.

The key to a variety of differences is to choose a start. These differences will create different binaries. When selecting a small start, some pixel effects appear as the target. If the initial size is large, some pixels of the target image are filtered out according to the sound [9, 10].

2.1.2. Symmetrical Frame Difference Method. The main idea of the symmetric difference is called the difference between the frames of three consecutive diagrams, to calculate the complete difference, get a binary diagram with the clear the beginning, and then do the "work of communication."

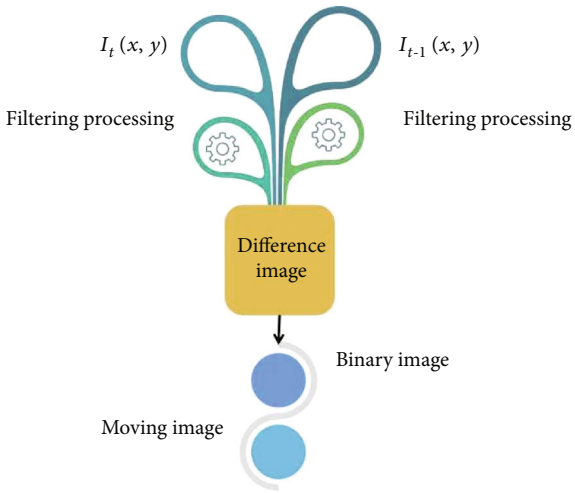

Figure 1: Flowchart of adjacent frame difference method.

The binary difference is a binary diagram, and the output is objective. The structure of the symmetric frame different ways is shown in Figure 2.

First frame:

$$P_1(x,y) = \begin{cases} 255, & \text{if} |I_i(x,y) - I_{i-1}(x,y)| > T, \\ 0, & \text{if} |I_i(x,y) - I_{i-1}(x,y)| \le T. \end{cases} \quad (2)$$

Second frame:

$$P_2(x,y) = \begin{cases} 255, & \text{if} |I_i(x,y) - I_{i-1}(x,y)| > T, \\ 0, & \text{if} |I_i(x,y) - I_{i-1}(x,y)| \le T. \end{cases} \quad (3)$$

Perform a "logical and" operation to obtain the detected target P:

$$P(x,y) = P_1(x,y) \cap P_2(x,y) = \begin{cases} 255, & \text{if} [P_1(x,y)] = 255 \delta\delta P_2(x,y) = 255, \\ 0, & \text{else}. \end{cases} \quad (4)$$

2.1.3. Background Difference Method. Background subtraction is one of the commonly used methods for moving target detection. The main idea is to compare the input video frame with the background image [11]. If the pixel features at the same position are different, the pixel area in this frame is considered to have changed. The background difference method extracts these changed areas through certain criteria to form the foreground target area. If these front spots are further processed, the target position, shape, size, and other information can be obtained. In this paper, the following contrast method is used to draw the individual contour. The first step in the difference in background is to get a stable, reliable background image, then count the differences between the current frame image and the image after to get a comparison image, and then make a binary diagram of the differences between the two to start the value to get

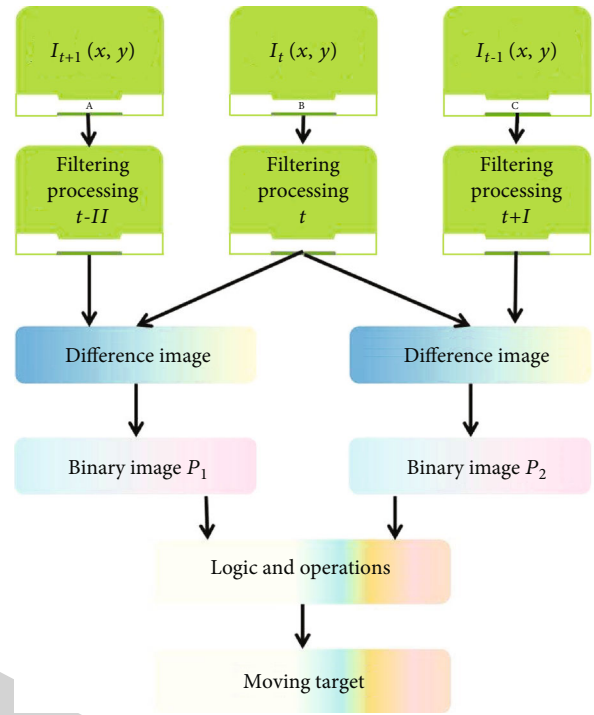

Figure 2: Flowchart of symmetrical frame difference method.

the contour of the object moving [12]. The test is taught in

$$P(x,y) = \begin{cases} 1, & I(x,y) - B(x,y) > T, \\ 0, & \text{else}. \end{cases} \quad (5)$$

The specific process is shown in Figure 3.

2.1.4. Optical Flow Method. The constraint equation of optical flow method meets

$$I(x(t), y(t), t) \approx I(x(t + \Delta t), y(t + \Delta t), t + \Delta t). \quad (6)$$

The Taylor series is used to expand the right side of the inequality sign of the above formula, and the optical flow constraint equation is

$$I(t) \approx I(t) + \frac{dI(t)}{dt}\Delta t + O_2(\Delta t), \quad \frac{dI(t)}{dt} = 0, \quad (7)$$

where $O_2(\Delta t)$ is the second-order derivative and the higher-order derivative assumption can be ignored. According to the chain rule, the optical flow equation is

$$\frac{\partial I}{\partial x}\frac{dx}{dt} + \frac{\partial I}{\partial y}\frac{dy}{dt} + \frac{\partial I}{\partial t} = 0. \quad (8)$$

It can also be written

$$I_x u + I_y v + I_t = 0. \quad (9)$$

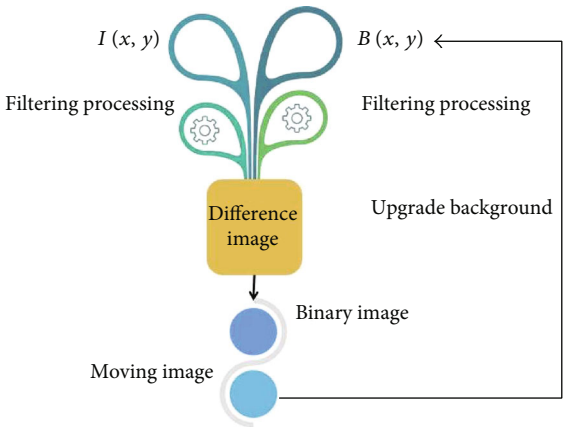

Figure 3: Flowchart of background difference method.

After the optical flow field is determined, the random noise and other small interference factors are removed, and the motion vector is always consistent on an object within a certain time range so that the motion parameters of the moving target at each time include speed and direction. Optical flow field-based motion target detection can calculate the target speed, but it is difficult to achieve in real time due to the long count time of the iteration operation [13]. As seen in Figure 4, a uniform cylinder rotates around its base axis, the camera is constant, the cylindrical image does not change over time, and the optical flux does not move to the surface of the material. In this case, the optical flow field is zero. In Figure 5, the sphere does not move, but the light source is moving and the optical current moves on the surface of the object; the optical flow field in this case is not zero [14].

2.1.5. Gaussian Model Method. Ideally, the background of two adjacent frames is consistent, and the difference of gray value should also be zero. However, due to the slight jitter of the camera, the small change of the external environment, and the unstable noise of the sensor itself, the background gray difference between the two sensors is not all zero. While the pitch change at that point can indicate that the average of 0 in the normal distribution of $N(0, \sigma^2)$, the change in pixel gray value can be averaged by analyzing the rule changes the pixel value at some point in the same background over a period of time [15]. It is expressed by the regular division of μ, $N(\mu, \sigma^2)$. Assuming that the average change of each pixel in a static result gives a normal distribution, its potential for speed is

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{(x-\mu)^2/2\sigma^2}, \quad -\infty < x < \infty. \tag{10}$$

2.1.6. Basic Algorithm of Mathematical Morphology. Mathematical morphology is a new concept in imaging. The principle is to use design principles to measure and decompose similar images in the image, thus allowing the image to be identified and analyzed. Different processes will yield different results.

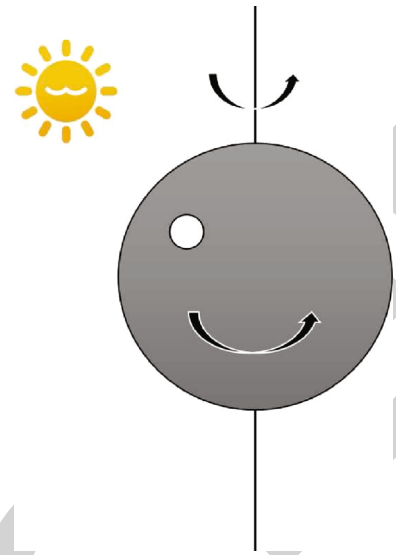

Figure 4: Motion but no optical flow change.

(1) Gray morphological expansion operation

$$(f \oplus b)(x, y) = \max\{f(x - s, y - t) + b(s, t) | (x - s, y - t)\} \in D_f; (s, t) \in D_b. \tag{11}$$

(2) Gray form decay candle operation

$$(f \Theta b)(x, y) = \min\{f(x - s, y - t) - b(s, t) | (x - s, y - t)\} \in D_f; (s, t) \in D_b. \tag{12}$$

(3) Gray form open operation

$$f \circ b = (f \Theta b) \oplus b. \tag{13}$$

(4) Gray morphological closure operation

$$f \bullet b = (f \oplus b) \Theta b. \tag{14}$$

2.1.7. Tracking Method Based on Motion Detection. The time difference method is to compare relative changes in identical pixels of two adjacent images in a continuous image sequence and make an initial work in progress into the contrast image to get the moving part in the image. If $I_i(i, j)$ is a figure of time t, $I_{i-1}(i, j)$ is a figure of time $t - 1$, $D(i, j)$ is the

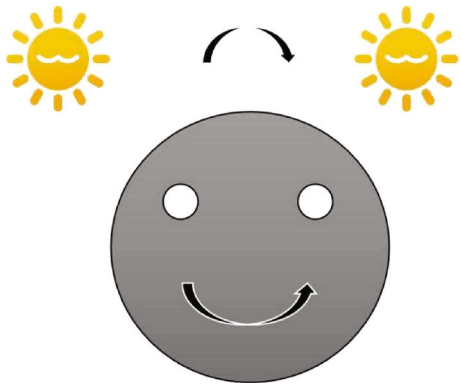

Figure 5: Optical flow change without movement.

difference, and t is the beginning:

$$D(i,j) = \begin{cases} 1, & |I_t(i,t) - I_{t-1}(i,t)| \geq T, \\ o, & \text{else.} \end{cases} \quad (15)$$

Time difference is a direct and simple method for moving target detection. It has the advantages of simple algorithm implementation, low complexity of program design, small amount of calculation, and good real-time performance. It has certain application value. The two-frame contrast method is used to extract moving objects from the video system, following the distribution and control goals. However, when the target moves slowly, the detected target may appear hollow or even ambiguous. If the target moves too fast, do not split the target [16].

2.2. Design of Human Moving Target Tracking System

2.2.1. System Design Idea. The processing process of the human moving target tracking system is as follows: firstly, the relevant image data of the detection and tracking area is collected through the visual sensor—CCD camera and image acquisition card, and then, the obtained video image sequence is preprocessed to reduce the impact of noise, and then, the collected video image is processed in real time to obtain the relevant motion information and extract the human moving target. Then, the video image is processed and analyzed, the target is tracked in the continuous image sequence, and the pedestrian motion trajectory is obtained. Finally, the motion behavior of the human target is understood. The core processing algorithm of the system is mainly composed of two parts: the segmentation and tracking algorithm of pedestrian target.

2.2.2. System Composition. CCD camera and image acquisition card, as the image data acquisition sensor, are the input devices of the whole system and have the image acquisition function. CCD is responsible for collecting image information. The image acquisition card controls the camera to complete image acquisition and digitization and provides a bus interface to complete the real-time transmission of images and coordinate the whole system. The function of the image main processor is to realize the main algorithm of the human moving target tracking system. By analyzing and processing the collected sequence images, the human moving target in the video image is extracted, and its motion tracking and behavior analysis are realized. Finally, the image processing results are displayed on the connected display device, as shown in Figure 6; they will be briefly introduced below.

Image acquisition module is the most front-end unit of the whole tracking system, providing input data for the whole system. In this system, the ultimate goal of target tracking is to determine the moving direction of the target in the scene, so the requirement for acquisition frequency is not high. Only one target is collected at least twice in the process of entering and leaving the scene, so the acquisition speed is 10 fps.

Depending on the weather, changes in lighting, choice of sensor type, and blur caused by pedestrians, the images will be mixed with different sounds. In addition, the image collected by the light source in the lighting creates noise when captured, converted, and transmitted, which can lead to image degradation. The presence of these noises makes it difficult to identify vehicle targets. The main role of the image before working module is to filter and strip the image [17].

Moving product segmentation is the process of deleting objects moving from the background to form images. This is the basis for product management. The quality of work at this stage directly affects the outcome of the next work. The main idea of improving the target mobile segmentation module is to separate the area of interest from the background, improve the segmented binary image, eliminate the distortion of the image, and apply the initialization method segmentation to get the finished image. Purpose section: the target location and similar features are extracted.

Tracking is to extract some features of moving objects in image sequences and match these features from one frame image to another. The processing idea of the target tracking module is that the position, area, and shape of the same moving target in the two adjacent frames will not change much, so it can be tracked from the features obtained from the moving target extraction. Mean shift tracking algorithm is a matching method based on color features. It has many good properties in the tracking field. It can still be tracked when the target is partially occluded, but the color histogram is also a weak description of the target features. When the target is seriously occluded and similar objects appear around, the tracking effect is not good. Therefore, it is considered to add spatial texture features to describe them and give each feature a dynamically updatable weight, so as to strengthen the robustness of the algorithm and create conditions for the subsequent behavior analysis of human moving objects [18]. The purpose of human moving target tracking is to determine the trajectory of the target, so as to further analyze its motion state, as show in Figure 7.

3. Moving Object Segmentation

3.1. Basic Methods of Image Segmentation. Image segmentation is an important technology for image analysis. In learning and using pictures, people usually only like certain parts

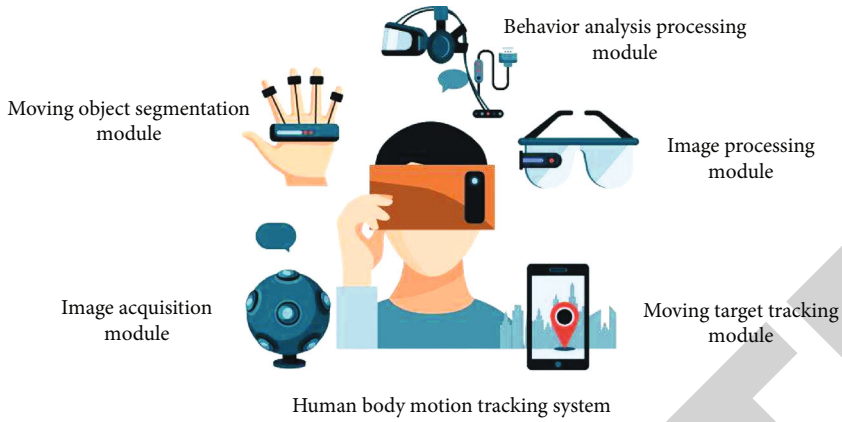

Figure 6: Overall system framework.

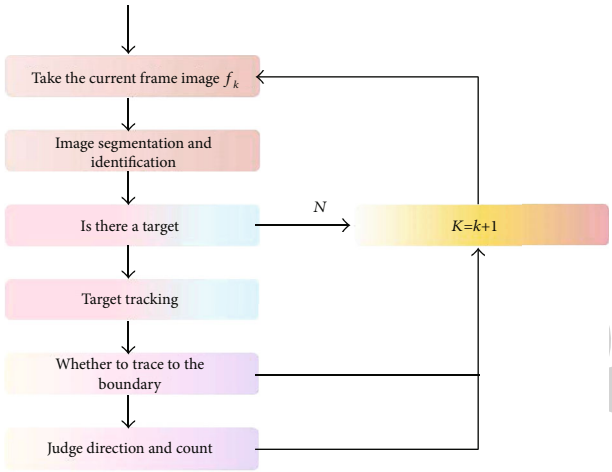

Figure 7: System processing flowchart.

of the picture. These sections are often called objectives or perspectives (other sections are called backgrounds). They are usually related to specific and unique areas in the figure. What can be special about this can be the gray value of the pixel, the curve of the object, the color, the texture, and so on. In order to identify the targets in the figure, they must be separated from the figure. Based on this, further objective measurements can be made and images can be used [19]. Thus, image segmentation is a technology and process of dividing images into areas of different objects and subtracting favorite objects. The classic image segmentation method is shown in Figure 8.

The simple idea is to assume that the image has a purpose and background with gray wings in a pattern. The gray values of the pixels that are adjacent to the target or background are related, but the gray values of the pixels on either side of the boundary between the target and the background are large and have two peaks (Figure 9). Therefore, the gray value corresponding to the difference between the two peaks can be selected as the starting point of the appropriate segmentation of the target and the background.

3.2. Human Motion Target Segmentation. By studying the video images collected in the field, this paper selects the head of the moving target as the recognition object. This is because the human head is a face image similar to an irregular circle. It not only has a uniform gray distribution but also has a lower gray value compared with the surrounding objects and the background, so it has obvious distinguishability. In addition, although the background in the video is relatively simple, we cannot use simple background difference which is sensitive to its changes due to the influence of shadows [20]. However, if the background update mechanism is introduced to eliminate the interference, it cannot meet the real-time requirements, so this paper adopts a two-step segmentation method to extract moving objects. The whole process of moving object segmentation is shown in Figure 10.

In this paper, the method of target extraction uses the gray value and the position characteristics of pixels and classifies by threshold. It mainly includes several steps: target segmentation, target identification, and target feature extraction.

3.2.1. Image Segmentation. Through half threshold segmentation, a large number of background images and some irrelevant interference images can be removed, and the concerned motion region can be extracted.

The gray value of the pixels in the head area of the moving target is mainly concentrated in the range of 0-40. However, considering the influence of external light, the threshold T is taken as 50 so that the head region can be roughly extracted from the image sequence. However, in the application environment of this paper, the background of the image sequence is close to the gray value of the target. Taking an image sequence of any frame in the image sequence as an example, it can be seen that the gray level of the image sequence is mainly distributed in the interval of [0100], and there is no particularly obvious boundary between the background pixel and the target pixel.

For the video images collected in the field, a method based on the combination of gray statistical half threshold and adaptive threshold segmentation of the head image is proposed to segment the image, and the head of the moving human target can be obtained through subsequent

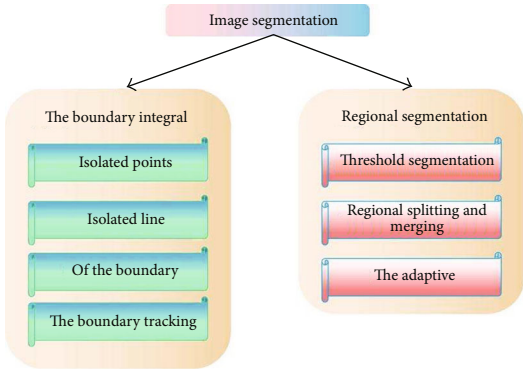

Figure 8: Image segmentation method.

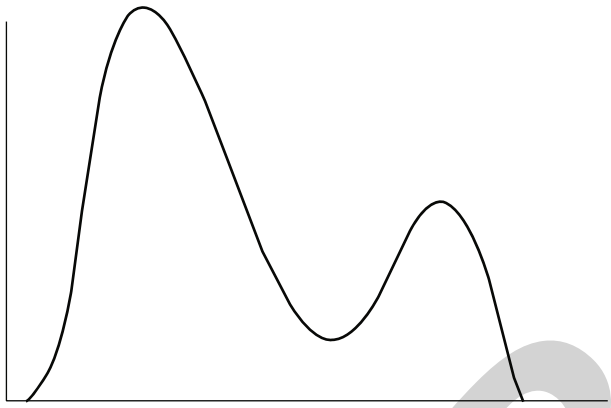

Figure 9: Bimodal histogram.

processing. The results show that this method can segment the moving objects in the image in real time [21].

4. Application of Target Tracking in Population Statistics

4.1. Establishment of Target Chain. In order to realize multitarget tracking and count the number of people entering and leaving the scene, it is not only necessary to record the head position of the detected moving target and carry out subsequent tracking processing according to the characteristic value of each target but also to record the results obtained by the mean shift tracking algorithm to judge the moving direction of the target and update the counter. When the target is detected for the first time, the size information of the human head target must be obtained. Only in this way can all pixels in the target area be included in the mean shift algorithm, and then, the human head target can be described as accurately as possible.

4.2. Realization of Counting Process. The specific process of this paper is as follows: firstly, the head target in each frame is extracted by using the target segmentation algorithm introduced in the previous chapter, and the center position and size range of the target are obtained. The target center is the result $s = (x, y)$ obtained in the target detection phase. At the same time, although the length L and width W of the external rectangle of the target can completely contain the pixels of the head area of the moving target, it may also contain the edge information of some other parts (such as the shoulder). In order to reduce the interference as much as possible and accurately reflect the characteristics of the target area, the kernel function bandwidth used in the process of determining the mean shift algorithm to implement target tracking is smaller than the length L and width W of the external rectangle of the target. We set min (L, w) as the bandwidth of the kernel function. Then, according to the target node of each tracked target, track all targets in the new video sequence, determine the position of each target in the new video sequence, and then refresh the target node for subsequent image tracking. Here, the target chain records the characteristics and motion state of the target and saves the position of the target in the latest image frame.

4.3. Experimental Results and Analysis. According to the tracking algorithm proposed in this paper, the motion trajectories of two moving targets in the image sequence are obtained, as shown in Figure 11. From the central coordinate position of the tracking target window, it can be seen that the circle marks the motion track of the head centroid of one person in the image sequence, while the square marks the motion track of the head centroid of another person in the image sequence, which reproduces the motion process of the moving target out of the scene [22].

The amount of calculation of tracking varies with the number of targets to be tracked, and the ultimate goal of tracking is to determine the moving direction of the target in the scene, as long as one target is tracked at least twice in the process of entering and leaving the scene. The video sequence collected in the field is 376 frames in total, and the frame rate is 10 frames/s. Due to the small traffic, the mean shift algorithm based on adaptive feature fusion is used to track the target every 2-3 frames. And set the inverse X direction as the direction of entering the scene and the X direction as the direction of moving out of the scene so that the allowable error of the distance between the detection and tracking results is 10. Using the tracking algorithm proposed in this paper, although the target disappears briefly, the distinguishability between the target and the background is enhanced due to the rotation invariance of LBP texture operator and the effective description of spatial information. Therefore, although the detection results show that there is no target at this position during the correlation counting of targets, the tracking algorithm can still track each target accurately at this time, which has strong robustness and plays a substitute role in the correlation counting method. Therefore, when the target reappears and is detected, the tracking window still tracks it on the target, so the number of people in and out of the scene can be counted accurately.

5. Conclusion and Development Trend

Due to its high real-time performance and accuracy, mean shift algorithm is widely used in the field of target tracking. However, in the case of similar object occlusion interference, the tracking results often deviate. This paper makes corresponding improvements to this defect and realizes the

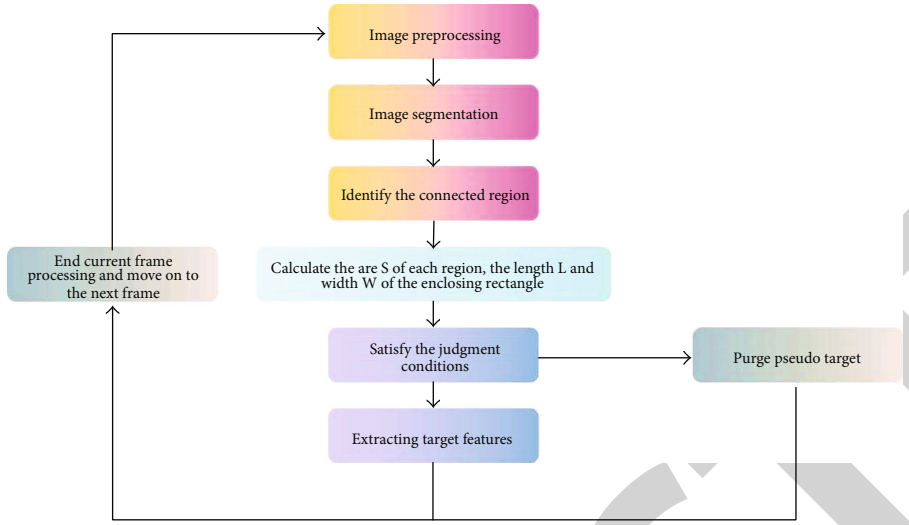

Figure 10: Flowchart of target segmentation.

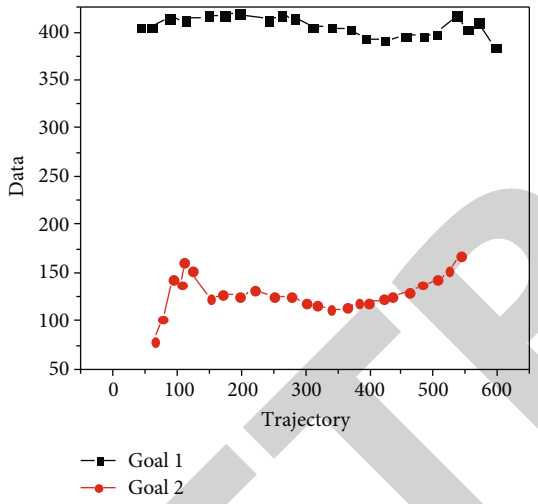

Figure 11: Moving track of tracking target center coordinate.

statistics of the number of people in and out of the scene on the basis of these studies. Firstly, the tracked target is extracted from the video image sequence. After studying some commonly used segmentation algorithms and analyzing the characteristics of video scene and moving target, this paper adopts a method combining half-threshold segmentation and adaptive threshold segmentation to segment the head of human moving target in the scene from the image in two steps and identify, locate, and extract the target features. Secondly, because a single feature cannot describe the target in detail, this paper combines HSV color space with local binary mode by introducing texture feature. The weight of each feature is dynamically updated through the similarity between the candidate model and the target model, which solves the problem that the mean shift algorithm is not robust enough when similar objects are occluded and interfered and achieves more accurate tracking. Finally, on the basis of the above research, the target chain is established, and the number of people in and out based on adaptive feature fusion tracking is realized. Experiments show that it can effectively achieve the statistics of the number of people entering and leaving the scene and has high accuracy and feasibility.

However, due to the limited personal ability and time, this paper only makes some preliminary exploration in human moving target tracking, and there are still many problems to be solved in the algorithm. At present, the intelligent monitoring system based on multicameras has attracted a lot of attention. It can not only greatly improve the monitoring range but also provide multiple different directional perspectives to solve the occlusion problem. It is currently considered the most effective method to solve the occlusion problem. However, when using multiple cameras to monitor the target, how to coordinate and schedule multiple cameras according to the events in the scene is a very difficult thing, which needs people to conduct in-depth research.

Data Availability

No data were used to support this study.

Conflicts of Interest

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

References

[1] G. Luo, G. Yao, X. Zhao, G. Wu, and L. Yang, "Simulation of sports monitoring system based on feature network," *Mobile Information Systems*, vol. 2022, Article ID 4048431, 8 pages, 2022.

[2] G. Chen, C. Han, L. Yan, Y. Li, Y. Zhao, and X. Zhang, "Simulation and application of external quantum efficiency of solar cells based on spectroscopy," *Journal of Semiconductors*, vol. 40, no. 12, p. 122701, 2019.

[3] A. P. Correia, N. Koehler, A. Thompson, and G. Phye, "The application of phet simulation to teach gas behavior on the

Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 8047582, 11 pages
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Research Article

Emotion Classification Method of Financial News Based on Artificial Intelligence

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With the continuous development of economy, the economic development model is constantly changing. Especially since China's entry into WTO, the scale of economic development has reached a new height. The continuous development of economy makes the financial news module evolve towards specialization. However, with the emergence of Internet of Things technology, a large number of data appear in the network, which brings some difficulties to the classification and analysis of data economy. Emotion classification refers to the complexity and diversity of people's emotions. It can be classified from different observation angles. Because the core content of emotion is value, human emotion should be classified mainly according to the different characteristics of the movement and change of value relationship it reflects. This paper is aimed at studying the emotional classification method of financial news based on artificial intelligence and expecting to use artificial intelligence technology and classification method to classify financial news. It allows more people to know the implied information of financial information and promotes economic development. Artificial intelligence is a branch of computer science. It attempts to understand the essence of intelligence and produce a new intelligent machine that can respond in a similar way to human intelligence. This paper mainly summarizes the topic selection characteristics and subdivision topic selection characteristics of financial data news through quantitative and qualitative methods and explores the classification of financial news. In this paper, a simplified classification algorithm based on convolution function is proposed for the classification of traditional financial news networks. The experimental results show that the classification accuracy of artificial intelligence method is improved by 4% compared with the traditional emotion classification method, and the classification accuracy of positive emotion is lower than that of negative emotion by 2%.

1. Introduction

News is a channel to transmit information to the outside world. Basically, each industry has its own news media. With the popularization of Internet of Things technology, network news has become an emerging way and an indispensable source of information. The rapid development of economy provides the material basis for the rise of financial news. Financial news transmits information to everyone with the help of Internet of Things technology. However, the Internet of Things is mixed with many negative information, which affects the dissemination of correct news. Therefore, we need to classify the news according to the news content and correctly identify the incorrect information. With the characteristics of freedom, virtuality, and concealment, the Internet of Things makes more and more people willing to express their views through the network. It obtains the necessary information, which provides conditions for the dissemination of false information. This paper uses artificial intelligence technology to classify the emotion of financial news and transmit positive and healthy financial information.

Through this research, this paper strives to achieve a comprehensive, objective, and comprehensive grasp of the

data reform of financial news. To some extent, it fills the gap in this research field. By analyzing the emotional tendency of network news, this paper can grasp the proportion of positive and negative news for a period of time and the positive and negative aspects of news hot events. This is very important for public opinion analysis. Through the study of emotion classification, we can timely understand the people's views and views on a government policy or news event, so as to take corresponding measures. It is of great significance to social stability and policy implementation.

Financial news is an important source for people to understand financial information, which provides an important basis for people to make decisions. Therefore, the emotional classification of financial news is very important. The experimental research shows that when the news theme word is 6, the accuracy rate of positive emotion is 69%, and the accuracy rate of negative emotion is 78%, and the accuracy rate is the highest. It shows that in the emotional classification of financial news, the more subject words, the better.

2. Related Work

As the existing offline communication mode has been transferred to the Internet, a variety of multimedia services are emerging. Unlike in the past, these jobs are a huge source of opinions and attitudes. In particular, various opinions and comments published on the Internet in real time can help the company or the country determine the policy direction. In this context, Park et al. have developed a machine learning-based emotional classifier for environmental problems, so as to understand how people identify climate change problems related to the environment from the comments issued below the news. Machine learning is a special study of how computers simulate or realize human learning behavior in order to obtain new knowledge or skills. It reorganizes the existing knowledge structure to continuously improve its performance. Based on this research, they applied machine learning technology SVM (support vector machine) and Naive Bayes to construct emotion classification algorithm. They compared different network information by using CNN (convolutional neural network) and BI—the deep learning technology vigorously studied recently, and compared their advantages and disadvantages [1]. Emoji is a graphic symbol that expresses things in the form of images. With emoji, they can read and understand the text according to its meaning. Among the things mentioned at that time, the researchers studied the classification of Twitter content according to the use of emoticons. Sendari et al. aimed to determine the emotional use of Twitter over a period of time. Each tweet on the Twitter timeline contains text and emoticons, which will be classified according to several categories. Naive Bayesian algorithm calculates the probability of emoji tweets to obtain text classification with emoji. The characteristic of Bayesian method is to combine a priori probability and a posteriori probability, that is, it avoids the subjective bias of using only a priori probability and the overfitting phenomenon of using sample information alone. The results show that the "happiness" category has become the emotional trend of Twitter users, in which emojis are dominant [2]. Due to the increase in the number of applications and their use in various fields, the research of text emotion classification has been growing steadily in the past few years. When making certain decisions in business analysis, stakeholders must understand users' emotions. Saranya and Jayanthy classified emotions with ontology and process ambiguous sentences with machine learning algorithm (SVM). Each emotion is mapped hierarchically according to its depth level, and each emotion is associated with weight. POS marker is used to split sentences into words corresponding to their part of speech. Anew thesaurus is used to provide the ranking of emotional words obtained from part of speech tagging in the form of three dimensions. Due to the use of ontology, the insertion of new emotion as a concept and the mapping of its attributes become simple. This ontology-based machine learning technology for text emotional classification has proved to be efficient and performs better [3]. Kuchibhotla and Niranjan focused on the classification of various acoustic emotional corpuses with frequency domain characteristics using feature subset selection methods. The number of speech emotion samples available for training in the corpus is less than the number of features extracted from the speech samples, which is called dimension disaster. Because of this high-dimensional eigenvector, the efficiency of the classifier is reduced and the computation time is increased. To further improve the efficiency of the classifier, it requires an optimal feature subset, which is obtained by using the feature subset selection method. This will improve the performance of the system, increase efficiency, and reduce the calculation time. Experiments have shown that SFFS enhances the performance of the classifier because it eliminates the nesting effect suffered by SFS. The results also show that the best subset of features is a better choice for classification rather than a complete set of features [4]. They used electroencephalogram (EEG) signals to more accurately identify human emotional states than nonverbal and verbal signals, because emotions are psychological and physiological processes associated with personality, motivation, mood, and temperament. Imah and Rahmawati used an adaptive multilevel generalized learning vector quantization algorithm to identify mood states based on EEG signals. The emotional condition for its categorization is price, that is, low price and high price. DEAP datasets are characterized by data imbalance. One of the advantages of AMGLVQ algorithm is to handle classification under imbalanced data conditions. The test results show that AMGLVQ has better performance [5] than random forest (RF) and support vector machine (SVM). In recent years, a lot of research has been done on emotional recognition in Parkinson's disease (PD). EEG signals have been found to be helpful in identifying the relationship between emotional status and brain activity. Rejith and Subramaniam used four features and two classifiers to analyze the classification of emotional recognition in Parkinson's disease based on electroencephalogram. For each EEG signal, they obtained alpha, beta, and gamma band frequency characteristics for four different feature extraction methods (entropy, energy entropy, spectral entropy, and spectral

energy entropy). Then, they associated the extracted features with different control signals and develop two different models (Probability Neural Network and K-Nearest Neighbors algorithm) to observe the classification accuracy of these four features. Experiments show that the proposed energy entropy feature is uniform for all six moods. Compared with other features, the accuracy rate is more than 80%, while different features with classifiers produce different results for a few emotions, with the highest accuracy rate exceeding 95% [6]. Although these theories describe financial news, they do not effectively process the data in financial news, so this paper expects to use artificial intelligence technology to process related data.

Artificial intelligence (AI) is an important technology to support daily social life and economic activities. It has made a great contribution to the sustainable development of the economy and has solved various social problems. Although recently developed AI technologies do perform well in extracting certain patterns, they also have many limitations. Most ICT models are overly dependent on large data and lack self-conceiving capabilities. Lu et al. developed a new concept of general intelligent cognitive technology called Beyond AI. Its core functions include computer vision, machine learning, natural language processing, robot, and speech recognition. Specifically, the plan to develop an intelligent learning model called Brain Intelligence (BI). The model uses imaginative artificial life to generate new ideas about events without experiencing them. This model will demonstrate the BI intelligent learning model developed in autodriving, precision medical, industrial robots, etc. [7]. The fields of neuroscience and artificial intelligence (AI) have a long and interwoven history. Recently, however, communication and cooperation between these two areas have become less common. Hassabis et al. believed that a better understanding of the biological brain can play a crucial role in building intelligent machines. They investigated the historical interactions between AI and neuroscience and highlighted the current advances in AI. These advances have been inspired by neurocomputational studies in humans and other animals. Finally, they highlighted common themes that may be key to future research in these two areas [8]. Although these theories introduce artificial intelligence, they are less practical to combine with financial news.

3. Emotional Classification of Financial News in Artificial Intelligence

3.1. Financial News. With the development of Internet of Things technology, various kinds of information appear in life, financial news is no exception, and in many cases financial news appears in the form of data news [9, 10]. Data news provides a new possibility by combining the traditional news narrative ability and sensitivity with massive data information. It is a way of news work based on the collection, analysis, and presentation of data information. The general track of China's economic news development is from economic information to economic news to financial news. In fact, financial news has been attached great importance and is closely related to China's entry into the WTO [11]. The emergence of financial news has promoted the evolution of financial media toward specialization [12]. The research objects of financial media mostly focus on professional financial media and comprehensive paper media. There are many studies on financial reports in comprehensive paper media. Figure 1 shows the basic system structure of financial news:

Before discussing the relevant content of financial news, we need to give a brief explanation of the concept of financial news. From the appearance time of financial news, the development time of financial news is not long, so there is no recognized concept [13, 14]. First of all, from the coverage, financial news refers to financial and other macroeconomic fields related to the state and government behavior. It is primarily related to financial aspects. From a macro perspective, financial news includes information about the whole society and the global economic situation, analysis, and prediction of economic development trend [15, 16]. The micro financial news focuses on smaller individuals, including enterprises, families, and individuals. It uses vivid cases to reflect social and economic life.

With the development of economy, news is gradually close to the public, and this trend also appears in financial news [17]. The audience of financial news is increasing. The audience of financial news is widely distributed in all corners of society, but it cannot be understood that every member of society is the audience of financial news [18, 19]. Among them, the real financial news audience refers to the part that has long adhered to and paid attention to the financial information on the news media. Their work is often closely related to the economic field, and they need to obtain a large amount of financial information from various channels in daily production and life [20]. The improvement of education also provides conditions for the popularization trend of financial news. Financial news has the characteristics of positioning and service in the trend of popularization. It includes the civilian selection of topics, the closeness between the theme and real life, the popularization of language, and the diversification of forms.

3.2. Artificial Intelligence. In recent years, with the development of artificial intelligence technology, a series of intelligent fields have emerged, and emotion classification is one of them. News is a kind of text. To deal with the text, we need to analyze the text elements.

$$A = (a_1, a_2, \cdots a_t). \tag{1}$$

V represents the vector, and t represents the components of the text.

$$S = (g_1, g_2, \cdots g_t). \tag{2}$$

The document S corresponds to the t dimension vector.

$$g_h = \frac{k}{w}. \tag{3}$$

h represents the corresponding position of the text, k

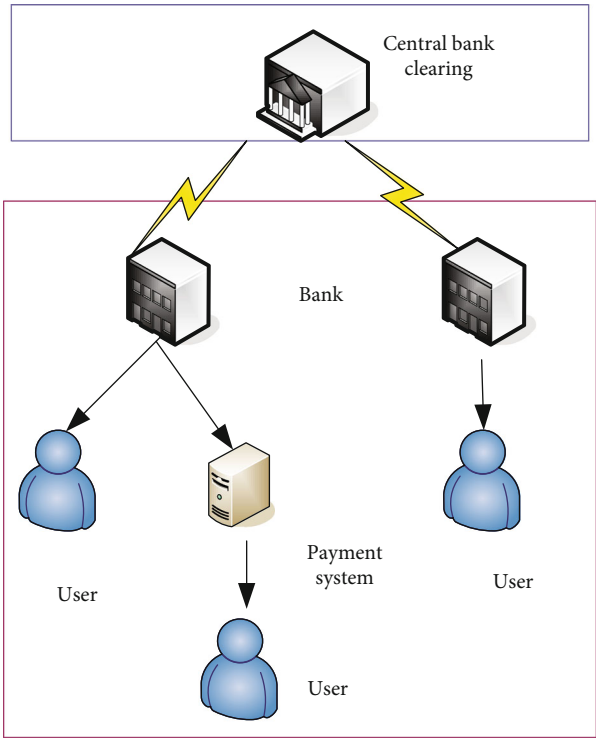

Figure 1: Basic system structure of financial news.

represents the occurrence of text elements, and w represents the total vocabulary of the text.

$$zx_{ab} = \frac{w_{ab}}{\sum h^{w} hb}. \tag{4}$$

b represents a part of the news document, a represents vocabulary, w represents the total vocabulary of the text, and k represents the occurrence of text elements. Figure 2 shows a common model of document structure

$$ruy_a = 1\log\frac{|Q|}{|(\ln_a \in u_l)|}. \tag{5}$$

$$p = \frac{1}{f}\sum_{j}^{f}\log g\left(h_j|h_{j-f}, \cdots h_{j+f}\right). \tag{6}$$

h_j represents whitening words, and f represents several words after j. When the model is solved by convergence, the vocabulary of the whole news can be obtained. The model structure is shown in Figure 3.

Neuron is an important part of neural network. A large number of neurons are connected with each other to form a neural network adaptive dynamic system. The system can be multi-input and single output, and its structure mode is

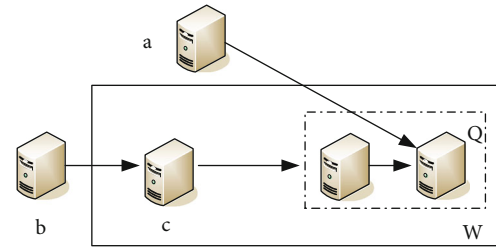

Figure 2: Document structure model.

shown in Figure 4.

$$\begin{aligned} h_a &= \eta_a + g_a, \\ \eta_a &= \sum_t \beta_o u_t, \\ k_a &= r\left(\sum_t \beta_o u_t + g_a\right). \end{aligned} \tag{7}$$

η_a represents the strength of the neural network, g_a represents the deviation, u_t represents the information input, and $r(*)$ represents the distance function.

By synthesizing the evidence of the recognition framework, the following expression can be obtained:

$$y(S) = y_1 \oplus y_2 = 0\begin{cases} \sum_{h,j} & y_1(S_h)y_2(A_j) \\ \dfrac{S_h \cap A_j}{1-u} & \\ 0 & \end{cases}, \forall S \subset \varphi, A \neq \varphi. \tag{8}$$

Among them, u reflects the degree of conflict between various evidences, which we call conflict factor.

$$Q(j(a)) = \frac{1}{l}\sum_{1}^{l} j(a)\beta(a). \tag{9}$$

Among them, $\beta(a) = y(a)/w(a)$.

$$w(a) = w_1(a_1)w_2(a_2|a_1)\cdots w_c(a_c|a_1 \cdots a_c). \tag{10}$$

a represents scalar or vector.

Convolutional neural network can solve the parameter problem on the model. Using this model can reduce the relevant parameters to be collected and improve the performance of the algorithm. Convolutional neural network can be connected locally, which greatly reduces the parameters of the network. Weight sharing is used to control the number of parameters. Downsampling in space or time gradually reduces the spatial size of data and the number of parameters in the network. It not only reduces the consumption of computing resources but also can effectively control over fitting.

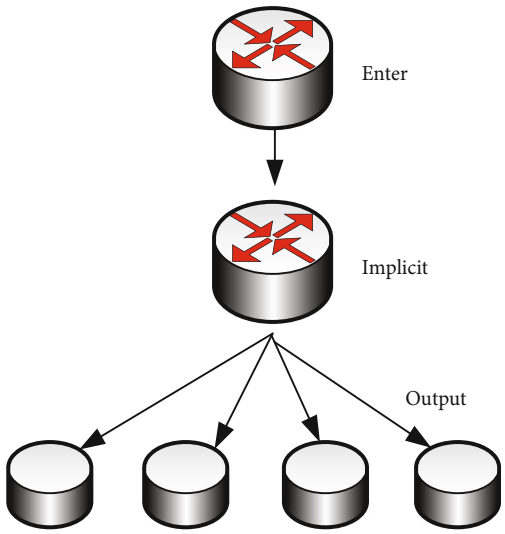

Figure 3: Convergence model structure diagram.

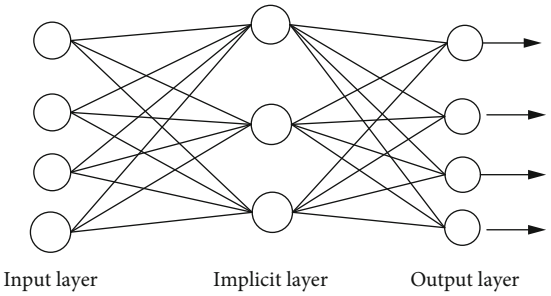

Figure 4: Neural network structure diagram.

The Gaussian distribution method is required to optimize the training parameters in the neural network model, and its function expression is as follows:

$$u = \sqrt{\frac{9}{y_i + y_{i+1}}}. \tag{11}$$

y_i, y_{i+1} represents the size of hidden layer before and after parameter optimization.

$$a_u = d_u(s_{u-1u}a_{u-1} + e_{u-1}). \tag{12}$$

Formula (12) represents the implicit output of the model. When $d = 1$, it can be obtained that the model vector is 0.

$$a_o = d_o(s_{o-1o}a_{o-1} + e_{o-1}). \tag{13}$$

Formula (13) represents the output data of each layer of the neural network.

$$\beta = \frac{1}{3}\sum_{h}^{d}(p_u - r_j). \tag{14}$$

Formula (14) represents the error range of model training, p_u represents the output value of the last layer.

$$u = 0.6\sum_{1}^{A}\sum_{1}^{B}(t^o - y^o)^3 = \sum_{o=1}^{A}u_o. \tag{15}$$

It first considers the weight change of the output layer of u.

$$\beta(a) = \frac{w(a) = w_1(a_1)w_2(a_2|a_1)\cdots w_c(a_c|a_1\cdots a_c)}{y(a) = y_1(a_1)y_2(a_2|a_1)\cdots y_c(a_c|a_1\cdots a_c)}. \tag{16}$$

The weight (16) represents the importance formula; among them,

$$\beta_j(a_j) = \beta_{j-1}(a_{j-1})\frac{y_j(a_{j-1})}{w_j(a_{j-1})}. \tag{17}$$

The forward relay formula of convolution layer is as follows:

$$u_n^x = f\left(\sum_c u_x^{x-1} \times W_L^x + C_n^x\right). \tag{18}$$

n represents the subscript, W_L represents the set of $x - 1$ layers connected with L feature maps of x layer, and C represents the convolution window.

3.3. Overview of Emotion Classification. With the rise of Internet technology, the relationship between people and people is becoming closer and closer. More and more people express their attitudes on the Internet. However, the information on the Internet of Things is too complicated, which also makes it difficult to sort out all kinds of information. Emotion classification is an integral part of emotion analysis, and emotion classification is a special text classification. Based on financial news, this paper mainly focuses on the classification of emotional tendency of text. The analysis of emotional tendency of financial news is our ultimate goal. News is a description of facts, which should abide by the "principle of authenticity." News narration generally shows the characteristics of "low subjectivity." Because the subjective characteristics of news are not obvious, it is not easy to carry out emotional analysis.

Sentence level emotion classification is a fine-grained emotion classification. For a given piece of text data, it first does sentence segmentation and locates to the level of sentence group or sentence block, then classifies the emotion of the sentence group or sentence block, and finally outputs the emotional tendency of the sentence group or sentence block. If efficiency is considered when classifying, the length of sentences needs to be considered.

When classifying the emotion of news, we need to consider the emotional words of subject sentences. After finding emotional words, they use relevant classification algorithms to calculate them. By counting the number of commendatory and derogatory words in the sentence, we can judge

the emotional tendency of the sentence, so as to determine the emotional attitude of the whole news. Figure 5 shows the system structure of emotion classification using artificial intelligence method:

4. Emotion Classification Experiment of Financial News

4.1. Financial News Data. With the development of Internet of Things and information technology, the data scale is developing rapidly. Efficient integration of all kinds of data is conducive to improving the utilization of resources. Since China's entry into WTO, financial information from all over the world has poured in. The correct classification and interpretation of financial news is conducive to grasp the economic law and improve the accuracy of decision-making for the audience.

According to the data in Table 1, we have investigated 130 financial news in the surrounding areas and simply classified them. According to the survey data, there are 33 articles on macroeconomy in the news, accounting for 25.3%. 36 articles explored industrial economy in the news, accounting for 27.7%; 21 articles explored financial development in the news, accounting for 16.2%; 27 articles explored the development of market economy in the news, accounting for 20.8%. 13 articles explored policies and measures in the news, with a proportion of 10%. According to the data, there are more news on macroeconomy and industrial development in financial news. It shows that people pay more attention to industrial economy in the current economic development. Among all the report categories, the policy news is the least, which is consistent with the actual situation of the introduction of the policy. It is noteworthy that the proportion of such news is increasing, indicating that people have paid more attention to the financial industry in recent years. This also shows the importance of classifying financial news.

According to the data in Table 2, we have investigated the publishing institutions of financial news. According to the survey, the news released by colleges and universities is 4, and the proportion is 3%. Caixin's news is 20, with a proportion of 15%. The news of official institutions is 30, with a proportion of 23%. The number of news released by enterprise organizations is 33, accounting for 26%. The news released by other media is 17, with a proportion of 13%. The number of news released by sorting out public materials was 26, accounting for 20%. According to the data, the proportion of financial news released by enterprise organizations and official institutions is large, which is very different from other types of news. In financial news, the data is mainly financial related information. Compared with other institutions, enterprises are easier to obtain and the data is true. For this reason, financial news is mostly reported by enterprises and official institutions. In addition, it is worth paying attention to the relevant financial news reported through public data. This kind of news is equivalent to the integrated release of data and information, and there are many such reports. It shows that people need to integrate financial information, which is also in line with today's fast pace of life.

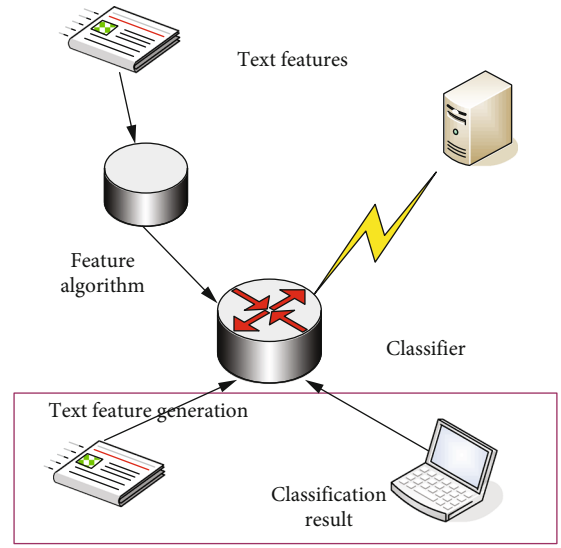

Figure 5: System structure of artificial intelligence method for sentiment classification.

4.2. News Classification Test. News is news that everyone can see. Everyone has his own opinion. Based on this situation, the same news will have different comments with different attitudes. Sentence level emotion classification is a fine-grained emotion classification. For a given piece of text data, it first does sentence segmentation and locates it at the level of sentence group or sentence block. It then classifies the emotion of the sentence group or sentence block and finally outputs the emotional tendency of the sentence group or sentence block. In order to classify the emotion of financial news, we have explored different algorithms, as shown below:

According to the data in Table 3, we have classified the financial news above. In the calculation and comparison, we select three reference models. Firstly, we use traditional methods to classify emotion types, in which the accuracy rate of single word classification is 94.7%, the recall rate is 94.3%, and the V value is 94.5%. The accuracy rate of random vocabulary classification was 86.3%, the recall rate was 86.5%, and the V value was 86.43%. The correct rate of word pair vector classification is 92.6%, the recall rate is 92.66%, and the V value is 92.57%. According to the data, under the calculation of traditional methods, the word vector generated by running a single word is the best, and the effect of random words is the worst. Therefore, when using word2vec for experiments, the optimal feature processing method is to use a single word vector.

According to the data in Table 4, when classifying emotions, we also use artificial intelligence method for comparative analysis. Under artificial intelligence technology, the accuracy rate of single word classification is 93.2%, the recall rate is 93.3%, and the V value is 93.27%. The accuracy rate of random vocabulary classification was 90.6%, the recall rate was 90.64%, and the V value was 90.61%. The correct rate

Table 1: Survey data analysis of financial news selection categories.

Category	Length	Proportion
Macroeconomics	33	25.3
Industry	36	27.7
Finance	21	16.2
Market	27	20.8
Policy	13	10

Table 2: Analysis of financial news sources survey.

Category	Length	Proportion
Efficient institutions	4	3
Caixin	20	15
Official institutions	30	23
Corporate organizations	33	26
Other media	17	13
Public information collation	26	20

Table 3: Traditional model test situation.

Category	Correct rate	Recall rate	V
Individual vocabulary	94.7	94.3	94.5
Random words	86.3	86.5	86.43
Word pair vector	92.6	92.66	92.57

Table 4: Artificial intelligence model test situation.

Category	Correct rate	Recall rate	V
Individual vocabulary	93.2	93.3	93.27
Random words	90.6	90.64	90.61
Word pair vector	94,4	94.66	94.57

of word pair vector classification is 94.4%, the recall rate is 94.66%, and the V value is 94.57%. According to the data, under the algorithm of artificial intelligence, the word vector generated by word pair vector is the best, and the effect of random vocabulary is the worst.

5. Result of Emotion Classification

5.1. Emotion Classification. In a complete news, the vocabulary involved is very large. News is a description of facts, which should abide by the "principle of authenticity." News narration generally shows the characteristics of "low subjectivity." Because the subjective characteristics of news are not obvious, it is not easy to carry out emotional analysis. However, words other than nonobjective descriptions will be collected in the overview of the whole news. We can classify the news according to these words.

According to the data in Figure 6, we made a comparative analysis on the emotional classification of news under the same conditions in the experiment. Firstly, we use artificial intelligence technology to analyze the overall situation. First, when the news theme word is 1, the accuracy of positive emotion is 48%, and the accuracy of negative emotion is 57%. When the news theme word is 3, the accuracy of positive emotion is 0%, and the accuracy of negative emotion is 59%. When the news theme word is 6, the accuracy of positive emotion is 52%, and the accuracy of negative emotion is 66%. When the news theme word is 9, the accuracy of positive emotion is 41%, and the accuracy of negative emotion is 44%. When the news theme word is 12, the accuracy of positive emotion is 33%, and the accuracy of negative emotion is 37%. According to the data, when the subject word is 6, the accuracy of emotion analysis is the highest.

In addition to the analysis of the full text, we also analyze the topic sentences. According to the data, when the news theme word is 1, the accuracy of positive emotion is 67%, and the accuracy of negative emotion is 76%. When the news theme word is 3, the accuracy of positive emotion is 68%, and the accuracy of negative emotion is 76%. When the news theme word is 6, the accuracy of positive emotion is 69%, and the accuracy of negative emotion is 78%. When the news theme word is 9, the accuracy of positive emotion is 60%, and the accuracy of negative emotion is 70%. When the news theme word is 12, the accuracy of positive emotion is 56%, and the accuracy of negative emotion is 65%. According to the comparison of the two groups of data, the accuracy of using topic sentences to analyze financial news is higher, and it also reaches the highest level when the topic word is 6.

In the experiment, we not only analyzed the emotional accuracy but also analyzed the positive and negative meanings. According to the data in Figure 7, we also conducted experiments on the full text and topic sentences. First of all, from the effect of the full text, when the news theme word is 1, the accuracy of positive emotion is 67%, and the accuracy of negative emotion is 78%. When the news theme word is 3, the accuracy of positive emotion is 65%, and the accuracy of negative emotion is 74%. When the news theme word is 6, the accuracy of positive emotion is 60%, and the accuracy of negative emotion is 68%. When the news theme word is 9, the accuracy of positive emotion is 51%, and the accuracy of negative emotion is 59%. When the news theme word is 12, the accuracy of positive emotion is 43%, and the accuracy of negative emotion is 54%. According to the data, when analyzing the positive and negative emotions of the full text, the more the number of topics, the lower the accuracy, and the decline rate of positive emotions is greater than that of negative emotions.

From the analysis of the positive and negative meanings of the topic sentence, when the news topic word is 1, the accuracy of positive emotion is 73%, and the accuracy of negative emotion is 74%. When the news theme word is 3, the accuracy of positive emotion is 74%, and the accuracy of negative emotion is 78%. When the news theme word is 6, the accuracy of positive emotion is 76%, and the accuracy of negative emotion is 80%. When the news theme word is 9, the accuracy of positive emotion is 68%, and the accuracy of negative emotion is 75%. When the news theme word is 12, the accuracy of positive emotion is 64%, and the accuracy of negative emotion is 70%. According to the data, when

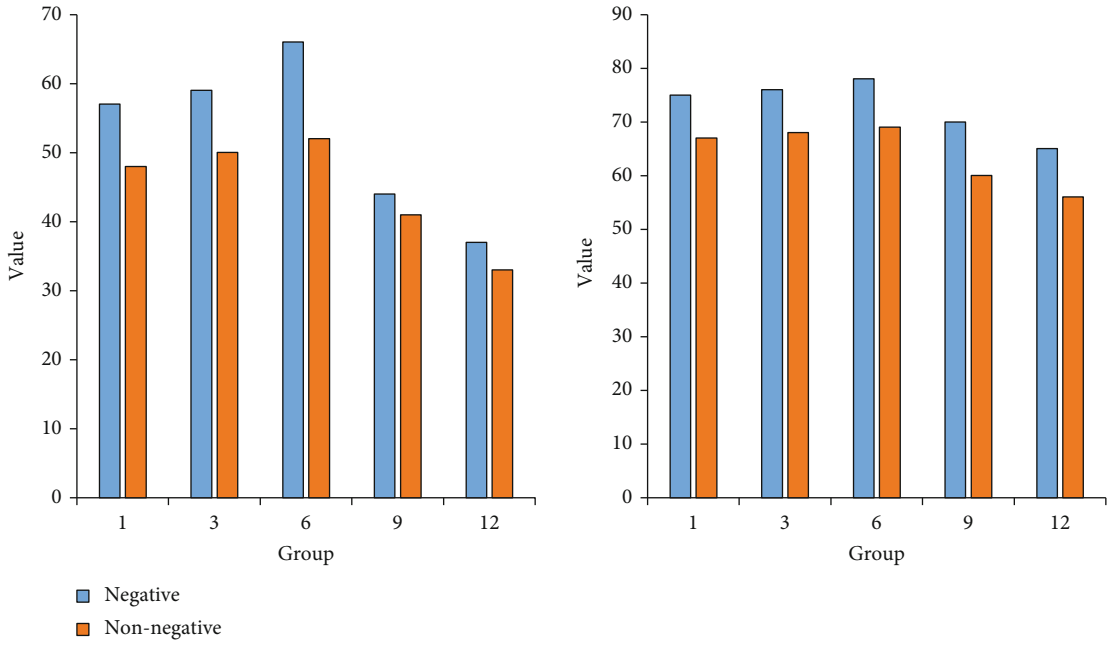

Figure 6: Prior knowledge and accuracy analysis.

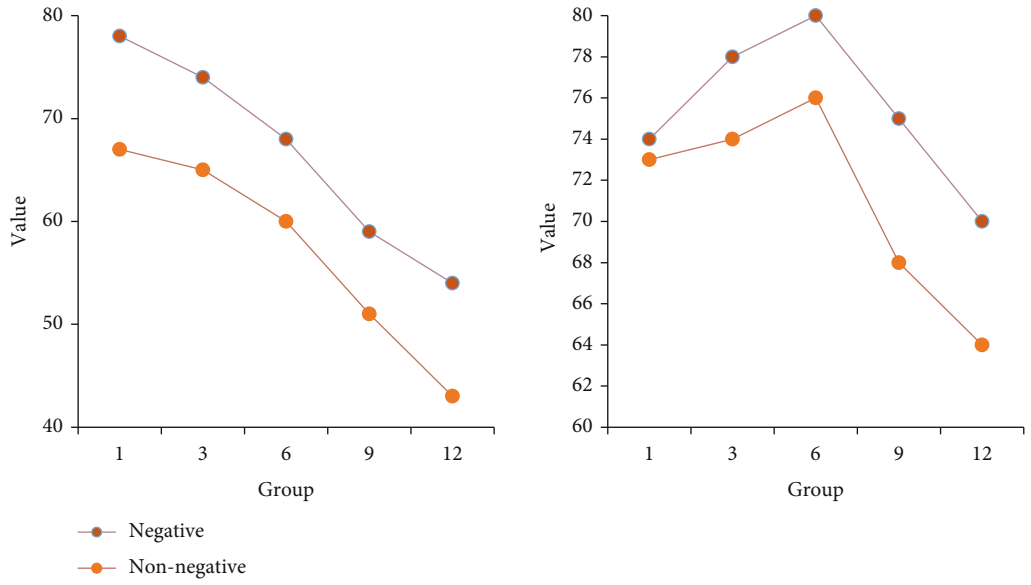

Figure 7: Analysis of emotions and attitudes toward praise and criticism.

analyzing the topic sentence, its accuracy first increases and then decreases. Although its accuracy decreases in the later stage, through the analysis and comparison of the full text, its accuracy is still high. Therefore, when analyzing the accuracy of financial news, we need to start from the subject sentence, and the subject words should not be too many.

5.2. Title Affectivity. The title includes the main title and subtitle. In many cases, we can have a general understanding of the attitude of the whole news according to the title. It is also suitable in financial news. To this end, we use artificial intelligence technology to classify the news according to the title.

According to the data in Figure 8, we have compared the full text and topic sentences, respectively. Firstly, we analyze the full text. When the news theme word is 1, the accuracy of positive emotion is 63% and the accuracy of negative emotion is 68%. When the news theme word is 3, the accuracy of positive emotion is 62%, and the accuracy of negative emotion is 69%. When the news theme word is 6, the accuracy of positive emotion is 61%, and the accuracy of negative emotion is 72%. When the news theme word is 9, the accuracy of positive emotion is 50%, and the accuracy of negative emotion is 60%. When the news theme word is 12, the accuracy of positive emotion is 44%, and the accuracy of negative

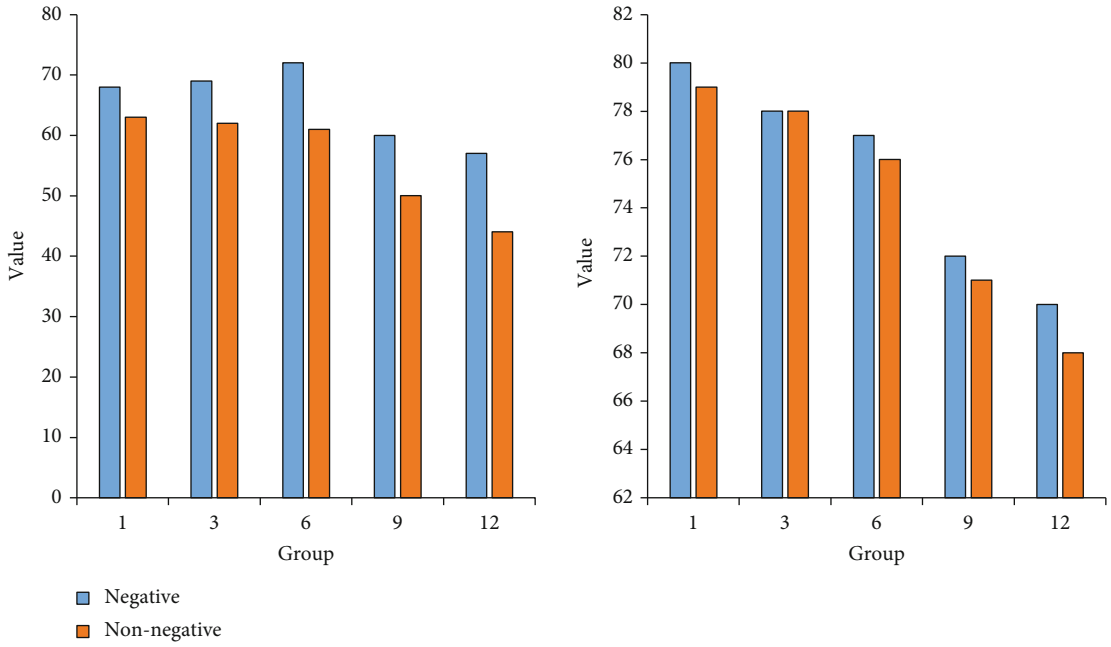

Figure 8: Title sentiment analysis.

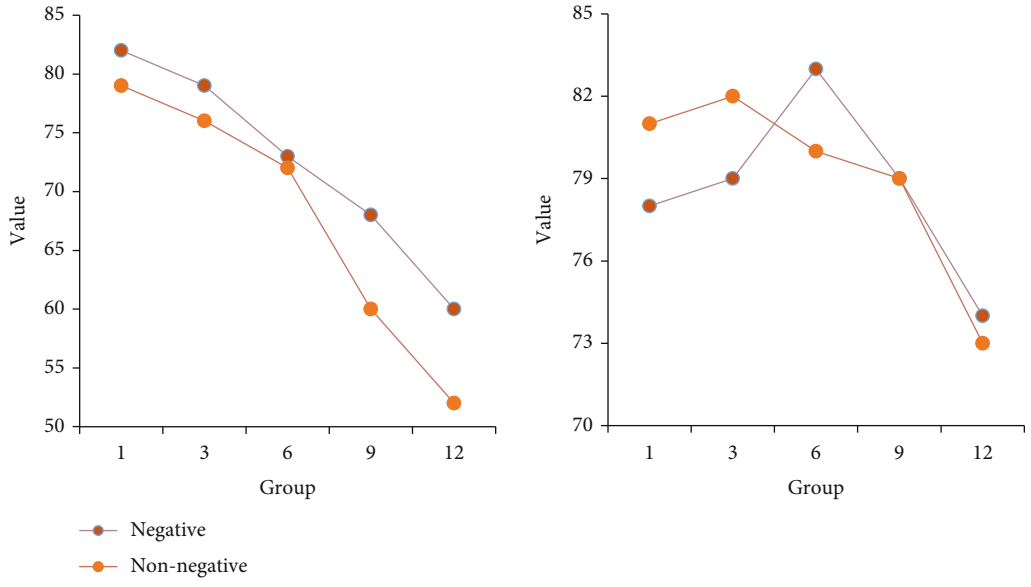

Figure 9: News comprehensive sentiment classification.

emotion is 57%. According to the data, the positive emotion analysis of the full text decreases with the increase of subject words. When the number of subject words is greater than 6, the decline is larger and larger. Therefore, it can be seen that the number of subject words should not be too large.

From the analysis of the topic sentence, when the news topic word is 1, the accuracy of positive emotion is 79% and the accuracy of negative emotion is 80%. When the news theme word is 3, the accuracy of positive emotion is 78%, and the accuracy of negative emotion is 78%. When the news theme word is 6, the accuracy of positive emotion is 76%, and the accuracy of negative emotion is 77%. When the news theme word is 9, the accuracy of positive emotion is 71%, and the accuracy of negative emotion is 72%. When the news theme word is 12, the accuracy of positive emotion is 68%, and the accuracy of negative emotion is 70%. According to the data, although the accuracy of the topic sentence is higher than that of the full text on the whole, its accuracy is declining, and there is little difference between the accuracy of positive emotion and negative emotion. It shows that the analysis of title and subject words is a more effective way.

5.3. Comprehensive Emotion Classification of News. In the above, we analyzed the emotion of news from different angles. In order to improve the comprehensiveness of the analysis, we combined the commendatory and derogatory meaning with the title for an overall analysis. The details are as follows:

According to the data in Figure 9, we analyzed the news from the full text and subject words, respectively. The accuracy rate of the full-text news is 82% when the emotion is negative, and the accuracy rate of the full-text news is 1%. When the news theme word is 3, the accuracy of positive emotion is 76%, and the accuracy of negative emotion is 79%. When the news theme word is 6, the accuracy of positive emotion is 72%, and the accuracy of negative emotion is 73%. When the news theme word is 9, the accuracy of positive emotion is 60%, and the accuracy of negative emotion is 68%. When the news theme word is 12, the accuracy of positive emotion is 52%, and the accuracy of negative emotion is 60%. According to the data, when all elements are considered comprehensively, the accuracy shows a downward trend, and the decline increases after the subject word exceeds 6. Therefore, it can be seen that the subject word needs to be reasonably selected in the comprehensive analysis.

From the analysis of emotional topic sentences, when the news topic word is 1, the accuracy of positive emotion is 81% and that of negative emotion is 78%. When the news theme word is 3, the accuracy of positive emotion is 82%, and the accuracy of negative emotion is 79%. When the news theme word is 6, the accuracy of positive emotion is 83%, and the accuracy of negative emotion is 80%. When the news theme word is 9, the accuracy of positive emotion is 79%, and the accuracy of negative emotion is 79%. When the news theme word is 12, the accuracy of positive emotion is 73%, and the accuracy of negative emotion is 74%. According to the data, the positive emotion analysis shows a downward trend, but its negative situation shows an upward trend first and then a downward trend. Therefore, when analyzing the attitude of news as a whole, we need to separate positive emotion from negative emotion and select different numbers of subject words when analyzing different emotional attitudes.

6. Conclusion

The continuous progress of the economy has forced the financial news to change to the direction of specialization, but the financial news has a short development time in China, and there are still many aspects to be improved. In order to adapt to the form of rapid economic development, it must classify financial news and provide accurate financial information for more people. This paper is aimed at studying the emotional classification method of financial news based on artificial intelligence and expecting to use artificial intelligence technology and classification method to classify financial news. It allows more people to know the implied information of financial information and promotes economic development. Although this paper has some conclusions on the classification of news, there are still deficiencies. This paper makes positive and negative classification for different news, but there is neutral news in news, which is not described in this paper.

Data Availability

No data were used to support this study.

Conflicts of Interest

There is no potential conflict of interest in this study.

References

[1] S. T. Park, D. Y. Kim, and G. Li, "An analysis of environmental big data through the establishment of emotional classification system model based on machine learning: focus on multimedia contents for portal applications," *Multimedia Tools and Applications*, vol. 80, no. 26-27, pp. 34459–34477, 2021.

[2] S. Sendari, I. Zaeni, D. C. Lestari, and H. P. Hariyadi, "Opinion analysis for emotional classification on emoji tweets using the Naïve Bayes algorithm," *Knowledge Engineering and Data Science*, vol. 3, no. 1, pp. 50–59, 2020.

[3] K. Saranya and S. Jayanthy, "Machine learning techniques for onto-based emotional classification of text," *International Journal of Pure and Applied Mathematics*, vol. 118, no. 8, pp. 357–362, 2018.

[4] S. Kuchibhotla and M. S. R. Niranjan, "Emotional classification of acoustic information with optimal feature subset selection methods," *International Journal of Engineering & Technology*, vol. 7, no. 2.32, pp. 39–43, 2018.

[5] E. M. Imah and E. Rahmawati, "Classification of emotional state based on EEG signal using AMGLVQ," *Procedia Computer Science*, vol. 157, pp. 552–559, 2019.

[6] K. N. Rejith and K. Subramaniam, "Classification of emotional states in Parkinson's disease patients using machine learning algorithms," *Biomedical and Pharmacology Journal*, vol. 11, no. 1, pp. 333–341, 2018.

[7] H. Lu, Y. Li, and C. Min, "Brain intelligence: go beyond artificial intelligence," *Mobile Networks and Applications*, vol. 23, no. 7553, pp. 368–375, 2017.

[8] D. Hassabis, D. Kumaran, C. Summerfield, and M. Botvinick, "Neuroscience-inspired artificial intelligence," *Neuron*, vol. 95, no. 2, pp. 245–258, 2017.

[9] C. Cath, S. Wachter, B. Mittelstadt, M. Taddeo, and L. Floridi, "Artificial intelligence and the 'good society': the US, EU, and UK approach," *Science and Engineering Ethics*, vol. 24, no. 7625, pp. 1–24, 2017.

[10] A. F. Chen, A. C. Zoga, and A. R. Vaccaro, "Point/counterpoint: artificial intelligence in healthcare," *Healthcare Transformation*, vol. 2, no. 2, pp. 84–92, 2017.

[11] R. K. Kaliyar, A. Goswami, and P. Narang, "EchoFakeD: improving fake news detection in social media with an efficient deep neural network," *Neural Computing and Applications*, vol. 33, no. 14, pp. 8597–8613, 2021.

[12] Y. Wu, "The current situation and innovation of news communication under the environment of financial media," *Journal of Environmental and Public Health*, vol. 2022, Article ID 3440217, 10 pages, 2022.

[13] R. Li, Z. Zhao, X. Zhou et al., "Intelligent 5G: when cellular networks meet artificial intelligence," *IEEE Wireless Communications*, vol. 24, no. 5, pp. 175–183, 2017.

[14] X. Zheng, G. Zhu, N. Metawa, and Q. Zhou, "Machine learning based customer meta-combination brand equity analysis for marketing behavior evaluation," *Information Processing and Management*, vol. 59, no. 1, article 102800, 2022.

[15] Z. Zhang, Y. Zhang, D. Shen, and W. Zhang, "The dynamic cross-correlations between mass media news, new media news, and stock returns," *Complexity*, vol. 2018, Article ID 7619494, 11 pages, 2018.

[16] E. Inan, "ZoKa: a fake news detection method using edge-weighted graph attention network with transfer models," *Neural Computing and Applications*, vol. 34, no. 14, pp. 11669–11677, 2022.

[17] V. Kakulapati, "Classification of emotional intelligence of sentiment polarity," *The Journal of Scientific and Engineering Research*, vol. 8, no. 9, pp. 381–386, 2017.

[18] C. Liu, W. Li, and X. Bi, "Emotional feature extraction and classification based on EEG signals," *Chinese Journal of Sensors and Actuators*, vol. 32, no. 1, pp. 82–88, 2019.

[19] P. Zola, P. Cortez, and E. Brentari, "Twitter alloy steel disambiguation and user relevance via one-class and two-class news titles classifiers," *Neural Computing and Applications*, vol. 33, no. 4, pp. 1245–1260, 2021.

[20] K. Topal and G. Ozsoyoglu, "Emotional classification and visualization of movies based on their IMDb reviews," *Interlending & document supply*, vol. 45, no. 3, pp. 149–158, 2017.

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Research Article

Evolutionary Game Analysis of Industry-University-Research Cooperative Innovation in Digital Media Enterprise Cluster Based on GS Algorithm

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In order to study all the advantages and disadvantages of digital media enterprises, technological innovation can only be completed through cooperation. A kind of industry-university-research cooperative innovation evolutionary game method based on GS algorithm is proposed for digital media enterprise clusters. This method analyzes the evolutionary game theory of innovation and puts forward the evolutionary stability strategy of cooperative innovation between enterprises and research institutions. The results show that decreasing V is beneficial for the evolutionary game to approach the equilibrium point (1,1); that is, the greater the cost of independent innovation is compared with collaborative innovation, the stronger the willingness of both sides of the game to collaborative innovation. Enterprises and scientific research institutions are two different subjects with different interests. If they want to complete innovation cooperation, they need to formulate a perfect set of rules so that both sides of the game can carry out cooperative innovation according to the principles, so as to achieve the goal of cooperation.

1. Introduction

For enterprises or decision-makers in reality, complete rationality is difficult to meet high standards and requirements, especially in the current economic environment, and when decision-making problems are relatively complex, the ideal limitations of decision-makers are very obvious. In this case, evolutionary game theory can provide these groups with more abundant game theory tools to deal with problems related to rational limitations, while in terms of industrial clusters and cooperative innovation behaviors among enterprises, there is a close relationship between them [1]. Industrial cluster can gather the same type of enterprises or related enterprises together and promote win-win cooperation among enterprises by means of cluster supply chain relationship. Enterprises in the cluster can also promote the formation of cooperative innovation network through the evolution of industry-university-research cooperative innovation, and the phenomenon of technology diffusion and knowledge spillover under this innovation mode can promote the spatial aggregation of enterprises. In the mode of industrial cluster, enterprise cooperative innovation between behavior is based on supply chain network and cluster supply chain network and needed a chain in the middle and lower reaches of the suppliers, manufacturers, distributors, and other support and also needed to merge the government agencies, research institutions, and financial institutions to provide support for cooperative innovation of industrial cluster [2]. Therefore, it can be seen that the evolution of industry-university-research cooperative innovation in enterprise clusters is not accomplished overnight and requires a lot of attention. Therefore, starting with GS algorithm and taking digital media enterprises (Figure 1) as the research object, this article focuses on the evolutionary game of cluster industry-university-research cooperative innovation.

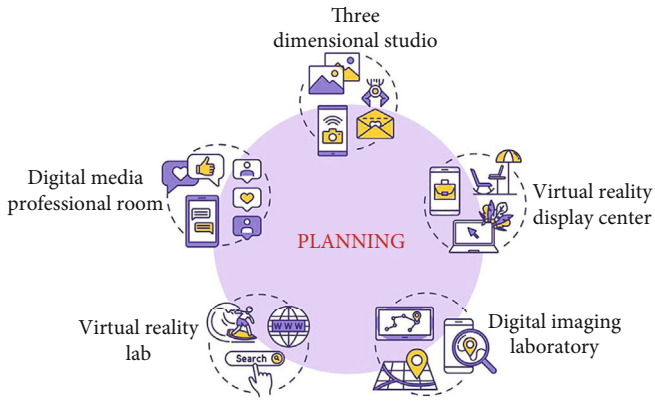

Figure 1: Digital media technology.

2. Literature Review

Wen et al. also introduced concepts such as enterprise cluster and industrial area for industrial cluster, but "industrial cluster" is the most widely used. The research on industrial cluster mainly focuses on the forming principle, the source of competitive advantage, and the evolution mechanism of industrial cluster [3]. According to Kobrin et al., the new economic geography school believes that the aggregation of industries in a certain region is caused by the external economy of enterprises, leading to the aggregation of related industries, and then the phenomenon of scale economy, scope economy, and path dependence is generated. And he thinks that historical accidental factors play an important role in the formation of industrial clusters [4]. Gao and Ding have made a comprehensive and specific definition of industrial cluster: Industrial cluster refers to the collection of enterprises and institutions in a specific field that are interconnected and located together, including a group of interconnected enterprises and other entities that play an important role in competition. In addition, he believes that industrial clusters will extend up and down the industrial chain, involving raw material suppliers and distributors, and there will be auxiliary enterprises and institutions to join [5]. Wang, Z. et al. analyzed the formation principle of industrial clusters in detail. Through the diamond model theory, he concluded that talent gathering, unobstructed information flow, cooperation between enterprises, interdependence between enterprises, capital supply, and public attitude are the endogenous factors promoting the formation of industrial clusters, and the government policy is the external driving force to promote the formation of industrial clusters, and the two together constitute seven main driving mechanisms for the formation of industrial clusters [6]. Lara-Prieto and Flores-Garza divided the location factors affecting industrial clusters into agglomeration factors and regional factors and believed that agglomeration factors were composed of two stages: The first stage is the scale expansion of enterprises through their own advantages. When enterprises expand to a certain scale, relevant industries will gather to them. This is the second stage of agglomeration factor, which is also the aggregation stage of relevant enterprises within the industry [7]. Zhang et al. believe that industrial clusters are formed when enterprises gather to a certain scale. In this book, he also analyzes the reduction of general costs as the reason for the clustering of industries in certain regions. Since the reform and opening up, China's economy has achieved rapid growth, especially after the 1980s, various regional economic factors are constantly active [8]. Mahmoud et al. took them as objects to academic the theory of industrial clusters. Starting from the core competitiveness of enterprises in the cluster, the learning ability of the cluster, and the aggregation degree of resources in the cluster, some scholars have concluded that the internal and external environment of the cluster plays an important driving role in the formation of the cluster brand [9]. Gangwar et al. divided the formation of cluster brands into four stages: brand initial stage, regional brand stage, cluster brand establishment stage, and brand maturity stage; Based on the academic of industrial parks in western China, it is found that the current construction of industrial parks in China only pays attention to the geographical concentration of enterprises and neglects the economic benefits of industrial clusters [10]. De Ayala et al. analyzed this phenomenon by applying the theory of regional economics and the theory of industrial cluster development and pointed out that this phenomenon was caused by the misunderstanding of the concept between industrial cluster and industrial park or the short-term behavior taken by the local government due to the policy pressure [11]. This phenomenon is not conducive to the long-term development of regional economy. Based on this, they put forward some policy suggestions to transform these unreasonable industrial parks into industrial clusters.

3. Method

3.1. Enterprise Industry-University-Research Cooperation GS Algorithm Matching Process. Small and medium-sized enterprises (SMES), the demander of technology in the industry-university-research cooperation, aim to maximize economic

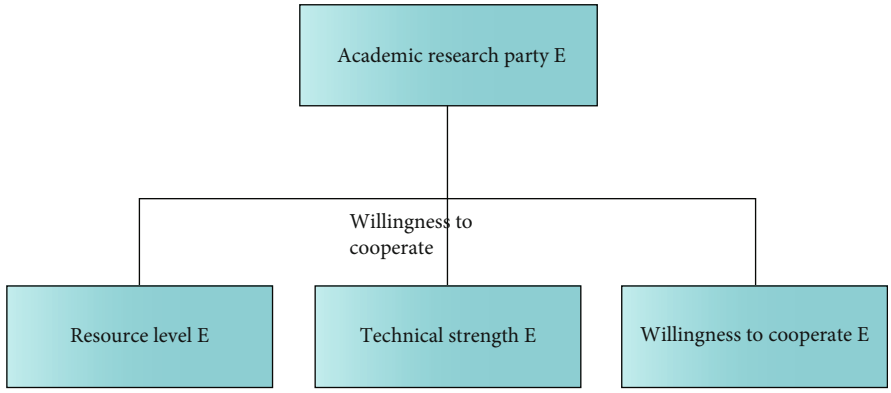

Figure 2: Factors taken into consideration by the industry side in preference to the research side.

benefits, whose purpose of participating in the cooperation is to improve their R&D strength, so that they can be in a favorable position in the future competition. As the product of the market economy, enterprises have information advantages that the academic and research sides do not have. They have good platforms and resources for the marketization of achievements, such as management and capital, and can transform scientific research resources into real productivity [12]. They can quickly grasp the changes of market demand through timely information feedback, When their research and development strength (except some large enterprises have their own research and development centers, which can develop innovative results to meet market demand, most small and medium-sized enterprises do not have these strength) cannot realize the innovation of technological products, the external competitive pressure will be transformed into the internal motivation to seek cooperation.

3.1.1. Analysis of Preference Factors. Colleges and universities and institutes are national key basic research; by the analysis of the above literature review, the small and medium-sized enterprises industry-university-institute cooperation pattern has a lot; for different cooperation modes, the factors involved are different, and the process is complex, and most of them are qualitative indicators [13]. Therefore, the industry side considers different factors in its preference for the research side. Based on interviews with small and medium-sized enterprises and relevant literature on their choice of cooperation partners, this article establishes the factors that small and medium-sized enterprises prefer to consider for universities and institutes, as shown in Figure 2.

3.1.2. The Formation of Preference Ranking of Industry Side. Since the factors used to evaluate the academic and research side are almost qualitative indicators with great uncertainty and difficulty in quantification, it is difficult to form the industrial side's preference for the academic and research side with quantified indicators. In this article, the fuzzy comprehensive evaluation method is used to analyze the formation of the preference ranking list of the industrial side to the academic and research side, which can transform the qualitative index into quantitative index [14].

3.1.3. The Fuzzy Evaluation Matrix Is Established. Fuzzy evaluation matrix of industrial side to academic and research side:

$$R = (R_1, R_2, R_3, R_4, R_5). \tag{1}$$

According to the questionnaire collected by industry experts and normalized, the fuzzy evaluation values of each factor are shown in Table 1:

Firstly, a fuzzy comprehensive evaluation is carried out on the second-level indicators, and its matrix is set as

$$\begin{aligned}
&B = (B_1, B_2, B_3),\\
&B_1 = W_1 \times R_1 = (0.15, 0.2, 0.4, 0.25)\\
&\quad \times \begin{pmatrix} 0.2 & 0.3 & 0.3 & 0.1 & 0.1 \\ 0.4 & 0.1 & 0.3 & 0.2 & 0 \\ 0.4 & 0.2 & 0.1 & 0.2 & 0.1 \\ 0.3 & 0.3 & 0.2 & 0.2 & 0 \end{pmatrix}\\
&\quad = (0.345, 0.22, 0.195, 0.185, 0.555),\\
&B_2 = W_2 \times R_2 = (0.1, 0.4, 0.2, 0.3)\\
&\quad \times \begin{pmatrix} 0.5 & 0.4 & 0.0 & 0 & 0.1 \\ 0.4 & 0.2 & 0.1 & 0.3 & 0.1 \\ 0.4 & 0.2 & 0.2 & 0.2 & 0 \\ 0.3 & 0.3 & 0.1 & 0.1 & 0.1 \end{pmatrix}\\
&\quad = (0.34, 0.25, 0.15, 0.19, 0.07),\\
&B_3 = W_3 \times R_3 = (0.4, 0.4, 0.2)\\
&\quad \times \begin{pmatrix} 0.6 & 0.1 & 0.2 & 0.1 & 0 \\ 0.4 & 0.3 & 0.2 & 0.1 & 0 \\ 0.5 & 0.2 & 0 & 0.2 & 0.1 \end{pmatrix}\\
&\quad = (0.5, 0.2, 0.16, 0.12, 0.02).
\end{aligned} \tag{2}$$

Table 1: Industrial party's evaluation matrix of academic and research party's ambiguity.

Second-level indicators	V_1	V_2	V_3	V_4	V_5
E_{11}	0.2	0.3	0.3	0.1	0.1
E_{12}	0.4	0.1	0.3	0.2	0
E_{13}	0.4	0.2	0.1	0.2	0.1
E_{14}	0.3	0.3	0.2	0.2	0
E_{21}	0.5	0.4	0.1	00.3	0
E_{22}	0.3	0.2	0.1	0.2	0.1
E_{23}	0.4	0.2	0.2	0.1	0
E_{24}	0.3	0.3	0.2	0.1	0.1
E_{31}	0.6	0.1	0.2	0.1	0
E_{32}	0.4	0.3	0.2	0.1	0
E_{33}	0.5	0.2	0	0.2	0.1

First-level indicators.

Secondly, fuzzy comprehensive evaluation is carried out on the first-level indicators.

$$A = W \times B = (0.35, 0.4, 0.25) \times \begin{pmatrix} 0.345 & 0.22 & 0.195 & 0.185 & 0.055 \\ 0.34 & 0.25 & 0.15 & 0.19 & 0.07 \\ 0.50 & 0.20 & 0.16 & 0.12 & 0.02 \end{pmatrix} = (0.38175, 0.227, 0.16825, 0.17075, 0.05225). \quad (3)$$

(1) Academic and Research Party. (1)1. Factors Taken into Consideration by the Academic and Research Side to the Industry Side and the Formation of Preference Ranking. In order to cooperate with the industry side, the academic and research side must first consider various factors and standards of the industry side; the same as the industry's selection of academic and researcher, the selection of academic and researcher is mostly at the qualitative stage at present, and many of them rely on subjective speculation. With the help of the relevant indicators of the balanced Scorecard theory and the cooperation willingness of the industry [15], this article designs the indicator factors considered by the academic and researcher for the industry, as shown in Table 2:

The balanced scorecard method balances the relationship between long-term and short-term indicators, internal and external indicators, financial and nonfinancial indicators, and related interest groups. The biggest advantage is to consider the innovation and learning perspective of the enterprise. However, since BSC is used to measure the performance and evaluate the strategy of an enterprise, it is impossible for the academic and research institute to obtain every indicator. Moreover, there are many indicators, and the academic and research institute has no energy to specialize in them. Therefore, the academic and research institute only use BSC to analyze the factors that the academic and research institute consider in favor of the industry.

(1)2. The Formation of Preference Ranking of Academic and Research Parties. This section is the same as the process of forming the preference ranking list of the industry side to the research side, and the fuzzy comprehensive evaluation method is used to form the preference ranking list of the research side to the industry side. The method is similar, but due to time constraints, the process is omitted here.

3.2. The Matching Process of GS Algorithm Matching Model for Small and Medium-Sized Enterprises. According to the known preference ranking list, it is assumed that small and medium-sized enterprises (i.e., industry) need to seek partners, while universities and institutes (i.e., universities and research institutes) also need to seek partners, but it is assumed that the demand is not as urgent as that of industry:

First of all, the industrial side of m expresses its intention to cooperate with the leading industrial side according to the ranking of the academic and research side [16]. After receiving the intention of the industrial side, the academic and research side accepts the industry side ranked in the first place according to its own ranking and rejects all the industries behind the ranking.

Secondly, the academic and research party ranked second in the rejected industry direction shows intention to cooperate with it. If the academic and research party has no partner, it will accept the industry party ranked first. At the same time, considering the situation that the academic and research party has already cooperated with them, if the industrial party that expresses its intention to cooperate with them now ranks ahead of the existing cooperative partner, the industrial party that expresses its intention to cooperate with them now is accepted, and the former cooperative partner is rejected; If the industry party that expresses its intention to cooperate with it is ranked behind the existing partner, it will reject the industry party that expresses its intention to cooperate with it and continue to cooperate with the former industry party.

In accordance with the above steps, the industry parties that are not accepted continue to express their interest to the other parties in order of preference until they are accepted by one of the parties [4]. The academic and research side will accept the industry side ranked first according to their preference, until all the industry side and the academic and research side find their own cooperation partners; the match will end, which is always stable. Intuitively, if an industry prefers to work with a particular institution rather than the one it is currently working with, it is because that particular institution has rejected it. Similarly, if a university prefers to work with a particular industry rather than its current partner, it is because that particular industry is already working with another university, but not itself.

3.3. Matching Process of GS Algorithm under Full Matching. In fact, there will be a lot of problems when GS algorithm is applied to the matching problem of industry-university-

Table 2: Factors taken into consideration for the preference of the academic and research parties to the industry side.

Industry party U	Financial perspective	Solvency ratio
		Operating capacity ratio
		Profitability ratio
		The scale of R&D spending
	The customer perspective	Social reputation
		Customer satisfaction
	Internal process perspective U3	Delivery time U31
		Production capacity U3
		Service process U32

research cooperation in SMES, which needs to be paid attention to. In fact, partners will look for a variety of strategic behavior, game behavior, resulting in unstable matching results [5].

3.3.1. The Strategic Behavior of Distorting Preferences of the Industry Side and the Academic Side. The preference ranking list of industry side and academic side is shown in Table 3:

The specific cyclic process of the algorithm model can be deduced from the preference ranking list, as shown in Tables 4 and 5: namely, whether the industry side first expresses the intention to cooperate with the academic and research side or the academic and research side first expresses the intention to cooperate with the academic and research side, the stable matching state can be obtained [17].

However, if e_2 knows that the partner obtained according to the GS algorithm is its third choice, e_2 may take a strategic behavior, distort its preference, and get the partner it thinks is more satisfied while hurting other partners. The rest are unacceptable choices, and the list of preferences becomes Table 6:

3.3.2. Game Behavior between Industry and Academic Research. The particularity of the industry-university-research cooperation of small and medium-sized enterprises, especially the diversification of interest demands in the purpose of economic behavior [18], and the incompleteness of the contract signed by the industry side and the research side, may lead to the distortion of preferences, resulting in strategic behavior, or the game between the two sides. If small and medium-sized enterprises send insincere signals to academic and research side, they need to pay a certain cost, indicating that strong small and medium-sized enterprises send low input resources, while weak small and medium-sized enterprises send high input resources.

In order to make weak small and medium-sized enterprises send out signals of true cooperation, the cost of sending false signals can be increased, so as to curb the speculation of small and medium-sized enterprises [19]. There are a large number of small and medium-sized enterprises, and the competition is not uniform. The academic and research side cannot know which small and medium-sized enterprises have technical needs, and they are unwilling to form a target set of small and medium-sized enterprises. Because universities and institutes are afraid to give their painstaking research and development innovation

Table 3: Preference ranking list of industry and academic.

Preference ranking	Industry party			Academic and research party		
	e_1	e_2	e_3	u_1	u_2	u_3
1	u_1	u_1	u_2	e_1	e_3	e_1
2	u_2	u_2	u_1	e_2	e_1	e_2
3	u_3	u_3	u_3	e_3	e_2	e_3

Table 4: The matching cycle in which the industry side first expresses its intention to cooperate with the academic and research side.

Circulation	u_1	u_2	u_3
The first circulation	e_1e_2	e_3	—
The second circulation	e_1	e_3e_2	
The third circulation	e_1	e_3	e_2

Table 5: Matching cycle process in which academic and research parties express their intention to cooperate with industry parties.

Circulation	e_1	e_2	e_3
The first circulation	u_1u_3	—	u_2
The second circulation	u_1	u_3	u_2

Table 6: Preference ranking list of both industry and academic and research sides.

Preference ranking	Industry side			Academic and research sides		
	e_1	e_2	e_3	u_1	u_2	u_3
1	u_1	u_1	u_2	e_1	e_3	e_1
2	u_2		u_1	e_2	e_1	e_2
3	u_3		u_3	e_3	e_2	e_3

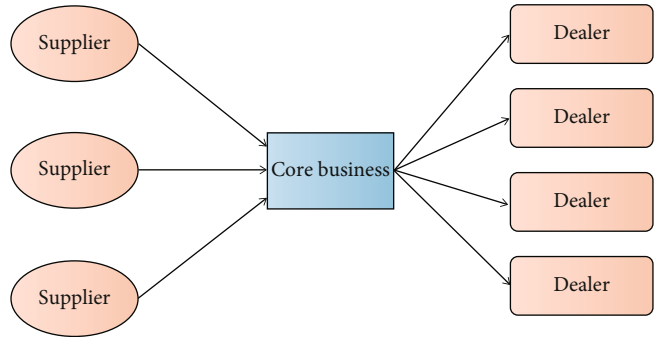

Figure 3: Organizational pattern diagram of single-core cluster supply chain.

results to small and medium-sized enterprises, they rarely consider cooperation with small and medium-sized enterprises, and even if they do consider cooperation with small and medium-sized enterprises, they only carry out low-end cooperation projects. Therefore, there may be universities and institutes do not have a preference ranking list for smes. However, in the algorithm matching model, the matching parties must form a strict preference sorting list and then obtain the matching result through matching GS algorithm, so a place that can form the preference sorting list must be established [20].

3.4. Organization Mode of Industry-University-Research Cluster Supply Chain

3.4.1. Organization Mode of Single-Core Industrial Cluster Supply Chain. The single-core cluster supply chain organization mode means that there is only one core enterprise in the producing area cluster. There are a large number of upstream and downstream enterprises as well as auxiliary enterprises or institutions around them, which form a relatively complete and complex supply chain network system, as shown in Figure 3.

3.4.2. Organization Mode of Multicore Industrial Cluster Supply Chain. The organization pattern of multicore industrial cluster supply chain is the most common in industrial cluster. In this organization mode, the core enterprise, like other links in the supply chain, has multiple competitors or potential competitors. Core enterprises form a complex supply chain network system by cooperating with upstream and downstream enterprises in logistics, capital flow, and information flow [21]. Each core enterprise has trade relations with several upstream and downstream enterprises, and the upstream and downstream enterprises may also have trade relations with several core enterprises at the same time, which makes the supply chain model of multicore industrial cluster more complicated. The multicore cluster supply chain can be divided into parallel multicore cluster supply chain organization mode and cross-multicore cluster supply chain organization mode according to the different cross situations among enterprises, as shown in Figures 4 and 5.

4. Experimental Analysis of Interfirm Cooperative Innovation in Industrial Cluster Supply Chain

4.1. Basic Model Analysis and Establishment

4.1.1. Establishment of Game Matrix. There are two types of enterprises in an industrial cluster, and these two types of enterprises have two behavior choices, respectively, innovation and imitation. If neither of them innovates, they each get a gain of 0, and if one of them innovates, they get a gain of 1. However, due to the technology spillover brought by informal communication in industrial clusters, innovative enterprises can only obtain M $(0.5 < m < 1)$ in income 1. Innovation will have innovation cost, and the enterprise that chooses imitation will gain 1-M through imitation and do not have to pay innovation cost. If both firms innovate, they will each get a return of p. In reality, it is difficult for the enterprises in an industrial cluster to be completely the same. Because of the differences in technological means, human capital, corporate culture, and other aspects, some enterprises are more suitable for innovation, while others are not, which can be reflected in the difference in innovation costs [22]. Therefore, the two types of firms are divided on the basis of their innovation costs. We can assume that the innovation cost of player 1 is lower than that of player 2, namely $z1 < z2$, because player 1 has more talent reserves and a more suitable enterprise culture for innovation. In reality, whether an enterprise innovates or not ultimately depends on which strategy can gain more benefits in market competition. Strategies that can gain more benefits will naturally be imitated and "inherited" by more enterprises, while those that cannot gain more benefits will naturally be abandoned by most enterprises, thus being "eliminated." This process of survival of the fittest does not happen in an instant but needs time.

In order to better reflect and explain the independent innovation behavior of enterprises under the condition of abandoning the completely rational hypothesis, we can only analyze the dynamic evolution process of enterprise innovation behavior determined by market choice. First, assuming that in an industrial cluster, not of all of the enterprise carry out independent innovation at the beginning (this also basically accords with the practice of China's manufacturing

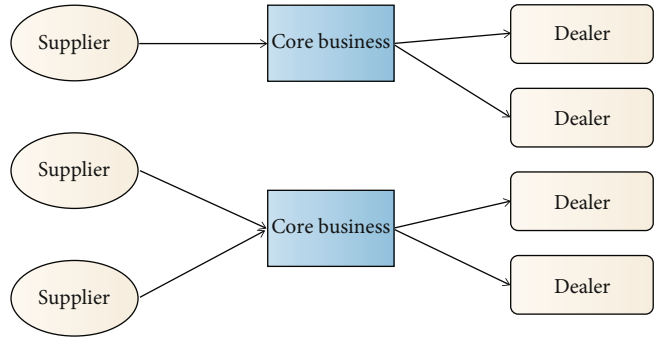

Figure 4: Organizational model of parallel multicore industry standard group.

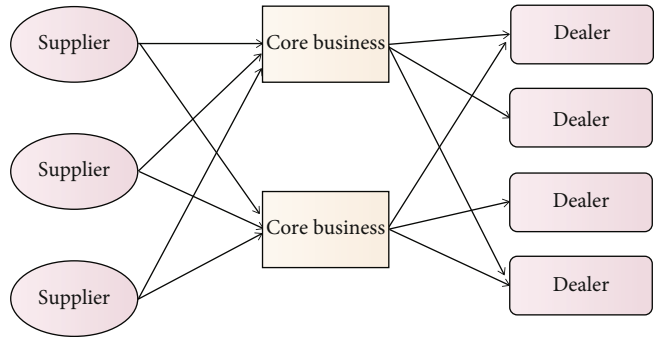

Figure 5: Organizational pattern of cross-type multicore industrial cluster.

industry cluster), but for some reason, there are some enterprises carry out independent innovation, so if this part of the enterprise to obtain the larger income, there will be more enterprises to study the enterprise to carry out the independent innovation strategy. However, if the enterprise of independent innovation fails to achieve success or even leads to losses, other enterprises will learn from experience and give up independent innovation.

4.1.2. Basic Model Analysis. Under normal circumstances, the market demand for products will increase with the increase of cooperative promotion investment between manufacturers and suppliers, and the cost per unit product will decrease with the increase of R&D investment. Assuming that 1 unit of product needs 1 unit of raw material, we can conclude that the total consumer demand function and the cost function of unit product are as follows:

$$\begin{aligned} D(I_r) &= D_0 + aI_r, \\ C(I_s) &= \frac{C_0 - bI_s}{D(I_r)}. \end{aligned} \tag{4}$$

among which $D(I_r)$ is the total demand of consumers, I_r is the cooperative promotion investment between manufacturers and dealers, when $I_r \geq 0$, and then D_0 is the market size when no promotion investment is made.

Through the above analysis, we can conclude that the profit function of the system is

$$\pi_0 = D(I_r)(w - C(I_s) - c_m) - I_r - I_s. \tag{5}$$

w is the unit price of the product and c_m is the production cost of the manufacturer excluding raw materials. In the above profit function, taking I_r and I_s as independent variables, the partial derivatives can be obtained according to the profit maximization conditions:

$$\begin{aligned} I_r &= \frac{bD_0 - 1}{ab}, \\ I_s &= \frac{a(w - C_0) - 1}{ab} I_r. \end{aligned} \tag{6}$$

The above I_r, I_s, and π_0, respectively, show the promotion cooperation investment, the R&D cooperation investment, and the maximum profit value of the system when there is only one supplier and one dealer.

The analysis is similar for suppliers associated with manufacturers. The game cooperation between raw material suppliers is also based on complete static information, and profit maximization is the prerequisite for cooperative investment of each supplier. The profit of the supplier is corresponding to the cost of the manufacturer. Therefore, in order to gain a larger market share, the supplier must reduce the price through technological research and development to reduce the cost of the manufacturer. Similarly, it is assumed that if a raw material supplier's R&D investment is higher than that of other suppliers, its demand for raw materials will be higher than that of other raw material suppliers, and other suppliers will make additional investment until all suppliers occupy the same market share. The total R&D investment of all raw material suppliers must be equal to

the amount that maximizes the manufacturer's profits. Because if the amount of investment is less than the value, additional investment can also reduce the cost, and if the value is greater than the value, the cost will be higher than the minimum value, resulting in unreasonable resource allocation. Therefore, according to the completely static game analysis, rational suppliers will also choose to evenly distribute raw material supply to maximize profits [23].

4.2. Game Analysis of Cooperative Innovation among Enterprises in Multicore Cluster Supply Chain. If one dealer spends more on promotion than the other dealers, its market demand will be higher than that of the other dealers, and all dealers are not willing to lag behind and increase their investment until each dealer has an equal market share. And the total investment of all dealers must be equal to the amount that maximizes the manufacturer's profits. If the investment is less than this value, the manufacturer will consider that the product supply is less than the optimal output in order to maximize its own profits, thus causing dealers to lose part of the market share to competitors. If the investment is greater than this value, it will cause waste due to market saturation. Therefore, dealers will choose to evenly distribute market share to avoid a lose-lose situation.

Then:

$$I_{Krj} = \frac{I_r^*}{N}. \tag{7}$$

Make w_1 the preferential product supply price offered by the manufacturer to the dealer. The total profit function corresponding to all dealers is

$$\begin{aligned}\pi_{Kr} &= D(I_{Kr}{}^*)(w - w_1) - s_{Kr} I_{Kr}{}^* \\ &= \left(D_{K0} + a_K \left(\sum_{j=1}^{N} I_{Kr}\right)\right)(w - w_1) - s_{K1}\left(\sum_{j=1}^{N} I_{Krj}\right).\end{aligned} \tag{8}$$

Taking Krj as an independent variable and taking its derivative and finding the optimal profit solution, it can be concluded that

$$\frac{d\pi_{Kr}}{dI_{Krj}} = a_K(N-1)(w - w_1) - N s_{K1} I_{Kij}. \tag{9}$$

To maximize profits when

$$\begin{aligned} s_{K1} &= \frac{a_K(N-1)(w - w_1)}{I_{Kij}^*}, \\ &\frac{w - \left(D_{K0} + a_K I_{Kij}^*\right)}{s_{K1} I_{Kij}^* < w_1 < w}. \end{aligned} \tag{10}$$

At this point, the sum of the maximum profits of all dealers is

$$\begin{aligned}\pi_{Kr} &= D(I_{Kr}{}^*)(w - w_1) - s_{Kr} I_{Kr}{}^* \\ &= (D_{K0} + a_K I_{Kr}{}^* - a_K(N\text{-}1)(w - w_1)).\end{aligned} \tag{11}$$

The game cooperation between raw material suppliers is also based on complete static information, and the analysis is similar to the organization mode of single-core cluster supply chain, so the repeated analysis will not be made here. Finally we can conclude that all suppliers have equal market share and the total R&D investment must be equal to the amount that maximizes the manufacturer's profit.

5. Conclusion

The cooperative innovation among enterprises can not only reduce the cost and improve the overall profit of supply chain, but also enhance the core competitiveness of industrial clusters. Therefore, the institutions and enterprises in the cluster should take some measures to promote the cooperative innovation behavior among enterprises. This article puts forward some countermeasures and suggestions from the government level, industry level, and enterprise level to promote the cooperation between enterprises in the supply chain.

5.1. Policy. The cooperative innovation among enterprises in the cluster not only promotes the improvement of the economic benefits of the enterprises that adopt the cooperative innovation strategy. At the same time, because of the existence of spillover effect, some enterprises that do not adopt cooperative innovation strategy will also have a positive promotion effect, which is easy to make some enterprises to adopt speculative strategy to reduce their own costs. If this behavior is not stopped, the overall benefits of the cluster will not be optimized and even affect the cooperation between enterprises in the supply chain. Therefore, the government must put forward reasonable policy suggestions to promote the smooth cooperation between enterprises in the cluster supply chain. The government's regulation of the market economy is mainly manifested in macroeconomic regulation and control as well as market supervision and guidance. Studies on the development of industrial clusters in some successful areas in China in recent years show that the regulation policy of the "invisible hand" of the government plays an important role in the development of industrial clusters and the construction of supply chains within clusters through policy guidance and provision of basic public goods and services. Especially in the initial forming stage of industrial cluster, the guidance of regional policy and the cultivation of regional cooperative innovation culture are very important.

5.2. Cluster Supply Chain Level. Information communication among enterprises in the cluster is not only between upstream and downstream enterprises in the supply chain, but also with government agencies, financial institutions, intermediary institutions, and scientific research and training institutions in the cluster. In this way, enterprises in the supply chain can make timely production adjustments according to the market and government information, realize the maximum

use of resources and cost savings, and bring greater economic benefits to the cluster. Therefore, it is very necessary for the development of the whole cluster to design a reasonable information communication platform and continuously strengthen the information exchange between enterprises and institutions on each node of the cluster.

In the industrial cluster supply chain system, the core enterprises dominate the development of the whole supply chain to a large extent. Core enterprises are located at the key nodes of the supply chain and have absolute advantages over upstream and downstream enterprises and related auxiliary enterprises in production and manufacturing, technological level, economic strength, and market position, which also leads to the development of core enterprises that determines the economic lifeline of the supply chain network. Therefore, giving full play to the leading role of the core enterprises in the cluster supply chain will achieve greater network benefits, which requires the core enterprise in their own development at the same time, also to strengthen the cooperation with businesses around and provide technical guidance and cost compensation to them, with core businesses in order to make sure they are able to improve the innovation ability, exert their own advantages, thereby giving impetus to the development of the whole supply chain, and enhance the core competition of the cluster.

Data Availability

No data were used to support this study.

Conflicts of Interest

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

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References

[1] T. Liu and Z. Yu, "The analysis of financial market risk based on machine learning and particle swarm optimization algorithm," *EURASIP Journal on Wireless Communications and Networking*, vol. 2022, 17 pages, 2022.

[2] Z. Sheikhhosseini, N. Mirzaei, R. Heidari, and H. Monkaresi, "Delineation of potential seismic sources using weighted k-means cluster analysis and particle swarm optimization (PSO)," *Acta Geophysica*, vol. 69, no. 6, pp. 2161–2172, 2021.

[3] Z. Wen, Q. Wang, J. Ren, L. Zhang, and Y. Yuan, "Dynamic gas diffusion model of capillary pores in a coal particle based on pore fractal characteristics," *Transport in Porous Media*, vol. 140, no. 2, pp. 581–601, 2021.

[4] K. V. Kobrin, V. A. Rudakov, V. A. Sledkov, Z. Li, and M. B. Manuilov, "Synthesis of a wideband diplexer based on interdigital resonators for the antennas of mobile-communication base stations," *Radiophysics and Quantum Electronics*, vol. 64, no. 7, pp. 494–504, 2021.

[5] H. Gao and X. Ding, "The research landscape on the artificial intelligence: a bibliometric analysis of recent 20 years," *Multimedia Tools and Applications*, vol. 81, no. 9, pp. 12973–13001, 2022.

[6] Z. Wang, L. Zhang, R. Zhang, R. Wang, and R. Huang, "Flow mechanism and transient pressure analysis of multi-stage fractured horizontal well," *Chemistry and Technology of Fuels and Oils*, vol. 57, no. 6, pp. 941–954, 2022.

[7] V. Lara-Prieto and G. E. Flores-Garza, "iWeek experience: the innovation challenges of digital transformation in industry," *International Journal on Interactive Design and Manufacturing (IJIDeM)*, vol. 16, no. 1, pp. 81–98, 2022.

[8] Y. Zhang, L. Jiang, L. Y. Kuang, J. du, and Z. Y. Liu, "Long-term creep buckling analysis and assessment method research of a finned tube at high temperature," *Strength of Materials*, vol. 53, no. 4, pp. 646–653, 2021.

[9] K. H. Mahmoud, A. S. Alsubaie, E. A. A. Wahab, F. M. Abdel-Rahim, and K. S. Shaaban, "Research on the effects of yttrium on bismuth titanate borosilicate glass system," *SILICON*, vol. 14, no. 7, pp. 3419–3427, 2022.

[10] D. S. Gangwar, S. Tyagi, and S. K. Soni, "A techno-economic analysis of digital agriculture services: an ecological approach toward green growth," *International journal of Environmental Science and Technology*, vol. 19, no. 5, pp. 3859–3870, 2022.

[11] A. De Ayala, S. Foudi, M. d. M. Solà, E. López-Bernabé, and I. Galarraga, "Consumers' preferences regarding energy efficiency: a qualitative analysis based on the household and services sectors in Spain," *Energy Efficiency*, vol. 14, no. 1, pp. 1–15, 2021.

[12] S. Khaledi, M. Rajabi, A. R. Momeni, H. A. Samimi, and J. Albadi, "Preparation and characterization of ca-modified Co/Al2O3 and its catalytic application in the one-pot synthesis of 4h-pyrans," *Research on Chemical Intermediates*, vol. 46, no. 6, pp. 3109–3123, 2020.

[13] Y. Wu, X. Gu, Z. Tu, and Z. Zhang, "System dynamic analysis on industry-university-research institute synergetic innovation process based on knowledge flow," *Scientometrics*, vol. 127, no. 3, pp. 1317–1338, 2022.

[14] C. Li, X. Cao, and M. Chi, "Research on an evolutionary game model and simulation of a cluster innovation network based on fairness preference," *PLoS One*, vol. 15, no. 1, article e0226777, 2020.

[15] M. A. Koondhar, M. Shahbaz, K. A. Memon, I. Ozturk, and R. Kong, "A visualization review analysis of the last two decades for environmental kuznets curve "EKC" based on co-citation analysis theory and pathfinder network scaling algorithms," *Environmental Science and Pollution Research*, vol. 28, no. 13, pp. 16690–16706, 2021.

[16] W. Cai and F. Xu, "The impact of the new environmental protection law on eco-innovation: evidence from green patent data of Chinese listed companies," *Environmental Science and Pollution Research*, vol. 29, no. 7, pp. 10047–10062, 2022.

[17] Y. Ye, Y. Pu, and A. Xiong, "The impact of digital finance on household participation in risky financial markets: evidence-based study from China," *PLoS One*, vol. 17, no. 4, article e0265606, 2022.

[18] S. X. Wang, H. W. Chen, Q. Y. Zhao et al., "Preserving scheme for user's confidential information in smart grid based on digital watermark and asymmetric encryption," *Journal of Central South University*, vol. 29, no. 2, pp. 726–740, 2022.

[19] N. Yuvaraj, K. Srihari, G. Dhiman, K. Somasundaram, and M. Masud, "Nature-inspired-based approach for automated cyberbullying classification on multimedia social networking," *Mathematical Problems in Engineering*, vol. 2021, Article ID 6644652, 12 pages, 2021.

[20] S. Shriram, J. Jaya, S. Shankar, and P. Ajay, "Deep learning-based real-time AI virtual mouse system using computer vision to avoid COVID-19 spread," *Journal of Healthcare Engineering*, vol. 2021, Article ID 8133076, 8 pages, 2021.

[21] L. Xin, L. Jianqi, C. Jiayao, and Z. Fangchuan, "Mn2O3/γ-Al2O3 catalysts synergistic double dielectric barrier discharge (DDBD) degradation of toluene, ethyl-acetate and acetone," *Chemosphere*, vol. 284, p. 131299, 2021.

[22] R. Huang, P. Yan, and X. Yang, "Knowledge map visualization of technology hotspots and development trends in China's textile manufacturing industry," *IET Collaborative Intelligent Manufacturing*, vol. 3, no. 3, pp. 243–251, 2021.

[23] H. Xie, Y. Wang, Z. Gao, B. Ganthia, and C. Truong, "Research on frequency parameter detection of frequency shifted track circuit based on nonlinear algorithm," *Nonlinear Engineering*, vol. 10, no. 1, pp. 592–599, 2021.

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Research Article

Deconstruction of Immersive Animation Image Interaction Design under Virtual Reality Technology

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With the increasing pressure of social life, people generally have different degrees of psychological problems, which brings serious troubles to people's life and work. As one of the main forms of art, animation is a good medicine for breaking fantasy and returning to reality. Animation is one of the ways of art therapy, and animation art design is the soul of animation therapy. However, the art design of traditional animation cannot bring a strong sense of resonance and cannot arouse people's inner emotions. Virtual reality can bring users an immersive experience, so it can really immerse the audience and release psychological pressure. The article firstly reoptimizes animation modeling technology and then combines it with art design, comprehensively uses art design and interactive technology to generate virtual space, and finally puts forward the concept of animation art design based on virtual reality technology. It aims to construct virtual animation from animation art design to help patients relieve psychological barriers. After repeated comparison experiments, it can be found that in the process of watching interactive animations on the virtual reality platform, if the overall style of the animation is more comfortable and warm, the user's psychological perception will reach 78%, and the emotional fluctuation range will be less than 10%. When the animation style is relatively dark and depressing, the user's psychological perception is only 45%, and the audience is very likely to think of a bad life experience, and the possibility of causing psychological disorders is 69.1%. This shows that the warm and comfortable animation art design can smooth people's emotional fluctuations and relieve psychological obstacles.

1. Introduction

With the rapid development of modern civilization, there has been an imbalance between people and their lives, and many contradictions and conflicts have arisen in their hearts. This has brought great psychological pressure to people and is very likely to form psychological disorders or mental illnesses. Art appreciation can transform people's emotions and relieve psychological barriers by allowing people to release pressure from the depths of their hearts. There are many ways of art therapy, among which animation, as a kind of film and television art, is one of the most important methods in art therapy. However, the traditional animation design process does not pay attention to the interactive design of animation, which cannot mobilize users to participate in empathy, so it cannot fundamentally alleviate the psychological problems of the audience. Moreover, the art design of traditional animation does not pay attention to the influence of factors such as color on the audience's emotions, so it cannot find the essence of the problem from the perspective of animation art design. Virtual reality technology can connect virtual and reality, so it can become an important tool in immersive animation interaction design. At the same time, virtual reality technology can simulate real scenes in reality, so the animation interaction design based on this can directly hit the user's heart, so as to achieve the effect of empathy. Virtual reality technology provides people with a new type of animation viewing option, but the intervention of technology is only a means to add icing on the cake for the expressive power of animation, not the ultimate goal. And from the perspective of animation art design, it can design scenes that are more in line with the user's heart, so that the effect of virtual realization technology is more significant, so as to subtly change the audience's heart, and

finally release their psychological pressure and break psychological barriers.

After a series of experiments, we can know that in the overall bright and warm animation scene, the audience's perception level is relatively high, up to 85%. This evokes the good in users and makes them feel longing. When the interactive animation style is more comfortable and simple, the user's psychological perception reaches 78%. This shows that in such an environment, the user's brain will also release more comfortable signals to help the audience get rid of the fetters of reality. Immersive interactive animations based on virtual reality can greatly attract users, with an appeal of 92.67%, and 81.6% of people say they feel relaxed, happy, and comfortable after watching such animations. This shows that the interactive animation design based on virtual reality can provide the audience with an immersive visual experience, which can achieve a good effect of art therapy.

2. Related Work

Animation therapy is the most important form of art therapy, which can create the most intuitive feeling for users. Robert pointed out that the current research on animation effects mainly focuses on online advertising; to broaden its application, he studied the effect of animation effects on people's psychology. In the course of his research, he explored the role of animation in emotional and cognitive processes using an extended SOR model and finally determined that animated images are an important tool for creating atmosphere [1]. Starting from the creative background of Makoto Shinkai, Laplante and Delaney analyzed the composition and self-expression of animation context and provided materials and references for the study of Makoto Shinkai's films and similar films [2]. Rowe R took the animation column of CCTV Children's Channel as an example to study the multidimensionality of animation image dynamic design. By analyzing the application of animation elements in dynamic animation images, he summed up the advantages and characteristics of dynamic animation images and the skills and methods of animation elements. And the application methods, principles, application effects, and advantages of animation elements in dynamic animation images are studied [3]. Javadi N experimented with the Remote Immersion Platform (TIP) in order to study the application of immersive technology in animation. During the investigation, he conducted qualitative analysis of group interviews of animation learners, field notes of researchers, and recordings of test sessions, as well as descriptive statistics of questionnaires. During the experiment, learners expressed positive feelings of surprise and excitement and believed that the technology enabled them to participate in the entire course [4]. The above experts and scholars have analyzed the role and development of animation from different perspectives, but they have not analyzed another layer of animation applications from the perspective of interactive animation.

Virtual reality technology can achieve the greatest degree of interaction, and in recent years, more and more scholars have turned their attention to this. The Aliyu F study discussed the latest applications of virtual reality technology (VRT) in educational settings. In the process, he highlighted the benefits of VRT for preservice chemistry teachers. These teachers face content knowledge difficulties in teaching abstract chemical concepts such as organic structure, molecular structure, chemical reactions, and stoichiometry [5]. Maples-Keller J L focuses on the existing literature on the effectiveness of incorporating VR into the treatment of various psychiatric disorders, with a particular focus on exposure-based interventions for anxiety disorders. To identify studies implementing VR-based treatments for anxiety or other psychiatric disorders, he conducted a systematic literature search. Among them, he reviewed the history of VR-based technology and its application in psychiatry, as well as the benefits of using VR for psychiatric research and treatment. After reading extensive literature, he made recommendations for incorporating VR into psychiatric care and discussed future directions for VR-based therapy and clinical research [6]. Cao D pointed out that the previous 3D intelligent image display system could not meet the needs of users due to its large size and poor accuracy. Therefore, he designed a three-dimensional image embedded intelligent display system based on virtual reality technology [7]. Lan L noted that fire safety education is critical to every student on campus. At the same time, he also pointed out that the existing VR-based fire safety education system has some shortcomings, such as lack of interactivity and high equipment complexity, resulting in low practicability. In order to improve the effect of campus fire safety education, he established a fire safety education system model and architecture based on VR technology [8]. The above experts and scholars have analyzed the application of virtual reality technology from different angles, but they have not extended it to the field of animation images, so the research is not very comprehensive.

3. Virtual Reality Technology and Animation Interaction Design

3.1. Animation Image and Art Design. Animation is an art that integrates many technologies, and its earliest birth was in the first half of the nineteenth century [9]. After years of development, the trend of combining animation with science and technology is becoming more and more obvious, which further promotes the vigorous development of animation. The principle of animation is the same as that of video, which uses the persistence of vision of the human eye. Therefore, in the actual production process of animation, designers often only need to decompose the expressions and movements of animation images and then use specific techniques to create continuous animation effects. Many categories have also been derived during the development of animation [10]. For example, according to technology, animation can be divided into hand-drawn animation, virtual animation, and real animation, and if divided according to media, animation can be divided into TV animation, science and education animation, and so on.

Art design is the soul of animation. The style of art design is not only visual; it even affects the rhythm and style

of the entire animation. In animation, the style of art design directly determines the style of the entire animation, so art design is also the visual externalization of animation [11]. The art style of animation generally includes the image design, background, and color of animation, but in the actual choreography process, the art style of animation is also reflected in the shooting techniques and evolution of animation. Therefore, the art of animation not only shows the color characteristics of the animated characters, but also shows the artistic form and aesthetic direction of the whole animation. Animation art design is an important part of animation. It not only reflects the creativity and positioning of the entire animation, but also the projection of the designer's own values and intentions. It is a unique form of artistic creation. Under the combined influence of these factors, animation art design plays an increasingly important role in animation design and presentation, and at the same time, it also puts on a gorgeous coat for the presentation of the inner meaning of animation [12].

After the animation art design is basically completed, the prototype of an animation work is born. With the development of the times, the cultural concepts presented in animation works have become more and more intense, and the forms of expression of the works have become more and more diversified [13]. But no matter how it develops, animation art design is always the basis for the eternal vitality and vitality of the work. The production of animation is a technology and a comprehensive art. Under the collision of many ideas, a formed animation work is often a fusion of ideas and culture, which reflects the externalization of collective will. Similarly, like music and other art forms, animation works also come from life, which is a highly condensed and concentrated expression of attitude towards life. The basic elements of animation works are shown in Figure 1.

A mature animation work is often composed of three parts: storyline, art design, and sound [14]. In these three parts, the storyline is the backbone of animation, the basis and reason for animation's existence. Among them, art design is the soul of animation works, and it is the confidence for animation to better go to the world. Finally, sound is the media medium of animation works and an inevitable product of the self-development of animation works.

With the emergence and development of new media and interactive technology, animation images have gradually formed a new form of animation. In the process of continuous development, modern animation mode has changed the circular narrative mode of traditional animation. On the one hand, traditional animation forms focus on rhythm, so they do not pay much attention to the interactivity of animation. In today's animation mode, animation is more of an interactive situation, which is the unity of audience and animation [15]. On the other hand, the storyline of traditional animation is not centered on the emotions of the audience but purely on the story, so this leads to animation becoming a tool for the story. Conversely, modern animation uses stories as a tool to express emotions, which can create a stronger emotional connection with the audience.

Interactive animation is another form of animation developed based on emerging technologies, which is a breakthrough and innovation to traditional animation [16]. First, interactive animations give the viewer the power to choose and control the direction of the animation, which creates an immersive atmosphere for the user. Secondly, the interactive animation makes full use of the advantages of art design and brings a wonderful psychological experience to the audience. Lastly, interactive animation is emotionally oriented, so it can tap into the minds of the audience. However, the animated images in the immersive space only reflect the pure visual picture and sense of form, but ignore the psychological experience of the audience immersed in it. The schematic diagram of the interactive animation image is shown in Figure 2.

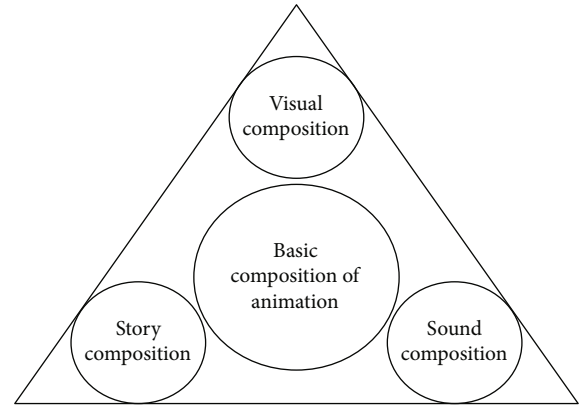

Figure 1: Basic composition of animation works.

In the interactive animation design process, the designer uses multimedia and other technologies to realize the interaction between the animation image and the audience. For example, while watching the animation, participants can set up a virtual character to enter and participate in the development of the animation's storyline. On this basis, the interactive animation image realizes the innovation of traditional animation and realizes the development and progress of animation [17]. However, by observing the above-mentioned interactive animation images, we can find that the interactive animation images do not pay attention to the influence of animation colors and other factors on the audience's emotions, so they cannot find the essence of the problem. In the figure, the color and overall style of the interactive animation images do not give people a comfortable feeling, so the audience often cannot really open themselves from the inside when interacting with such animations, which makes it impossible to achieve emotional resonance. At the same time, the art design of animated characters will also directly express people's emotions.

3.2. Virtual Reality Technology. Virtual reality is a composite subject that integrates multiple technologies, and it has virtual characteristics beyond reality. Virtual reality technology is an emerging computer technology that can generate realistic virtual reality spaces. In the process of continuous development, three main characteristics of virtual reality technology have emerged: multisensing, immersion, and interactivity [18]. Under the combined effect of these characteristics, people can create a fully human-friendly

Figure 2: Interactive animated images.

multidimensional information space based on virtual reality. For example, the experiencer can directly touch the simulated object in the virtual environment with his hand. At this time, the hand has the feeling of holding something and can feel the weight of the object. With the continuous development of this technology, it is widely used in simulation reconstruction and human-computer interaction. The main application areas of virtual reality technology are shown in Figure 3.

To put it simply, virtual reality is to use the power of technology to let people experience a virtual environment [19]. The changes of virtual reality technology to animation are increasingly and profoundly affecting the creation method, presentation form, viewing experience, and audience psychology of animation. In the context of the rapid development of science and technology, the animation technology revolution has not only changed the technology, but also brought very profound changes to the entire animation art. In particular, the entry of digital technology into all aspects of animation production has a huge impact on the creation, dissemination, and viewing of animation. With the innovation of virtual reality technology and its promotion and application in various fields, a new era of virtual reality is slowly unveiling its mysterious veil, which also makes virtual reality technology have an opportunity to apply to animation [20]. Virtual reality technology provides people with a new option for watching animations, but the intervention of technology is only a means to add icing on the cake for the expressiveness of animation, not the ultimate goal. What really embodies the value of animation is the value coordinates of truth, goodness, and beauty behind the magnificent imagination of the animation world, public values, and its actual effect on the audience.

The integration between virtual reality technology and animation is getting closer and closer. In general virtual reality platforms, designers often use spatial coordinates to locate the target, so as to complete the reproduction of reality on this basis. In the process of platform design and implementation, designers often use 3D modeling technology to build animation models, but this does not guarantee that what is ultimately presented to people is a highly interactive animation model. In order to make the concept of interaction deeply rooted in people's hearts from the beginning, we decided to start with the scene, and let the interactive experience integrate into every corner of the animation scene.

$$X = x^{\alpha} + d * \mathrm{col}(\omega)^{\beta}, \tag{1}$$

$$Y = y^{\alpha} + \delta * \mathrm{row}(\theta)^{\gamma}, \tag{2}$$

$$Z = z^{\beta} + \mu * \mathrm{del}(\sigma)^{\alpha}. \tag{3}$$

Among them, X, Y, and Z, respectively, express the three-dimensional coordinates of any point in the 3D modeling, and the establishment of its position is mainly affected by the joint influence of the abscissa and ordinate. Next, the interaction design should be based on this, but there is still a key problem that needs to be solved before that. In the just-established coordinate position, with the establishment of the target position, the field of view of the target is also established, so it is necessary to analyze the range of interactive animation changes before interactive design. The schematic diagram of the variation range of the interactive animation elements is shown in Figure 4.

By observing the changes of the above-mentioned interactive animation elements, it can be known that different interactive elements have different interactive effects, all of which serve the overall interactive animation. Therefore, a set of animation models are redesigned for interactive animation elements with different characteristics.

$$D = \sqrt{\mathrm{col}(||\Delta x - \Delta y| * |\Delta y - \Delta z||)}, \tag{4}$$

$$\theta = \sum_{i=1}^{n} \left(x^{i} + y^{i} + z^{i}\right) * \sin D^{\sigma}, \tag{5}$$

$$\Delta x = \lim_{x \longrightarrow 0} \|x_n - x_i\|. \tag{6}$$

Among them, D represents the reconstructed animation scene, θ represents the distribution of interactive animation elements in this process, and Δx represents the animation

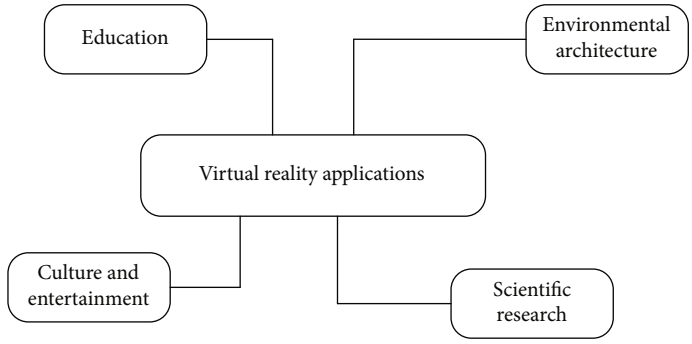

Figure 3: Main application areas of virtual reality.

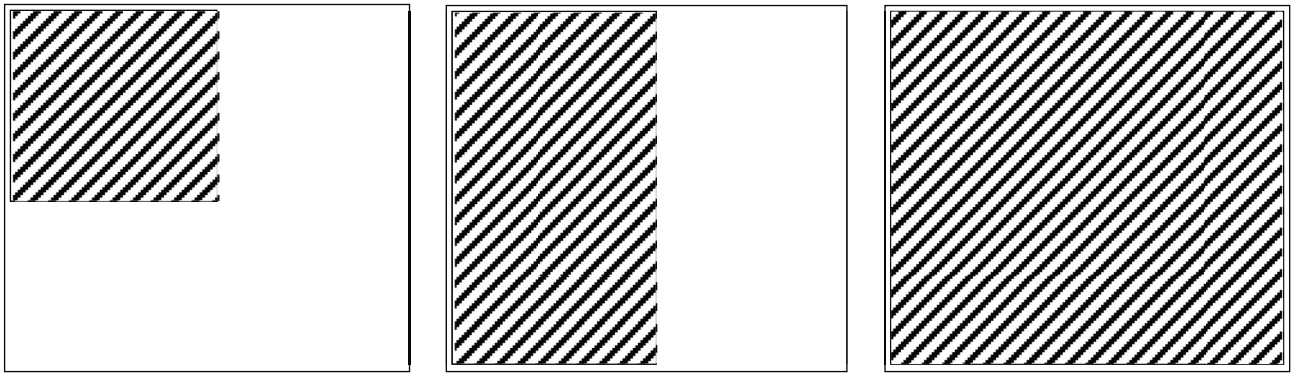

Figure 4: Variation range of interactive animation elements.

interaction trend in the process of changing the target coordinates. In this process, extreme operations are performed on the situation where the target position changes, in order to simulate the best and worst results of the animation interaction.

In the process of interaction, users can achieve different interaction effects by triggering certain nodes. Among them, the sensor nodes in the virtual reality model will monitor the user's actions in real time and then deploy different interaction modes.

$$\begin{bmatrix} x_d & 1 \\ y_d & 1 \\ z_d & 0 \end{bmatrix} = \begin{bmatrix} a_x & 0 & 0 \\ 0 & a_y & 0 \\ 0 & 0 & a_z \end{bmatrix}. \tag{7}$$

Among them, a_x, a_y, and a_z, respectively, refer to the coordinate axis factor in the interactive animation scene, and x_d represents the abscissa pixel point in the animation scene. If set x_m expresses the coordinates of the interactive animation scene that has undergone certain processing, then in the virtual reality environment, the calculation process of its dynamic coordinate position is as follows:

$$x_m = \begin{bmatrix} x & x_a \\ y & y_a \end{bmatrix} = \begin{bmatrix} 1 & x_a & 0 \\ \vdots & \ddots & \vdots \\ \rho & y_a & 1 \end{bmatrix}, \tag{8}$$

$$\rho = \sum_{x,y \in D} (x_m * \omega \Delta x). \tag{9}$$

Among them, ρ represents the tangential distortion value of the abscissa, and its value range is between $[0, 1]$. Based on this, people can perform the same recursion on the ordinate and spatial coordinates, and finally get a dynamic interactive animation model.

As we all know, the color and beauty of animation design will directly affect the user's emotions, so people have also improved the virtual reality platform in the interactive design of animation images.

$$\{x_w\} = \|M\| * \left(\left[Y_x^{\text{out}} - Y_x^{\text{int}}\right]\right), \tag{10}$$

$$Y_x^{\mu} = \frac{\sqrt{x_m}}{\sqrt{Y_{\mu}^{\rho}}}, \tag{11}$$

$$M = \int_x^y \int_{\mu}^x [\sin mx * (x_m - x_i)] dx. \tag{12}$$

Among them, Y_x^{out} represents the external link of the virtual reality platform, Y_x^{int} represents the internal link of the virtual reality platform, and M represents the linear index.

In this process, the most direct way to evaluate the effect of animation interaction is to identify the user's emotion, so

the emotion factor τ is added on this basis.

$$\gamma = \rho_i^{\tau} \bullet \sqrt{\Delta\omega}, \tag{13}$$

$$X = \sigma_{\varepsilon}^{\max} \bullet \varphi(x). \tag{14}$$

Among them, γ represents the user emotion index under the action of various emotions, and $\Delta\omega$ represents the interaction effect. In the process of multiple modeling and adjustment, it can be found that scenes with bright colors will bring great emotional fluctuations to users. Therefore, people added the emotional fluctuation characterization function based on the emotional factor, which is described as follows:

$$B = \sum_{i=1}^{n} \gamma_i \mu * (x^n - y^n)^2, \tag{15}$$

$$\varphi = \lambda(x) + \phi(y) - B(\eta). \tag{16}$$

Among them, B depicts the emotional fluctuation function, and its fluctuation will change with the change of the user's emotional index, and φ represents the inverse function of the function, which depicts the user's emotional stability. After these two functions are incorporated into the virtual reality platform, the platform can realize the real-time emotional state of the user, so that the interactive animation content can be continuously adjusted.

$$C = \max_{K \longrightarrow n} \cos x^k, \tag{17}$$

$$K = x \bar{\oplus} y * \sin x^y. \tag{18}$$

In the above formula, it can be seen that there is a parameter K in the main function C, which represents the adjustment process of the interactive animation. But just tweaking the interactive animation will not fundamentally solve the problem, so people also introduce a simple mental assessment model on top of that.

$$E = \frac{\sqrt{\rho_x - \rho_y}}{\sum C_x}, \tag{19}$$

$$Q = \lim_{m \longrightarrow 0} \sum_{i=1}^{n} \sum_{j=1}^{m} \left[\left(x_i - y_j \right)^{1/2} * \left(\rho^x + \rho^y \right) \right]. \tag{20}$$

Among them, E represents the user's psychological evaluation result, and its value is always positive, and Q represents the user's psychological index, which depicts the user's approximate mental health. Based on this, the virtual reality platform is successfully integrated with the interactive animation, and it can also judge the basic psychological condition of the operating user in real time, so as to continuously adjust the content of the interactive animation. This can help users better face their inner fears and ultimately overcome psychological barriers.

3.3. Interactive Design of Immersive Animation Image Based on Virtual Reality. In the process of interactive animation design, the art design of interactive animation is the top priority. When people first come into contact with animation, people first pay attention to the art style of animation, so if the audience is truly immersed in the process of interacting with animation, the first thing to pay attention to is the art design of animation. The art design process in the animation interaction design process is shown in Figure 5.

In the process of interactive animation art design, the first thing people need to do is to draw materials from life and then carry out model design. In interactive animation design, animation often talks about the real emotions of the audience, so it is necessary to design with these emotions in the design process, and then let the audience resonate with it. Next, the art design of the virtual platform should be carried out with reference to the basic principles of art design and the basic characteristics of virtual reality design [21]. In this design process, the virtual platform will amplify our cognition and activate mirror neuron cells in the brain to induce emotional responses in the audience. A single point is that when people see other people's actions or emotions, mirror neurons will be activated immediately, and then they can imitate and reproduce such actions or emotions in their brains, so as to empathize with other people's emotions. In this process, the emotion detector built into the virtual platform in advance will play a role, and then different design scenarios will be replaced according to the different emotions of users. Ultimately, it subtly guides users to change their negative emotions and establish a positive attitude towards life. Among them, the schematic diagram of the scene designed in the virtual reality world is shown in Figure 6.

The more realistic the environment in virtual reality, the more efficient the activation of our mirror neurons, which affects the user's emotions and feelings. Emotional empathy in virtual reality animation means that the audience can interpret those whimsical or realistic and profound stories through the real environment and the realistic virtual world. Let the audience feel the expected reality through their eyes and directly hit the audience's inner world. In the process, the interactive experience can awaken the deep memory of the audience, including common expressions, emotions, physiological reactions, subconsciousness, and presumed experiences, affecting the audience's long-held deep emotions. VR animation not only has a profound impact on the cognitive ability of the audience, but also to a certain extent, the audience can affect their perception ability during the interactive experience with the virtual environment. In different animation scenes, different color styles will bring people different psychological experiences. Among them, the sunny scene design brings people a sense of pleasure, which will make people unconsciously relax their body and mind and release psychological pressure. The depressing animated scenes, on the other hand, remind people of real-life misfortunes, which in turn exacerbate their depression. Therefore, in the process of interactive animation scene design, it is necessary to incorporate more positive elements. And design unique animation scenes for different users to arouse the audience's deep emotions, which really help them open their hearts and break down psychological barriers.

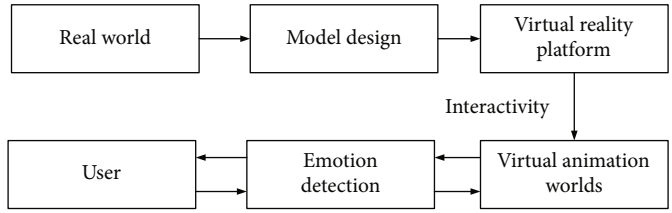

Figure 5: Interactive animation art design process.

Figure 6: Animation scene design based on virtual reality technology.

4. Deconstruction of Interactive Animation Design Based on Virtual Reality Technology

In interactive animation, the visual scene of animation is often the most impressive. Therefore, the article explores the cognitive memory and emotional index of the audience in different scenarios. In order to explore the degree of people's memory of different scenes and to fully study the role of visual impact on people's inner world, four frames of animation were randomly selected from VR interactive animation, and the distribution of basic elements of the four frames of animation is shown in Table 1.

Table 1 shows that the proportion of interactive elements in different animation frames is different. The second frame of animation has fewer interactive elements, accounting for only 35%, and the first frame of animation has a higher proportion, which is 85%. In terms of color, style, and content, the differences between the four frames are not particularly obvious. The colors are mainly bright and gorgeous, the style is based on cuteness, and the content is divided into two types: realistic and anthropomorphic. Then, people repeatedly scrolled and played these four frames of animation images to explore the general cognition of different interactive animation people. The cognitive memory under different interaction modes is shown in Table 2.

Table 2 shows that in the virtual reality platform, people are able to achieve immersive animation interaction, which helps them remember the details in the animation. For four animated images, people's memory remains around 90%. For general interaction methods, people's memory is mainly affected by the proportion of interactive elements. The second frame of animation images accounted for only 35%, so this also led to people's memory basically maintained at 60%.

In the above cognitive memory data, it is found that there is a big difference in the cognitive memory data of one or two frames, so the T test is performed on the relevant data. The test data table based on Frame 1 and Frame 2 is shown in Table 3.

Table 3 shows that there is a significant difference in the cognitive memory scores of the above two samples. Among them, the maximum difference between the mean values of the two is 1.7, and the maximum standard error value is 0.5726. This shows that the cognitive performance of the first frame is significantly better than that of the second frame.

It can be seen from the above experiments that interactive animation based on virtual reality can arouse people's hearts and can have a certain memory impact on the audience. Therefore, people decided to continue to explore the impact of interactive animation on people's psychological emotions on this basis. The emotional effects of different interactive forms of animation are shown in Table 4.

Table 4 shows that the immersive interactive animation based on virtual reality can greatly attract users, and the attractiveness reaches 92.67%. And 81.6% of people said they felt relaxed, happy, and comfortable after watching such animations. This shows that the interactive animation design

Table 1: Distribution of basic elements of animation.

	Interactive elements (%)	Color	Style	Content
Frame 1	85	Bright	Lovely	Personification
Frame 2	35	Showy	Cute	Realistic
Frame 3	60	Showy	Lovely	Realistic
Frame 4	80	Lucid	Cute	Personification

Table 2: Cognitive memory under different interaction modes.

Description	Frame 1	Frame 2	Frame 3	Frame 4
VR interactive animation	10	9	10	9
General interactive animation	9	6	7	9
Average situation	9.5	7.5	8.5	9

Table 3: Inspection data table based on Frame 1 and Frame 2.

Item	Distribution of variance	Mean difference	Standard error	Difference 95% confidence interval
Distribution of variance	Variance greater than constant	1.7	0.5426	-1.4402
	Variance less than fixed	1.6	0.5123	-1.4418
	Variance equals constant	1.53	0.5726	-1.4202

Table 4: Emotional effects of animations with different interactive forms.

Items	Easy	Pleasant	Comfortable	Attractiveness
General animation	61.5	66.2	64.3	69.6
VR animation	73.6	73.9	75.1	76.5
VR interactive animation	81.6	82.5	85.61	92.67

based on virtual reality can provide the audience with an immersive visual experience, which can achieve a good effect of art therapy.

5. Interactive Animation Art Design Effect Deconstruction

Inner emotions directly affect people's actual behavior and mental health. In the above, the effect of interactive animation on people's inner emotions was initially explored, and the next article will focus on analyzing its effect on mental health. The emotion index and emotion fluctuation detection function are built into the virtual reality platform, and their basic values are tested before the experiment starts, and the results are shown in Figure 7.

It can be seen from Figure 7 that people's emotional index is generally not high before the start of the experiment, and the average index score is around 7. Moreover, people's emotional fluctuations in different scenarios are relatively severe, and the range of emotional fluctuations exceeds 15%. This shows that in the process of people interacting with animation, the art style of animation will directly affect the audience's emotions, causing people's emotional fluctuations.

Therefore, based on the above cognitive experiments and combined with the emotional changes of the audience, people studied and compared the effects of no interactive animation, ordinary interactive animation, and virtual reality-based interactive animation in animation design. Among them, the comparison of interactive animation design effects in different modes is shown in Figure 8.

Figure 8 shows that the interactive animation design effects in different modes are not the same. Among them, the interactive effect based on ordinary interactive animation design is relatively obvious, and its effect value is up to 81.2%, but its interactive effect is not stable, and the data distribution fluctuates obviously. In contrast, the immersive animation interaction effect based on virtual reality is obvious, the highest effect value reaches 92.5%, and the average value distribution is concentrated at 85%. This shows that autonomous interaction can be achieved to the greatest extent based on virtual reality.

However, at this time, the author do not know how the specific scene perceives the audience's animation interaction, so the author selected 8 representative scenes to analyze the user's emotional perception, and the results are shown in Figure 9.

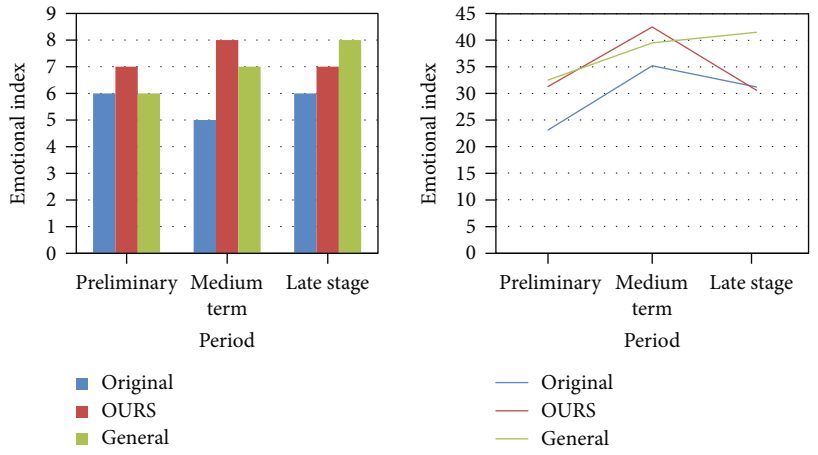

Figure 7: Audience sentiment changes in different periods.

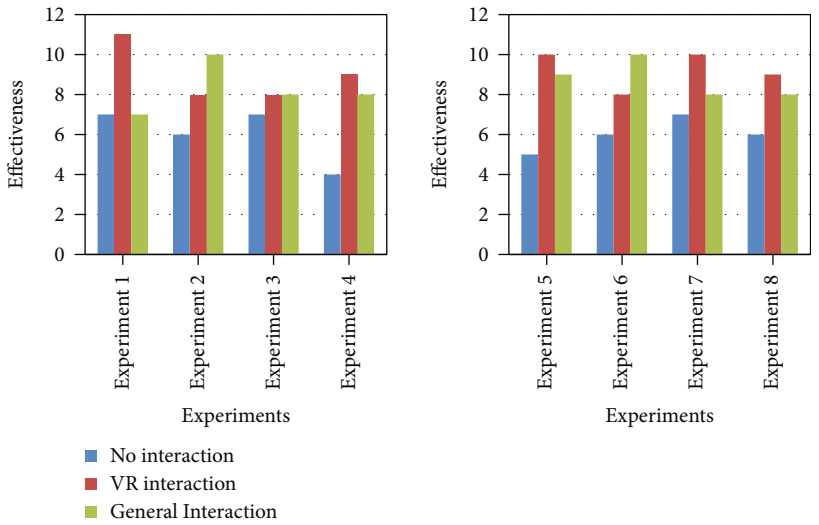

Figure 8: Comparison of interaction effects under different design modes.

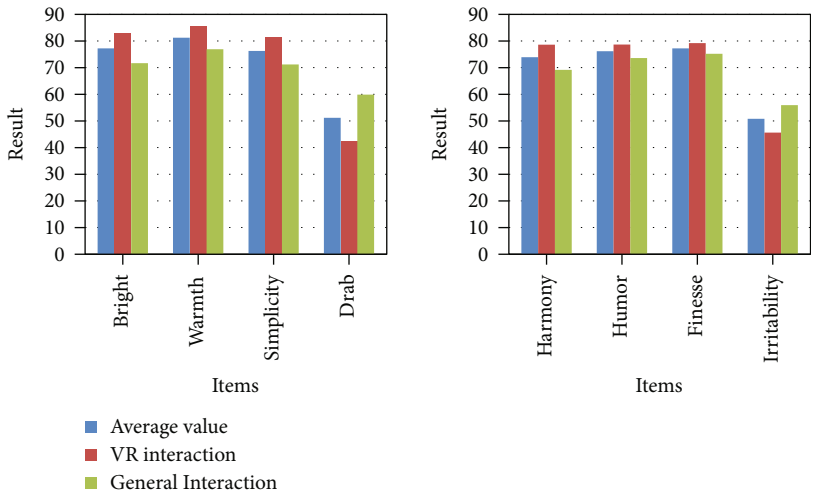

Figure 9: Audience perception in different scenarios.

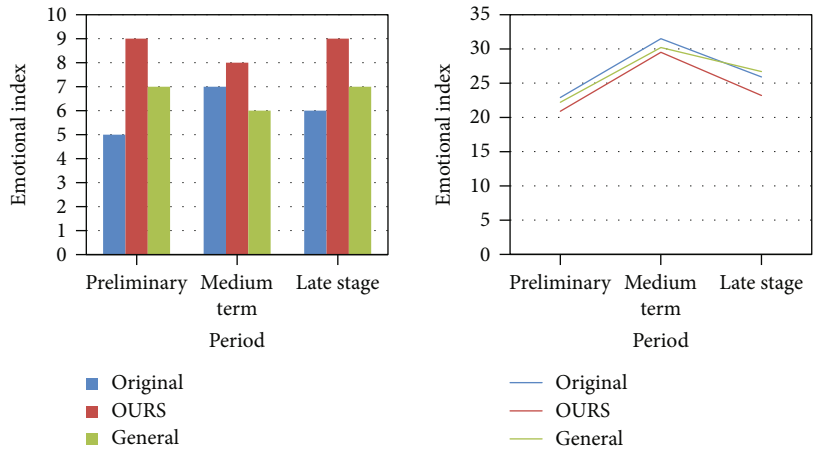

Figure 10: Audience emotional changes under virtual reality.

Figure 9 shows that in a scene where the animation is bright and warm as a whole, the audience's perception level is relatively high, up to 85%, which can arouse the good side in the user's heart and make them feel longing. When the interactive animation style is more comfortable and simple, the user's psychological perception reaches 78%. This shows that in such an environment, the user's brain will also release more comfortable signals to help the audience get rid of the fetters of reality. For dark and depressed styles, the user's psychological perception is only 45%. This shows that under the influence of this style, the audience will also have relatively negative emotions, and think of unfavorable life experiences.

It can be seen from the above experiments that the interactive animation scene will be directly projected into the user's emotions. Therefore, in the process of designing interactive animations, it is necessary to establish a relatively positive scene to guide users to form positive emotional changes. After a series of experiments, the audience's emotional index and mood fluctuations were remeasured. The emotional changes of the audience under virtual reality are shown in Figure 10.

Figure 10 shows that after the experiment was carried out for a period of time, people's emotional index generally improved, and the index score increased to about 8, in which people's emotional fluctuation range was less than 10%. This shows that immersive animation interaction design based on virtual reality can smooth people's emotional fluctuations and provide support for people to shape healthy psychology.

6. Conclusions

The continuous development of virtual reality technology is like a wonderful magic, making it possible to imagine unrestrained and unrestrained wandering into reality. Starting from the concept and characteristics of animation images, the article first analyzes the manifestations and characteristics of general animations and then explores the special features and utility of interactive animations. Then, the article analyzes the concept and characteristics of virtual reality technology and focuses on the advantages of combining virtual reality technology with interactive animation. At the same time, from the perspective of animation art design, the article clarifies the importance of virtual reality technology in the process of art therapy. Then, the article focuses on how to carry out interactive animation art design under the background of virtual reality technology and proposes some methods. Experiments show that interactive animation design based on virtual reality technology can alleviate people's psychological problems and provide help for the treatment of psychological diseases. However, due to time reasons, the research on the interactive animation art design is not very in-depth, and its actual benefits and effects are not analyzed from the psychological level. In the future, the article will focus on studying the specific effects of animation art design in art therapy to help people face psychological problems correctly.

Data Availability

No data were used to support this study.

Conflicts of Interest

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

Acknowledgments

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References

[1] G. Robert, "Animated images in the analysis of zebrafish behavior," *Current Zoology*, vol. 63, no. 1, pp. 35–44, 2017.

[2] L. H. Laplante and S. Delaney, "Male mate choice for a female ornament in a monogamous cichlid fish, Mikrogeophagus ramirezi," *Journal of Fish Biology*, vol. 96, no. 3, pp. 663–668, 2020.

[3] R. Rowe, "Shaping girls: analyzing animated female body shapes," *Animation*, vol. 14, no. 1, pp. 22–36, 2019.

[4] N. Javadi, M. Rahmanian, and A. Alipour, "Comparison of effectiveness of presenting images in visual education of students on brain function," *Journal of Medical Education Development*, vol. 11, no. 32, pp. 1–12, 2019.

[5] F. Aliyu and C. A. Talib, "Virtual reality technology," *Asia Proceedings of Social Sciences*, vol. 4, no. 3, pp. 66–68, 2019.

[6] J. L. Maples-Keller, B. E. Bunnell, and S. J. Kim, "The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders," *Harvard Review of Psychiatry*, vol. 25, no. 3, pp. 103–113, 2017.

[7] D. Cao, G. Li, and W. Zhu, "Virtual reality technology applied in digitalization of cultural heritage," *Cluster Computing*, vol. 22, no. 4, pp. 1–12, 2017.

[8] L. Lan, Y. Fei, and D. Shi, "Application of virtual reality technology in clinical medicine," *American Journal of Translational Research*, vol. 9, no. 9, pp. 3867–3880, 2017.

[9] S. Hughes, K. Warren-Norton, P. Spadafora, and L. Tsotsos, "Supporting optimal aging through the innovative use of virtual reality technology," *Multimodal Technologies and Interaction*, vol. 1, no. 4, pp. 23–33, 2017.

[10] Z. Liang and R. Shuang, "Research on the value identification and protection of traditional village based on virtual reality technology," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 4, pp. 592–600, 2017.

[11] H. Zhang and H. Zheng, "Research on interior design based on virtual reality technology," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 6, pp. 380–385, 2017.

[12] P. Lai and W. Zou, "The application of virtual reality technology in medical education and training," *Global Journal of Information Technology Emerging Technologies*, vol. 8, no. 1, pp. 10–15, 2018.

[13] L. Zeming, "Design and implementation of a Korean language teaching system based on virtual reality technology," *Agro Food Industry Hi Tech*, vol. 28, no. 1, pp. 2156–2159, 2017.

[14] O. Atsz, "Virtual reality technology and physical distancing: a review on limiting human interaction in tourism," *Journal of Multidisciplinary Academic Tourism*, vol. 6, no. 1, pp. 27–35, 2021.

[15] J. Pang, X. Li, and X. Zhang, "Coastline land use planning and big data health sports management based on virtual reality technology," *Arabian Journal of Geosciences*, vol. 14, no. 12, pp. 1–15, 2021.

[16] H. S. Lee and J. H. Lee, "The effect of T-ball class on physical self-efficacy of elementary school students using virtual reality technology(VR)," *Korean Journal of Sports Science*, vol. 29, no. 3, pp. 613–624, 2020.

[17] D. R. Singla, R. Giuseppe, and P. Vikram, "Scaling up psychological treatments for common mental disorders: a call to action," *World Psychiatry*, vol. 17, no. 2, pp. 226-227, 2018.

[18] S. Fischer and A. J. Cleare, "Cortisol as a predictor of psychological therapy response in depressive disorders: systematic review and meta-analysis," *Journal of Anxiety Disorders*, vol. 47, no. 2, pp. 60–68, 2017.

[19] Z. Mirhosseini, M. Arabrahmatipour, and G. Arab-Rahmatipour, "Treatment and prevention of the prevalence of psychological disorders of human resources working in organizations and medical centers following the COVID-19 pandemic," *Expositions*, vol. 5, no. 2, pp. 53–55, 2021.

[20] M. Bidisha and M. Gouranga, "Epigenomics: the interplay of genetic and epigenetic factors behind psychological disorders," *Research Journal of Biotechnology*, vol. 16, no. 2, pp. 231–236, 2021.

[21] M. P. García-Vera, J. Sanz, and A. Sanz-García, "Ten things every psychologist should know about treating psychological disorders in victims of terrorism," *Psicothema*, vol. 33, no. 2, pp. 177–187, 2021.

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Research Article

Correlation Financial Option Pricing Model and Computer Simulation under a Stochastic Interest Rate

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With the continuous expansion of the consumer interest rate market today, the risks brought by interest rate fluctuations have had a huge and far-reaching impact on the financial markets of many countries and it is becoming more and more important to simulate the pricing of financial options. In the traditional pricing model of financial options, the pricing standard of the pricing model is generally set as a financial product with random disturbance characteristics and the market price of its transaction does not follow the arbitrage principle of financial product pricing. It is easy to generate errors and cause risks, and the accuracy of traditional financial option pricing models is not high, and the simulation time is long, which greatly reduces the rate of financial transactions. To improve the accuracy of option pricing models, this paper uses computer simulation technology to simulate the pricing of correlated financial options under stochastic interest rates. From the four aspects of error, risk parameters, success rate, and simulation time, it is tested to observe the influence of computer simulation technology on the financial option pricing model. The final results show that by using computer simulation technology, the error of the correlation financial option pricing model under the random interest rate is reduced, the success rate is improved, the risk parameter is reduced by 3.03%, and the simulation time is reduced by 0.605 seconds.

1. Introduction

Option price is very important in option terms, and it will change as the contract terms change. Its speed of change directly affects the profit and loss of both buyers and sellers. Simulation of option pricing is an important issue in option trading. Uncertainty about the cost-effectiveness of options is a big problem for investors in the process of creating and developing global stock markets. The cost-effectiveness of options is one of the most important variables in the financial market, and its changes will have a great impact on the entire financial market and even the entire economic system. Using computer simulation technology to analyze the stochastic interest rate of the option pricing model can timely understand the change of the financial option price and carry out a reasonable price, which can avoid the occurrence of financial risks and promote the development of the financial industry.

Option pricing models are widely used in financial transactions, and more and more scholars are devoted to the study of option pricing models. Tomovski et al. evaluated the empirical performance of a calendar option pricing model with latent variables. The model uses the stochastic volatility formula, and through experiments, it is found that the values of the relative risk aversion coefficient and the intertemporal elasticity of substitution gradually decrease [1]. Tunaru and Zheng embed the Black-Scholes option pricing model in a quantum physical environment, resulting in a function. This function helps determine the existence of a "financial" state function. It has been experimentally demonstrated that the Black-Scholes model can be captured in a quantum physical environment, incorporating arbitrage in other arbitrage-free models in a natural way [2]. Gong and Zhuang investigated a method for pricing options in the context of a CEV model using Lie algebra techniques when model parameters are time dependent. The method can be easily extended to other alternative-valued models with clear algebraic systems. Further results can be generated using various functional forms of the rate and index text structures [3]. Dubinsky et al. proposed a fuzzy pricing model for the

volatility (fuzzy volatility) in the binary tree option pricing model. By using the binomial pricing option model, more stocks can be obtained, thereby improving the accuracy of option pricing simulated in financial markets. Accurate option pricing can allow investors to avoid financial risks [4]. Orbay et al. researched and developed an option pricing model that incorporates randomly distributed option returns, which is used to simulate market option prices to assess the need for financial market risk. Experiments were conducted to evaluate the performance of the new model with experimental numerical simulations, and the final experimental results proved that the model performed better than other models [5]. Mollapourasl et al. proposed a coupled nonlinear volatility and option pricing model, which produces a leverage effect, that is, stock volatility is (negatively) correlated with stock returns, which can be seen as a coupled nonlinear wave alternative pricing model for Black-Scholes options [6]. Parker proposed a European option pricing model using an advanced model (MOR) approach. The European option pricing model based on the Black-Scholes equation is implemented using the FDM method, and the MOR model is at least 2 times faster than the original FDM model in terms of computational cost with negligible compromise in accuracy [7]. The above studies have shown the advantages of option pricing models, but with the emergence of new technologies, options pricing models also have new problems.

Computer simulation technology is one of the new technologies applied in most modern operating systems. Many scholars have done research on computer simulation technology. Atkinson et al. believed that computer simulation technology has become an important tool for structural analysis and design. Under the action of disaster loads such as explosion, penetration, collapse, or typhoon, the test method is difficult to analyze and the advantages of computer simulation method such as safety, high efficiency, and low cost are more obvious in these problems [8]. Straka et al. developed a new type of electromagnetic wave induction heating equipment XAEMH-1, using a computer simulation system to dynamically predict and evaluate the efficiency of this electromagnetic heating process. The effectiveness of the new technology is verified through experiments, and satisfactory results have been achieved [9]. Based on the existing research results and simulation cases, Niek et al. introduced the application and progress of computer simulation technology in structural seismic design, seismic evaluation of existing structures, structural response analysis under extreme external forces, seismic planning or evaluation of urban large-area systems, etc. [10]. In order to explore and evaluate the application of computer simulation technology combined with multimedia teaching in CPR training, Niek et al. conducted the CPR theory and skill tests on 62 emergency physicians. It was found that computer simulation technology combined with multimedia teaching has important application value in cardiopulmonary resuscitation training, which can significantly improve team work ability [11]. Wang et al. has found computer simulations to be an effective way to pretest proposed systems, programs, or policies before developing expensive prototypes, field testing, or actual implementation. In a simulation analysis, the computer tracks the implications and consequences of a proposed system or course of action in detail. Simulations are more realistic, easier to understand, and more conclusive than other forms of analysis [12]. In order to shorten the development cycle of new vehicles and reduce the manufacturing cost of prototype vehicles, Mrozek and Burczynski proposed a new simulation method to predict the use of various parts of the car body through computer simulation, which can search for the acceleration and dynamic response of a specific area and the corresponding energy density [13]. Song discussed the application and function of computer simulation technology in medical physics teaching and analyzed the necessity of computer simulation technology in medical physics teaching. According to the characteristics of the relevant teaching content, he expounded and explained the role and advantages of computer simulation technology through appropriate teaching examples [14]. Appeal research shows that computer simulation techniques have applications in various industries.

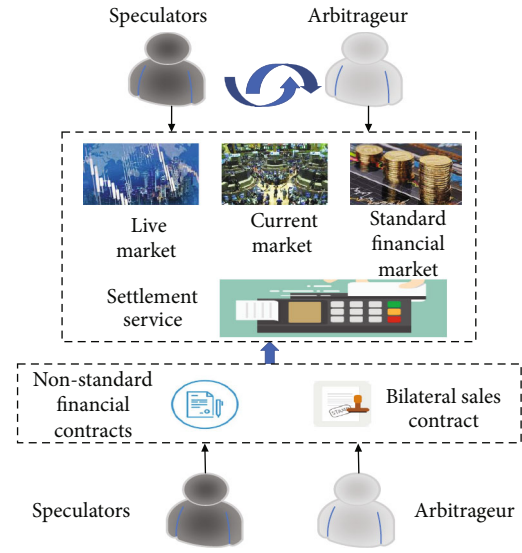

Figure 1: Financial option pricing models.

Computer simulation technology is a very active research field developed in recent years. Computer simulation technology has strong adaptability to solve all kinds of complex optimization problems. Using computer simulation technology to calculate the pricing of correlated financial options under random interest rates can avoid errors to the greatest extent and reduce risks. This paper applies the computational simulation technology to the financial option pricing model to increase the accuracy of option pricing and promote the development of the financial market.

2. Computer Simulation on the Financial Option Pricing Model

2.1. Financial Option Pricing Model. Computer simulation technology can be a flexible tool for financial market participants to avoid risk. If the right pricing model can be

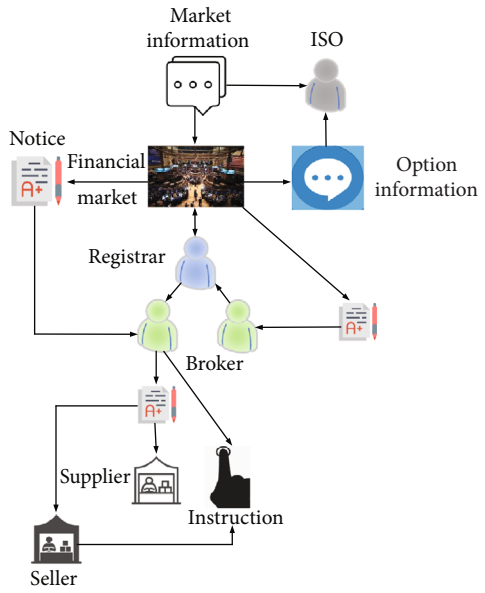

Figure 2: Option pricing transaction process.

combined with computer simulation technology, on the one hand, the advantages of stock options can be exerted, and on the other hand, the unstable changes of direct assets and the risks of market currency transactions can be avoided, allowing participants to complete transactions more smoothly. Due to the nonstorable characteristics of financial items, the system dispatch center must strictly control the transaction plan and repeatedly verify the security of the financial option pricing model system [15–17]. This requires a large amount of information exchange between the participants and the option pricing model, which increases the accuracy of option pricing to a certain extent and avoids risks [18]. Figure 1 presents a typical financial market including option pricing, which provides a reference for the design of the financial option market. Participating members can judge the future trend of financial option pricing based on the information obtained by computer simulation technology.

The scale of the market has multiple meanings, one refers to the size of the spot market, and the other refers to the size of the option market. The system includes a series of financial derivatives such as futures, options, and forward contracts, which involve not only financial transactions but also a large number of speculators and arbitrageurs using the leverage of options to gain profits in the market, greatly enhancing the liquidity and activity of the financial market.

2.2. Option Transaction Process. Financial market participants are mainly e-commerce sellers and e-commerce buyers, traders (risk), and arbitrageurs (buying multiple options at once to lock in risk opportunities) [19–21]. First, market participants send trade orders to the option pricing model system and instruct managing brokers in financial transactions to trade for them. Managing brokers submit trade orders to the authority for product prices, final prices, types of buy and sell contracts, and strike prices and receive comments on price order information. When participants receive all the information from the managing broker, all

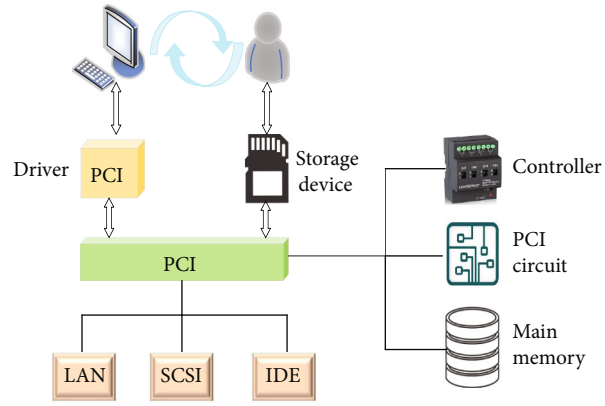

Figure 3: Computer simulation system structure diagram.

orders are bought and sold through the electronic trading system in accordance with the principle of "money and time first." An independent system administrator is responsible for accounting for system security data, and they need to ensure that the system is secure and stable [22, 23]. After the transaction is completed, the electronic trading system determines the price and volume of the transaction and feeds back the notification of the transaction option to the managing broker, which then sends it to the corresponding client, as shown in Figure 2.

2.3. Computer Simulation System Structure. The option pricing model is studied using a computer simulation system. The computer simulator must have the following functions: the system controls the computer to set the program and transfer data to the infrared driver, collect information in frames from a special table, and send it to the crawler. The directional infrared tracker data and location information are then sent through the panel management applicant's job capture card. Frame information is returned to the desired information memory. It is then sent through the local channel to the product control computer for storage display and setting changes. Option information is stored and transmitted to a computer simulator. A computer simulator is a combination of a control panel and a special panel [24]. The main function of the control computer is to complete functions such as human-computer interaction, data storage, and scheduling, including device drivers, human-computer interaction interfaces, and storage devices, as shown in Figure 3.

Option pricing models require a computer simulation program to complete the application and software design. According to its structural characteristics, the design is divided into three parts. The first part mainly involves the design of option pricing and the drafting of device drivers. The bus of the model is a bus that is not connected to a specific processor; it can maintain high performance at high clock frequencies and support plug-and-play and any compatible card access system work. The second part is the design of the compatible card. One end of the compatible card is connected to the infrared controller through half-side serial communication, and the other end communicates with the company's control computer through the channel

and control. The computer communicates with the infrared image via the researcher information bus. Compatible cards have good electrical insulation properties, thereby improving the anti-interference and security of the motherboard system. The third part realizes human-computer interaction through the human-computer interaction view processing the human-computer interaction interface design of the pop-up simulation program, exploring function definitions, state information provided by the main control, etc., so as to realize human-computer interaction [25].

2.4. Recommendation Algorithm

2.4.1. B-S Option Pricing Model. The model uses stochastic differential equations to describe the market fluctuation law of derivatives. According to this law, the current value of the derivative product is determined, which is the differential equation that the price of any derivative product without dividends paying the underlying asset must satisfy. By solving this equation, the B-S option pricing model finally obtains the pricing formulas for European call options and put options [26].

The value of the underlying asset is similar to the "Brownian motion," that is, the value of the underlying asset randomly follows the rate of change during the transfer. Therefore, regardless of the time period, the distribution of the value of the underlying assets is normal [27]. The variance of the underlying performance return does not change, and the background value of the underlying price S follows the following stochastic process:

$$dS = \mu S dt + \sigma S dq. \tag{1}$$

Among them, μ is the expected return of the underlying asset and σ is the volatility of the underlying asset price, both of which are constants. q is a variable of the Wiener process, that is, $dq = \varepsilon\sqrt{dt}$ obeys a standard normal distribution (that is, a normal distribution with a mean of 0 and a standard deviation of 1.0).

Let f be the price of the derivative security priced at S; then, f is some function of S and t. According to equation (1), we have the following:

$$df = \left(\frac{\partial f}{\partial S}\mu S + \frac{\partial f}{\partial t} + \frac{1}{2}\frac{\partial^2 f}{\partial S^2}\sigma^2 S^2\right)dt + \frac{\partial f}{\partial t}\sigma S dq. \tag{2}$$

Discrete equations (1) and (2), respectively, to get the following:

$$\Delta S = \mu S \Delta t + \mu S \Delta q, \tag{3}$$

$$\Delta f = \left(\frac{\partial f}{\partial S}\mu S + \frac{\partial f}{\partial t} + \frac{1}{2}\frac{\partial^2 f}{\partial S^2}\sigma^2 S^2\right)\Delta t + \frac{\partial f}{\partial t}\sigma S \Delta q. \tag{4}$$

The portfolio is now constructed as follows: -1 corresponds to derivative securities and $+(\partial f/\partial S)$ is the underlying asset.

That is, the number of derivative securities sold is 1 and the number of underlying assets purchased is $+(\partial f/\partial S)$. Definition $\mathfrak{J}$ represents the value of a portfolio of securities; then,

$$\mathfrak{J} = -f + \frac{\partial f}{\partial S}S. \tag{5}$$

After time Δt, the value of the portfolio changes to $\Delta\mathfrak{J}$ as follows:

$$\Delta\mathfrak{J} = -\Delta f + \frac{\partial f}{\partial S}\Delta S. \tag{6}$$

Substituting equations (3) and (4) into (6) yields the following:

$$\Delta\mathfrak{J} = \left(-\frac{\partial f}{\partial t} - \frac{1}{2}\frac{\partial^2}{S^2}\sigma^2 S^2\right)\Delta t. \tag{7}$$

This process does not include uncertainty Δz, so portfolio $\mathfrak{J}$ is obtained from Δt and does not create risk. The immediate rate of return on this portfolio is the short-term risk-free rate w. In any case,

$$\Delta\mathfrak{J} = w\mathfrak{J}\Delta t. \tag{8}$$

Combining equations (5) and (7) yields the following:

$$\left(\frac{\partial f}{\partial t} + \frac{1}{2}\frac{\partial^2 f}{\partial S^2}\right)\sigma^2 S^2 \Delta t = w\left(f - \frac{\partial f}{\partial S}S\right)\Delta t, \tag{9}$$

which is simplified to the following:

$$\frac{\partial f}{\partial t} + wS\frac{\partial f}{\partial S} + \frac{1}{2}\sigma^2 S^2\frac{\partial^2 f}{\partial S^2} = wf. \tag{10}$$

Equation (10) is the well-known B-S differential equation [28]. This differential equation applies to the pricing of all derivative securities whose price depends on the price of the underlying security S. This equation has different solutions for different derivative securities. Different derivative securities use different boundary conditions when solving this equation. For European call/put options, the basic boundary conditions are as follows:

$$\begin{aligned} f &= \max(S - X, 0), \quad t = T, \\ f &= \max(X - S, 0), \quad t = T. \end{aligned} \tag{11}$$

Combining equation (8) with (11), the pricing formulas of financial market options and import options can be obtained:

$$c = SN(d_1) - Xe^{-w(T-t)}N(d_2). \tag{12}$$

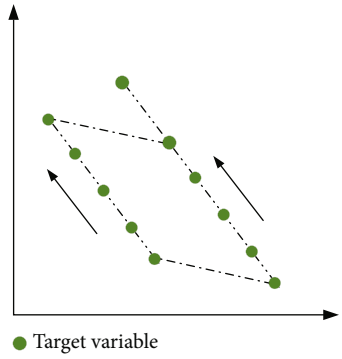

Figure 4: Schematic diagram of the mutation process.

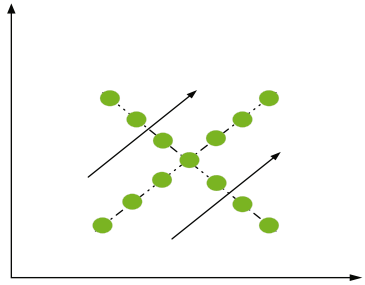

Figure 5: Schematic diagram of the crossover process.

Among them,

$$d_1 = \frac{\ln(S/X) + \left(w + \sigma^2/2\right)(T-t)}{\sigma(T-t)^{1/2}}, \qquad d_2 - d_1 - \sigma(T-t)^{1/2}. \tag{13}$$

$N(x)$ is the cumulative function of the standard variable. By invoking the parity formulas $p = c - S + Xe^{-w(T-t)}$ and $N(x) + N(-x) = 1$, the value p of the incremental value t is as follows:

$$p = -SN(-d_1) + Xe^{-w(T-t)}N(-d_2). \tag{14}$$

In formula B-S, the value of an option is based on five variables: the value of the underlying asset, exercise rate, risk-free rate, time to maturity, and underlying volatility. Of these five variables, interest rates and volatility are unknown and the volatility of interest rates and options must be predicted.

When calculating the B-S equation, it is necessary to know whether the derivative security $\mathfrak{F}$ is safe and whether there is a risk. $+(\partial f/\partial S)$ changes as S and t change when it is confirmed that there is no risk. Therefore, the relative proportions of derivative securities and assets should be constantly adjusted to avoid risks.

2.4.2. Basic Particle Swarm Optimization Algorithm. When the p particle is in the D-dimensional position, it forms a population $(x_1, x_2, \cdots, x_p)$ flying at a certain speed. Each particle has the ability to adjust the flight speed and position according to its own flight experience [29]. Among them, the position of each particle can be expressed as $x_i = (x_{i1}, x_{i1}, \cdots, x_{iD})$ and the respective velocity of each particle is expressed as $v_i = (v_{i1}, v_{i1}, \cdots, v_{iD})$, $1 \le i \le p$, $1 \le d \le D$. For the ith particle, the best position that the particle has flown is expressed as $q_i = (q_{i1}, q_{i1}, \cdots, q_{iD})$ and the best position that the local particle has experienced $q_g = (q_{g1}, q_{g1}, \cdots, q_{gD})$.

Table 1: Experimental data.

	Industry	Time to market	Option net price
1	Winemaking	20	6.88
2	New energy industry	21	4.79
3	Car industry	25	5.64
4	Electrical industry	22	2.79

$$v_{iD}^{k+1} = v_{iD}^{k} + c_1\xi\left(q_{iD}^{k} - x_{iD}^{k}\right) + c_2\eta\left(q_{gD}^{k} - x_{iD}^{k}\right), \qquad x_{iD}^{k+1} = x_{iD}^{k} + v_{iD}^{k+1}. \tag{15}$$

Among them, c_1 and c_2 are called accelerometers and c_2 is called accelerometers. r_1 and r_1 are usually random numbers between [0,1]. The speed of the particles is controlled in the range of $[-V_{\max}, V_{\max}]$.

2.4.3. Principle of the Differential Evolution Algorithm. $X_{i,G}$ $(i = 1, 2, \cdots, MP) = X_{i,G} = [x_{1,G}, x_{2,i,G}, \cdots, x_{n,i,G}]$ = DEuses the parameter vector of the variable$M$as the population for each generation, and rand(0,1) represents a single ID number created within [0,1] [30].

In the DE algorithm, the creation of the first population is generally obtained from all random obey uniform probability, which is as follows:

$$x_{j,i,0} = \text{rand}\,[0,1]\left(u_j - l_j\right) + l_j, \quad (i = 1, 2, \cdots, MP; j = 1, 2, \cdots, m). \tag{16}$$

The mutation evolution algorithm is to create a new population by changing the individual mutation of the current population. Randomly select 3 different individuals from the current G generation for transformation, mutate, and generate mutant individual $V_{i,G+1}$, namely,

$$V_{i,G+1} = X_{rl,G} + D(X_{r2,G} - X_{r3,G}), \quad r_1 \ne r_2 \ne r_3 \ne i. \tag{17}$$

Among them, r_1, r_2, and r_3 are randomly selected vector serial numbers, which are different from each other and different from the serial number i of a single vector target. F is the differentiation factor. The mutation process is shown in Figure 4.

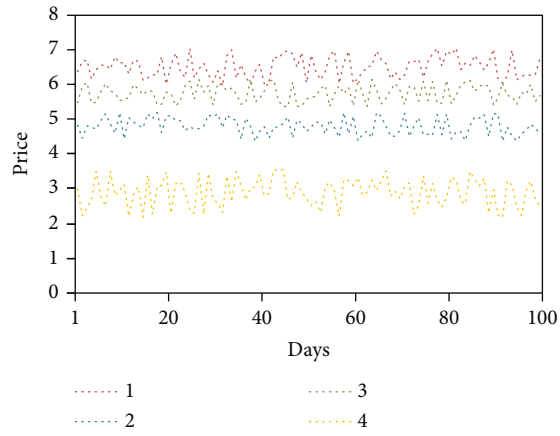

Figure 6: Option pricing volatility.

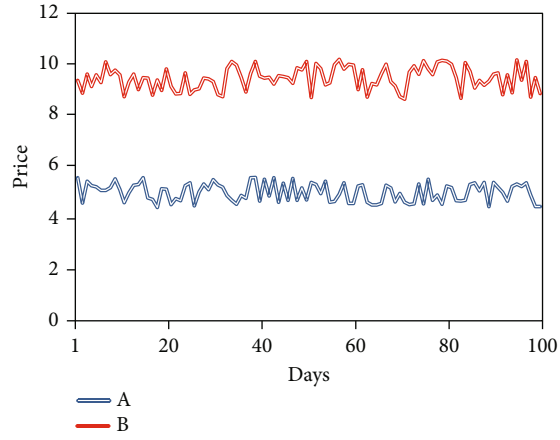

Figure 7: Accuracy comparison chart.

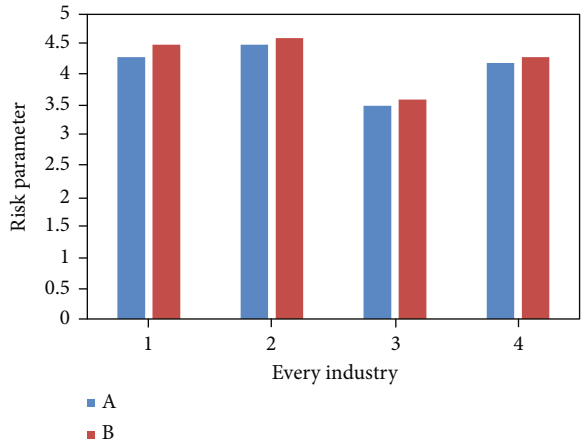

Figure 8: Risk parameter testing.

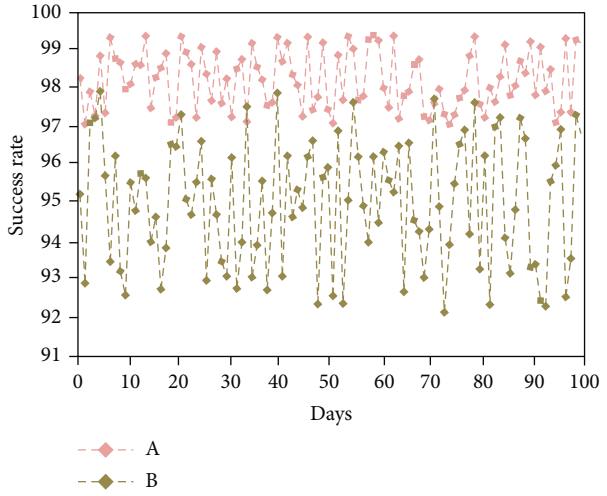

Figure 9: Success rate test.

Using crossover operations to increase the richness of data, the operation process is as follows:

$$U_{i,G+1} = u_{j,i,G+1} = \begin{cases} v_{j,i,G+1}, & \text{if rand } (j) \le CR \text{ or } j = \text{rnd}(i), \\ x_{j,i,G}, & \text{otherwise.} \end{cases} \tag{18}$$

When using the differential evolution algorithm, four running parameters need to be set in advance: (1) The population size is N. For general problems, take 20–50. The larger the N, the stronger the diversity of the population and the greater the probability of obtaining the optimal solution, but the longer the calculation time is. (2) The maximum number of iterations is G. The setting of G depends on the specific problem. The larger the G, the more accurate the optimal solution and the longer the calculation time. (3) The variation factor F is between 0 and 2, usually 0.7. (4) Crossover probability CR, between 0 and 1, usually takes 0.4.

Rand(j) is a uniformly distributed random number between [0, 1], CR is called the crossover probability, and rnd(i) is a random number between $\{1, 2, \cdots, n\}$. The crossover process is shown in Figure 5.

According to equation (18), each test vector $U_{i,G+1}$ is compared with each individual vector $X_{i,G}$ corresponding to the current population and the individual with the best fitting value is selected to enter the next-generation population [31].

3. Option Pricing Model Experimental Design

3.1. Experimental Process. A financial market is selected as the research object, and four options are simulated and simulated, which are tested from the four aspects of error, risk parameters, success rate, and simulation time. After the traditional financial option pricing model is simulated, the computer simulation technology is used to simulate the research again. Then, compare with the actual option pricing results to observe the changes of applying computer

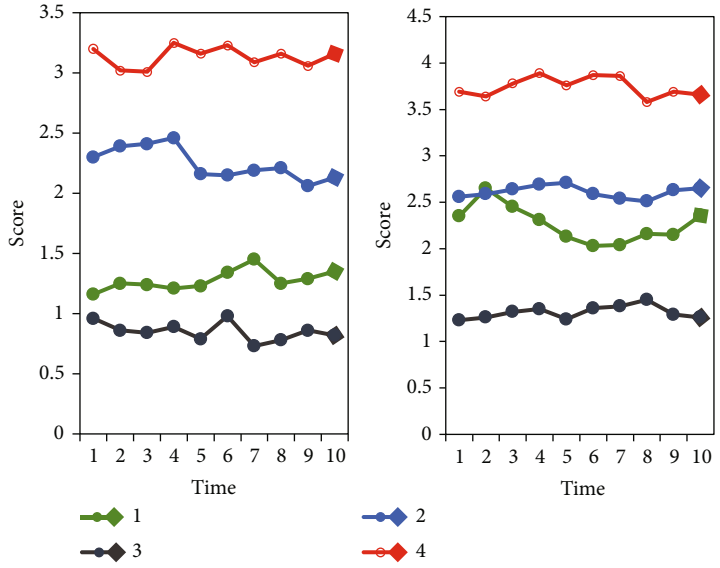

Figure 10: Simulation time test.

simulation technology to the option pricing model compared with the traditional financial option pricing model.

3.2. Experimental Data. Five different industries were randomly selected as the experimental objects, and the specific data of the five experimental objects are shown in Table 1.

3.3. The Purpose of the Experiment. Changes were observed in the application of computer simulation techniques to option pricing models compared to traditional financial option pricing models. Whether it is possible to improve the accuracy and reduce the error is the key to avoid risks.

4. Option Pricing Model Experimental Design Results

4.1. Error Test. In order to ensure the accuracy of the experiment, the simulation experiment of option pricing error is carried out on 4 industries and the 100-day option pricing changes are tested to observe which model has a smaller error between the traditional financial option pricing model and the option pricing model using computer simulation technology. Figure 6 shows the 100-day option pricing fluctuations of four companies, and Figure 7 shows the error comparison chart, where A is the error value of the option pricing model using computer simulation technology and B is the error value of the traditional financial option pricing model.

It can be seen that the option pricing model of the computer simulation technology is closer to the actual financial option pricing, with an average error of less than 6.5%, while the average error of the traditional financial option pricing model is less than 10.3%. It can be seen that the computer simulation technology can more fully analyze the option pricing situation and the simulated data is closer to the actual value. The accuracy rate of the option pricing model using computer simulation technology is higher than that of the traditional financial option pricing model, and the error is smaller.

4.2. Risk Parameter Test. Carry out risk simulation tests on 4 enterprises, among which A is the risk parameter of the option pricing model using computer simulation technology and B is the risk parameter of the traditional financial option pricing model. The results are shown in Figure 8.

It can be that the risk parameter of the computer simulation technology option pricing model is slightly lower than that of the traditional financial option pricing model. The average risk parameter of the computer simulation technology option pricing model of the four companies is 4.125, the risk parameter of the traditional financial option pricing model is 4.25, and the risk parameter is reduced by 3.03%. It can be seen that the application of computer simulation technology to the financial option pricing model can reduce the risk parameters and ensure the stability of the financial market.

4.3. Success Rate Test. The traditional financial option pricing model and the option pricing model using computer simulation technology are tested for the success rate, and the actual pricing of options in 4 industries is tested. The simulation results are compared with the actual results to see which model has a higher success rate. Among them, A is the success rate of the option pricing model using computer simulation technology and B is the success rate of the traditional financial option pricing model. The results are shown in Figure 9.

It can be seen that the success rate of the option pricing model of computer simulation technology is much higher than that of the traditional financial option pricing model. The success rate of the traditional financial option pricing model fluctuates at around 95%, and the success rate of the computer simulation technology option pricing model fluctuates at around 98%. The success rate of the traditional financial option pricing model has a large fluctuation area,

and the computer simulation technology option pricing model has a small fluctuation area of the success rate. The success rate of the computer simulation technology option pricing model is more stable than that of the traditional financial option pricing model.

4.4. Simulation Time Test. The simulation time of the option pricing model and the traditional financial option pricing model using computer simulation technology was recorded separately to observe the difference in time between the two, and 10 simulation tests were conducted on 4 industries. The results are shown in Figure 10.

It can be seen that the simulation time of the computer simulation technology option pricing model is lower than that of the traditional financial option pricing model. The average simulation time of the option pricing model of the computer simulation technology is 1.877 seconds, and the average simulation time of the traditional financial option pricing model is 2.482. The computer simulation technology increases the simulation time by 0.605 seconds. It can be seen that the algorithm process of computer simulation technology is simpler and the simulation speed is faster.

5. Discussion

The research on people's understanding of finance begins by challenging the traditional financial market hypothesis and expected utility theory and analyzing and understanding traditional financial science from the perspective of psychology. It not only provides new research methods for financial market research but also brings new research perspectives to financial science research. In this paper, a computer simulation study is carried out from the correlation finance under the stochastic interest rate and an option pricing model is established, which uses the basic particle swarm optimization algorithm and differential evolution algorithm to establish the option pricing model. Although many achievements have been made in the pricing of financial options, due to the influence of external factors, the experimental results will have certain errors, which will not affect the final results, which can greatly reduce the risks existing in the financial market and promote the development of financial enterprises.

6. Conclusion

As an advanced simulation technology, computer simulation technology can bring the simulation results close to the actual results to the greatest extent. In this paper, the B-S option pricing model is used to apply computer simulation technology to the option pricing model and the basic particle swarm optimization algorithm and differential evolution algorithm are used to simulate the relevant financial option pricing under stochastic interest rates. The performance, success rate, risk parameters, and simulation time are superior to traditional option pricing models.

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

References

[1] Z. Tomovski, J. Dubbeldam, and J. Korbel, "Applications of Hilfer-Prabhakar operator to option pricing financial model," *Fractional Calculus and Applied Analysis*, vol. 23, no. 4, pp. 996–1012, 2020.

[2] R. Tunaru and T. Zheng, "Parameter estimation risk in asset pricing and risk management: a Bayesian approach," *International Review of Financial Analysis*, vol. 53, no. 11, pp. 80–93, 2017.

[3] X. Gong and X. Zhuang, "Option pricing and hedging for tempered stable jumps driven stochastic volatility models based on improved PSO algorithm," *Systems Engineering-Theory & Practice*, vol. 37, no. 11, pp. 2765–2776, 2017.

[4] A. Dubinsky, M. Johannes, A. Kaeck, and N. J. Seeger, "Option pricing of earnings announcement risks," *Review of Financial Studies*, vol. 32, no. 2, pp. 646–687, 2019.

[5] L. Zhang, Y. Sun, and X. Meng, "European spread option pricing with the floating interest rate for uncertain financial market," *Mathematical Problems in Engineering*, vol. 2020, Article ID 2015845, 8 pages, 2020.

[6] B. Orbay, R. Güllü, and W. Hörmann, "Mispricing in option pricing models versus market payoffs: an efficiency-based performance metric," *Wilmott*, vol. 2017, no. 92, pp. 44–57, 2017.

[7] R. Mollapourasl, M. Haghi, and R. Liu, "Localized kernel-based approximation for pricing financial options under regime switching jump diffusion model," *Applied Numerical Mathematics*, vol. 134, pp. 81–104, 2018.

[8] W. S. Parker, "Computer simulation, measurement, and data assimilation," *The British Journal for the Philosophy of Science*, vol. 68, no. 1, pp. 273–304, 2017.

[9] J. A. Atkinson, D. Knowles, and J. Wiggers, "Harnessing advances in computer simulation to inform policy and planning to reduce alcohol-related harms," *International Journal of Public Health*, vol. 63, no. 3, 2017.

[10] M. Straka, R. Lenort, S. Khouri, and J. Feliks, "Design of large-scale logistics systems using computer simulation hierarchic structure," *International Journal of Simulation Modelling*, vol. 17, no. 1, pp. 105–118, 2018.

[11] Z. Niek, H. Wouter, and L. Van, "Preoperative computer simulation for planning of vascular access surgery in hemodialysis patients," *Journal of Vascular Access*, vol. 18, no. 1, pp. 118–124, 2017.

[12] C. L. Wang, S. Chinnugounder, D. S. Hippe et al., "Comparative effectiveness of hands-on versus computer simulation-based training for contrast media reactions and teamwork skills," *Journal of the American College of Radiology: JACR*, vol. 14, no. 1, pp. 103–110.e3, 2017.

[13] A. Mrozek and T. Burczynski, "Examination of mechanical properties of graphene allotropes by means of computer

simulation," *Computer Assisted Mechanics & Engineering Sciences*, vol. 20, no. 4, pp. 309–323, 2017.

[14] C. Song, "Design and application of financial market option pricing system based on high-performance computing and deep reinforcement learning," *Scientific Programming*, vol. 2022, Article ID 8525361, 12 pages, 2022.

[15] L. Lv, C. Zheng, and L. Wang, "Option pricing under the subordinated market models," *Discrete Dynamics in Nature and Society*, vol. 2022, Article ID 6213803, 8 pages, 2022.

[16] E. Hajizadeh and M. Mahootchi, "Optimized radial basis function neural network for improving approximate dynamic programming in pricing high dimensional options," *Neural Computing and Applications*, vol. 30, no. 6, pp. 1783–1794, 2018.

[17] P. Wang and W. Han, "Autonomous motivation and self-disclosure intention," *Journal of Organizational and End User Computing (JOEUC)*, vol. 33, no. 6, pp. 1–27, 2021.

[18] D. V. Halkin and O. M. Halkina, "Organizational and legal principles of Soviet militia dispatch center's functioning during 1969–1991," *Bulletin of Kharkiv National University of Internal Affairs*, vol. 89, no. 2, pp. 15–25, 2020.

[19] N. Schmitt and F. Westerhoff, "Heterogeneity, spontaneous coordination and extreme events within large-scale and small-scale agent-based financial market models," *Journal of Evolutionary Economics*, vol. 27, no. 5, pp. 1041–1070, 2017.

[20] A. S. Chen, M. T. Leung, S. Pan, and C. Y. Chou, "Financial hedging in energy market by cross-learning machines," *Neural Computing and Applications*, vol. 32, no. 14, pp. 10321–10335, 2020.

[21] X. Zheng, G. Zhu, N. Metawa, and Q. Zhou, "Machine learning based customer meta-combination brand equity analysis for marketing behavior evaluation," *Information Processing and Management*, vol. 59, no. 1, article 102800, 2022.

[22] S. N. Alsubari, S. N. Deshmukh, A. A. Alqarni et al., "Data analytics for the identification of fake reviews using supervised learning," *CMC-Computers, Materials & Continua*, vol. 70, no. 2, pp. 3189–3204, 2022.

[23] A. Freij, K. Walid, and M. Mustafa, "Deep learning model for digital sales increasing and forecasting: towards smart E-commerce," *Journal of Cybersecurity and Information Management*, vol. 8, no. 1, pp. 26–34, 2021.

[24] L. Xu, L. Zhang, and D. Yao, "Optimal investment and reinsurance for an insurer under Markov-modulated financial market," *Insurance Mathematics & Economics*, vol. 74, no. 6, pp. 7–19, 2017.

[25] None, "Editorial board for the 2015 International Society for Biopharmaceutical Statistics (ISBS) and DIA China special issue," *Statistics in Biopharmaceutical Research*, vol. 10, no. 1, pp. 70–75, 2018.

[26] B. Zhang, D. D. Wu, and L. Liang, "Optimal option ordering and pricing decisions with capital constraint and default risk," *IEEE Systems Journal*, vol. 11, no. 3, pp. 1537–1547, 2017.

[27] H. Allouba and Department of Mathematical Sciences, Kent State University, Kent, Ohio 44242, "Brownian-time Brownian motion SIEs on $\mathbb{R}_{+}$ × $\mathbb{R}^d$: ultra regular direct and lattice-limits solutions and fourth order SPDEs links," *Discrete & Continuous Dynamical Systems*, vol. 33, no. 2, pp. 413–463, 2013.

[28] A. H. Msmali, A. M. Alotaibi, and M. A. El-Moneam, "A general scheme for solving systems of linear first-order differential equations based on the differential transform method," *Journal of Mathematics*, vol. 2021, no. 2, 9 pages, 2021.

[29] H. Zhou, J. Pang, P. K. Chen, and F. D. Chou, "A modified particle swarm optimization algorithm for a batch-processing machine scheduling problem with arbitrary release times and non-identical job sizes," *Computers & Industrial Engineering*, vol. 123, no. 12, pp. 67–81, 2018.

[30] A. Tombari and L. Stefanini, "Hybrid fuzzy - stochastic 1D site response analysis accounting for soil uncertainties," *Mechanical Systems and Signal Processing*, vol. 132, no. 11, pp. 102–121, 2019.

[31] P. Wang, W. Wang, and N. Meng, "Multi-objective energy management system for DC microgrids based on the maximum membership degree principle," *Journal of Modern Power Systems & Clean Energy*, vol. 6, no. 4, pp. 668–678, 2018.