

## Retraction

# Retracted: Recursive Neural Network-Based Market Demand Forecasting Algorithm for Calligraphy Practice Products

### Journal of Mathematics

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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) Manipulated or compromised peer review

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

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

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

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

### References

- [1] Y. Xue, "Recursive Neural Network-Based Market Demand Forecasting Algorithm for Calligraphy Practice Products," *Journal of Mathematics*, vol. 2022, Article ID 8086789, 10 pages, 2022.

## Research Article

# Recursive Neural Network-Based Market Demand Forecasting Algorithm for Calligraphy Practice Products

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In today's society, calligraphy, which reflects one's basic writing skills, is becoming more and more important to people. People are influenced by calligraphy in their studies, work, etc. Improving calligraphy writing skills has become one of the key directions for developing one's abilities at this stage. As an important means of improving writing skills, calligraphy practice products are attracting more and more attention and purchases. In particular, in recent years, as the market economy has developed in a deeper direction, people's demand for calligraphy practice products has diversified and calligraphy practice product companies have launched a variety of products to meet the public's calligraphy practice needs in order to adapt to the reality of consumer demand. However, with the development of the Internet culture industry and influenced by objective factors such as school holidays and seasons, the current market demand for calligraphy practice products is rapidly and dynamically changing, making market changes difficult to grasp and leading to poor sales, which directly affects the profits of calligraphy practice product-related companies. The artificial intelligence neural network method realizes the nonlinear relationship between the input and output of sample data through the self-learning ability of each neuron and has a certain nonlinear mapping ability in prediction, which plays a great role in the market demand prediction of many commercial products. Based on this, this paper proposes a recursive neural network-based algorithm to predict the future demand and development trend of calligraphy practice products through extensive and in-depth research, so as to provide positive and beneficial guidance for enterprises' future production and sales.

## 1. Introduction

China has been a cultural power since ancient times, and after more than a thousand years of historical evolution, the major ancient Chinese civilizations have long influenced each other and merged. Today, a China with a splendid culture stands in the East of the world with its colorful cultural elements. An important part of Chinese culture is writing, and the different aesthetic forms of writing form the art of calligraphy [1]. The art of Chinese calligraphy, with its long and unbroken history, has attracted generations of calligraphers to cultivate and tread the paths of the ancients, to experience the essence of the culture that has been precipitated for thousands of years, and on the other hand, to read ten thousand books, travel ten thousand miles, capture the world, cultivate their bodies, and express it in their brushstrokes, creating a style of calligraphy appropriate to the times. Together with other forms of art, they form a

vast sea of Chinese culture. The art of calligraphy has always been respected by the nation as an elegant, erudite, and nurturing art form. The art of Chinese calligraphy is a manifestation of Chinese culture and is one with the spirit of the Chinese nation. The spirit of Chinese culture is the unity of heaven and man, the valuing of harmony, and the shunning of center. The Chinese culture's value of "harmony is precious" is perfectly embodied through the beauty of harmony in the art of calligraphy [2]. Calligraphy practice products collection is shown in Figure 1.

Chinese calligraphy, with its ability to express the richness and complexity of human thought and emotion in the simple shape of lines, has great aesthetic value. The study of Chinese calligraphy is a great help in understanding Chinese art and culture. Calligraphy exists alongside the written word and is concerned with brushwork, strokes, and strokes of meaning. With the help of Chinese characters, calligraphy is an expression of sentiment and sentimentality



FIGURE 1: Calligraphy practice products collection.

and has a strong national character and high artistic taste. Chinese calligraphy has been steeped in thousands of years and is ubiquitous in Chinese life. It is closely related to residential culture, landscape culture, educational culture, religious culture, political culture, coin culture, folk ritual customs, and the arts of painting, architecture, dance, arts, and crafts [3]. As shown in Figure 1, Chinese calligraphy is a unique visual art that still exudes a fascinating artistic charm after thousands of years. The artistic beauty of Chinese calligraphy is composed of two elements: form and spirit. The beautiful and distinct artistic effects and infectious power of calligraphy reflect a unique national style. The composition of traditional painting and calligraphy requires the author not only to make a subjective and rational judgment but also to take the various elements of the picture and to achieve a dialectical unity between the whole and the parts so that the picture can achieve balance and harmony, which can be regarded as the earliest theory of composition in Chinese painting [4]. The aesthetic value of the art of calligraphy has many applications in home decoration, where its content has a subtle effect on the human spirit, gaining knowledge and culture, drawing inspiration and strength. At the same time, calligraphy with its unique means of art life and service life is widely used in the design of patterns for product packaging. The art of Chinese calligraphy, which on the surface appears to be very common, is nothing more than taking a brush and dipping it in ink to write Chinese characters on paper (of course, other writing carriers are sometimes used), but it is this extreme simplicity and richness of variation that has made calligraphy less attractive in contemporary times due to the advancement of modern science and technology, especially the spread of computers and the reduction of handwriting. It has become one of the most popular art forms in contemporary China, with the largest number of participants and the widest audience. Calligraphy is widely recognized for its ability to

cultivate the body and nourish the mind. Calligraphy is indeed a great source of health benefits, allowing the whole body to move, the waist and arm strength and eye strength to be harmonized, and the rigidity and flexibility to be combined with movement and stillness, as well as strengthening the body and brain, eliminating fatigue, regulating the psyche, and quieting the mind. Calligraphers and calligraphy education work have also become a highly respected profession in society. The Chinese Calligraphers Association, which consists of national calligraphers, seal carvers, calligraphy theorists, calligraphy educators, and calligraphy activity organizers and management workers, has become a national professional organization and a group member of the Chinese Federation of Literary and Art Circles. Calligraphy enthusiasts have relatively good social recognition. This intangible social recognition and support provide great assistance in the spread, learning, and development of calligraphy [5].

Chinese calligraphy has always been an excellent traditional culture that we are proud of, with thousands of years of history. As life has improved, many parents have begun to pay attention to the cultural development of their children. Learning calligraphy can lay the foundation for children's writing and can improve their overall quality. China's contemporary design started late, and so did the stationery industry's design system, with a large proportion of domestic stationery manufacturers borrowing or directly copying foreign stationery products in the early days. However, as a local cultural product, it is difficult to find a mature product from abroad that is worth learning from. With the rapid development of the Internet culture industry, calligraphy practice products are now combined with modern design to create new developments that shine in a different light [6]. As a representative of traditional culture, the calligraphy practice product industry is also facing unprecedented impact, challenges, and opportunities in the Internet era,

and it is worthwhile to deeply explore the artistic value of calligraphy and promote it, thus creating economic value and prosperity for the calligraphy industry. In recent years, with the rapid development of computer technology, the Internet is deeply integrated with various traditional industries. The Internet economy, represented by the booming e-commerce, has become an important engine of economic development. This will provide great development potential and broader development space for the rise of the Internet economy. The Internet has changed people's lifestyles and brought more possibilities for consumption upgrading and industrial development. The further integration of the Internet with traditional industries has changed the way the original industries produce, sell, and communicate, bringing new opportunities for development. As a typical representative of traditional industries, the calligraphy practice product industry is also integrating Internet technology, quietly undergoing the biggest change in thousands of years. Artificial intelligence is a new technical science that studies and develops theories, methods, technologies, and application systems used to simulate, extend, and expand human intelligence. Artificial intelligence-based market demand forecasting method refers to the method of using artificial intelligence techniques, mainly machine learning and deep learning, etc., to simulate industry experts for market demand forecasting, which differs from fundamental analysis and technical analysis methods in terms of modeling methods, and focuses on the use of artificial intelligence techniques to uncover potential connections between data from various sources in the market and market movements. In order to adapt to the new environment of the Internet culture industry, it is necessary to design and study new intelligent field demand forecasting algorithms for the calligraphy practice product market using artificial intelligence techniques.

In this paper, we start by presenting related works in Section 2; then, in Section 3, we discuss an artificial intelligence neural network method that has certain nonlinear mapping ability in prediction; and for the concerned method, we do experiments in Section 4 and evaluations and finally put a conclusion in Section 5.

## 2. Related Work

*2.1. Calligraphy Practice Products Market Analysis.* As an important part of art and culture, calligraphy has gradually moved from the study to the marketplace, forming the basic chain of industrialization, the emergence of specialized calligraphic art dealers and collectors, and the involvement of merchants in the operation of calligraphic artwork that has to some extent further guided the development of calligraphy in the direction of industrialization. At the same time, the development of a related industrial chain plus the framing of calligraphic works and the trading of the Four Treasures of calligraphy market gradually took shape. As the national economy is developing rapidly and people's consumption levels are increasing, the art of calligraphy is also seeing better opportunities for development. People have more time and money for calligraphy-related consumption.

First, consumables such as ink, paper, and inkstone are relatively inexpensive compared to other hobbies, such as musical instruments and photography equipment. The vast majority of consumers can afford them. Beginners can basically get all the materials they need to learn calligraphy for under \$1,000. With the rise of productivity and the economy, the cost of consumables for calligraphy practice is no longer an issue that hinders the spread of calligraphy learning. Secondly, the calligraphy training industry is also in full swing with economic development. As more and more families reach the well-off level and have a relatively good income, parents have the funds and ability to send their children to calligraphy training courses to learn calligraphy. The cost of calligraphy education is in the middle of the range of hobby learning costs and is becoming more and more acceptable to parents and families. The good economic development and the increase in consumption power have created a good development environment and opportunity for the calligraphy training industry. In addition, economic development has led to the development of the Internet and online education, and payment for knowledge has become the consensus of the times. Online education and online paid courses in calligraphy are also being accepted by more and more adult learners, all of which have brought great prosperity and opportunities to the calligraphy practice products market. Practitioners of calligraphy practice products have also enjoyed the dividends of economic development, and calligraphy, an important art form, has gradually become a leisurely and elegant way of life for the general public after the majority of people have solved the problem of food and clothing [7].

With the development of society and the advancement of technology and culture, the calligraphy industry has also seen unprecedented growth. Various calligraphy practice products have become abundant, the four treasures of calligraphy supplies continue to innovate, and new teaching models and online classes have become popular with the advancement of video and live streaming technology. Online shopping, online payments, and interpersonal trust have taken calligraphy practice products from offline to online. It can be said that the calligraphy industry has also enjoyed the great convenience of the Internet and technological advances, and the dissemination of calligraphy has become easier and more convenient. However, the calligraphy market still has its limitations [8]. Calligraphy is a niche industry with a small group of learners, and although calligraphy can be found everywhere in life, it is still a minority of people who actually learn and come into contact with calligraphy, so the small consumer base and low degree of consumer demand are the biggest obstacles to building a calligraphy industry chain. Compared to the entertainment and leisure industries, such as movies, music, dance, and food, which have a high degree of popularity, calligraphy is still relatively inactive. Calligraphy is a quiet art, limited to the line and visual appreciation, lacking auditory and gustatory stimulation, with limited impact and limited influence, and with the popularity of computer fonts, the practicality of calligraphy is even weaker. Many people are not involved, making market activity and demand

lukewarm. The cycle of production (creation), sales, and consumption of calligraphy are slow, circulation is tiny, age groups are large, and innovation is slow. Calligraphy products are also nondepleting; many calligraphy products can be used for years, and many calligraphy paintings can be preserved for years, which makes the replacement of new calligraphy products slow, and low consumption and low attrition make it difficult for demand for calligraphy products to rise. Calligraphy is an elegant, high-end, spiritual art with a high skill threshold, requiring a certain level of practice, cultural heritage, and knowledge to resonate, love, and appreciate. Calligraphy also has regional and cultural limitations, limited to a few countries such as China and Japan, and from an international perspective, it lacks global demand and circulation. All of this has hindered the rapid development of the calligraphy market. The calligraphy industry is a more stable, long-term lukewarm state of development, with an overall stable Baidu search index and information index with a slight increase. Calligraphy is a traditional culture of thousands of years, and even with the impact of the Internet and artificial intelligence, it will continue to be relatively stable and will not experience major ups and downs [9]. The calligraphy industry is inactive, and the calligraphy auction industry is relatively sluggish, with fewer influential calligraphy works and calligraphy masters, although precious calligraphy works can fetch high prices. The calligraphy industry is in disarray, with small calligraphy practice product manufacturers stealing and evading taxes, and calligraphers with low tax capacity or conducting private transactions without paying taxes. Numerous small and scattered calligraphy training institutions are popping up, and paying taxes is not regulated enough. The state does not have much revenue to spend on the calligraphy industry, and there is no major investment. In the calligraphy industry analysis, the competition in the same industry for sales of calligraphy products also needs to be mastered. Offline competition can be judged by market research; whether there are local calligraphy training institutions, calligraphy galleries, and calligraphy stores, etc., and how the customer flow and sales are can be investigated. Competition on online e-commerce platforms can be obtained through big data analysis tools on e-commerce platforms, allowing for a clear, accurate, real-time grasp of competition in the same industry. The Internet and big data provide tremendous and convenient help for marketing analysis and business decisions. In conclusion, calligraphy practice products have enjoyed the dividends of the Internet technology era, but there are also great limitations and space, which requires the joint efforts of every calligraphy lover and calligraphy industry practitioners to pioneer and innovate and constantly explore to make it prosperous and strong.

Calligraphy practice is often easy to start and difficult to become a master, or it is easy for beginners to practice calligraphy through text posters. China's calligraphy post industry according to user classification is mainly divided into the K12 calligraphy post market (the main users are kindergarten to high school), adult calligraphy post market, and professional calligraphy post market (the main users with certain career characteristics, such as doctors, civil

servants, etc.). K12 calligraphy post is the largest segment of the entire calligraphy post industry, accounting for more than 60% of the market. At present, China's character post industry is mainly led by several well-known calligraphers, and there are mainly two types of calligraphy practice character post usage forms, one is the tracing character post, and the other is the water writing character post. Their common drawback is the lack of interaction, the use of a single mode, the use of boring, and not being able to write a variety of fonts. It is based on the lack of interaction between the existing handwriting posters and the practitioner where the laser projection technology and VBK keyboard technology are integrated into the interactive laser projection calligraphy practice product, which has the advantages of easy writing, strong interactivity, and assistance in correcting posture. It has three practice modes. First, learning mode: the laser emitter projects the trajectory and strokes of calligraphy on the paper, visually demonstrating the writing technique; second, copying mode: the laser emitter projects the outer outline of the font on the paper, and the user can directly copy the practice; third, practice mode: the laser emitter projects the meter grid on the paper, and the user can practice writing, and after the writing is completed, the product's intelligent scoring function will rate and voice correct the user's writing. After writing, the product's intelligent scoring function will rate the user's writing and voice correction. At the same time, the system is set up with a library of different types of fonts, so users can choose different types of fonts for practice. The interactive laser projection calligraphy practice product makes up for the shortcomings of the existing calligraphy posters while enriching the functions of the calligraphy practice tool to better meet the needs of consumers. In terms of product functionality, the interactive laser projection calligraphy practice product has a great advantage in that it allows for good human-computer interaction and can meet the requirements of users with different fonts, while being able to detect and correct the words written by the user, preserving a realistic writing experience. In terms of functionality, this product is the equivalent of a calligraphy postcard with thousands of fonts in one and a calligraphy teacher at the same time, providing a one-stop service for learning, practicing, and correcting calligraphy, which is not possible with the calligraphy practice products currently available on the market. The interactive projection calligraphy practice product has advanced technical support to ensure that its function is achieved. The product uses the currently mature laser projection technology and VBK keyboard technology, with a built-in laser emitter to project the interface information on the surface of any paper and then track the finger movements through infrared technology to finally complete the acquisition of input information. High-tech products are a trend for future product development, and consumer enthusiasm for high-tech products is always growing. When high-tech elements are incorporated into a product, then the product can stand out among similar products. The interactive laser projection calligraphy practice product is precisely the integration of laser projection technology and VBK keyboard technology that makes the product stand out

among calligraphy practice products. With the increasing popularity of high-tech products, interactive laser projection calligraphy practice products will be favored by many consumers. According to the “Guideline for Primary and Secondary School Calligraphy Education” published on the website of the Ministry of Education, elementary school grades 3 to 6 are required to schedule one class period per week for brush writing study. According to statistics released by the National Bureau of Statistics on February 24, 2015, it can be seen that 93.6 million students were enrolled in general elementary schools nationwide in 2015. There is such a huge group of calligraphy practitioners among children. The latest survey results released by Regus, a world-renowned office solutions provider, said that the stress suffered by office workers in mainland China in the past year ranked first in the world. Nowadays, office workers’ life is accelerated and their work life is irritating; they are also eager to seek a new way to reduce stress. Practicing calligraphy can cultivate the mind, practice qi, and benefit the brain, nurture respect, and greatly reduce the stress from life. With the development of society and the aging of the population, more and more elderly people are experiencing “retirement syndrome” because they do not know how to organize their lives after retirement. In addition to considering retirement as a rest, the elderly should also maintain a certain level of tension so that life does not become boring. This shows that there is a huge demand for calligraphy practice tools. In this regard, we did an interview survey, by interviewing some parents, teachers, students, office workers, and retired elderly people, the survey results show that primary and secondary school students have the need to practice calligraphy, and it is very important for the development of students. Working people have to sign contracts, agreements, examinations for titles, etc., and they need to improve their writing skills urgently, and the demand for word practice is also great. Secondly, retired seniors: surveys show that many retired seniors prefer to read and write then to play cards and watch TV and other similar activities. So according to the survey results, the target market for calligraphy practice products should be basically located in primary and secondary school students, office workers, and retired seniors [10].

**2.2. Recursive Neural Networks.** Artificial neural network (ANN) has been named deep learning at the time of rapid development of computer storage, communication, and computing power and has set off the third artificial intelligence boom in the world’s history with unprecedented scale. “Deep” gives neural networks the ability to abstract information in a hierarchical way, giving them the “intuition” that people have [11]. Overnight, many fields that had been firmly dominated by fine-grained mathematical models let go of their previous obsession with equations and their prejudice against the inscrutable black box and jumped into the deep learning bandwagon. In this transformation, a recursive neural network (RNN) is responsible for modeling sequential data. Common serial data include signals, text, video image sequences, and serial data such as stock prices

that characterize trends. In daily applications, RNN models are widely used in tasks such as speech recognition and machine translation, bringing convenience to people’s lives. In the biomedical field, sequence data are even more diverse and large in scale, in which RNNs are widely used for tasks such as health monitoring, auxiliary diagnosis, and information extraction, making great contributions to medical development as well as human health. Most biomedical signals are time-varying (time-variant) nonlinear signals, including electrocardiogram (ECG), electroencephalogram (EEG), and electromyogram (EMG). Based on ECG signals, RNN can be used for arrhythmia diagnosis. Based on EEG signals, RNN can be used for sleep signal classification. In addition, in the brain-computer interface, RNN can be used to decode EEG signals and improve the grasping accuracy of neural prostheses. In recent years, the multimodal (multimodal) biomedical signal utilization approach has become a trend. For example, RNN can simultaneously utilize EEG signals as well as functional near-infrared spectroscopy (fNIRS) for epilepsy monitoring. Text in biomedicine is even more complex and diverse, and it is natural that RNNs can perform natural language processing (NLP) on such data [12]. For example, RNN-based biomedical named entity recognition (BNER) technology can help researchers extract useful information from massive biomedical texts. In clinical practice, medical images including ultrasound images, CT images, and MRI images are an important basis for disease diagnosis. Based on ultrasound image sequences, RNN models can significantly improve the detection accuracy of prostate cancer. In computer-aided detection (CAD), RNN can improve the accuracy of early breast cancer detection using current X-ray scans as well as previous scans. At the microscopic scale, RNNs have also been successful in the task of target tracking in time-lapse cell image sequences. In the clinical setting, electronic health record (EHR) data contains sequences of different modalities, which is typical of multimodal data. Based on EHR, RNN can perform disease prediction and also predict the risk of readmission of discharged patients over a period of time, providing the possibility of early initiation of targeted intervention programs for patients at risk of readmission, effectively reducing the probability of readmission, and controlling the cost of care. In recent years, dynamic treatment recommendation systems based on large-scale electronic health records have emerged as the key to the successful improvement of actual clinical outcomes. However, these successes do not conceal a series of problems that arise during the backpropagation of error signals in the depth structure when training RNN models with gradient descent, mainly including the vanishing and exploding gradient problem and the gradient conflict. The former is the most common problem in the general feed-forward neural system. The former is also frequently mentioned in general feed-forward neural network (FNN) research [13]. Before the popularization of Rectified Linear Unit (ReLU), FNNs with deeper structures were often difficult to train due to these problems (especially the gradient vanishing problem). Unlike FNNs, the depth structure of RNNs is inherent, because even an RNN model that contains only a single layer of hidden units in space

becomes very deep when it is expanded in time. RNN models have the ability to remember, are Turing complete, and can theoretically learn dependencies at any time interval in a sequence. However, the long-time memory capability of RNNs is not reliable due to the aforementioned problems. Specifically, it is very difficult to rely on gradient descent to train RNN models to learn long-time dependencies, and early RNN models with simple structures are often deep in the quagmire of gradient disappearance. The Long Short-Term Memory (LSTM) proposed at the end of the last century largely alleviated the gradient disappearance problem, which made RNNs shine in this century's boom, and the LSTM structure itself became the standard configuration of most RNN models. However, LSTM has not fundamentally changed the dilemma that the RNN family is in, and gradients still vanish in the face of longer time series. On the other hand, the gradient explosion problem has never been properly solved. At the time of writing this paper, the third wave of neural networks is still going on. The amount of data available for learning by various neural models is increasing dramatically, and new sequence data and their corresponding learning tasks are emerging. The long-time dependencies embedded in the sequence data are becoming richer, longer in time span, and more obscure in presentation, and capturing these long-time dependencies efficiently and accurately is the key to dealing with such problems. On the other hand, neural network models are increasing day by day. Increasing the network size by stacking model layers and increasing link lengths usually accelerates the decline of model memory. In this context and historical trend, it is urgent to investigate the RNN architecture and related algorithms with long-time memory capability. The method proposed in this paper is the market demand prediction of calligraphy practice products with long- and short-term memory network architecture.

### 3. Method

The internal structure of neurons in recurrent neural networks is shown in Figure 2.

A neural network is a model with strong learning ability, especially effective in dealing with pattern recognition, intelligent control, and other problems. In recent years, with the booming development of computer science and technology and hardware devices, neural networks have gradually become a hot research topic in the field of artificial intelligence [14]. However, Full Connected Neural Network (FCNN) has the limitation that the nodes of the same layer are not connected to each other, and FCNN cannot be used when the information of the previous moments of the sequence is needed. Since FCNNs cannot share features between different locations of a sequence, they can only handle one input individually, i.e., there is no relationship between the previous input and the next input, and they cannot handle inputs that are related back and forth in time or space. However, many learning tasks need to deal with sequential information, such as time series prediction and task-based dialogues, which require the model to learn from sequential inputs. Recursive Neural Network (RNN) was

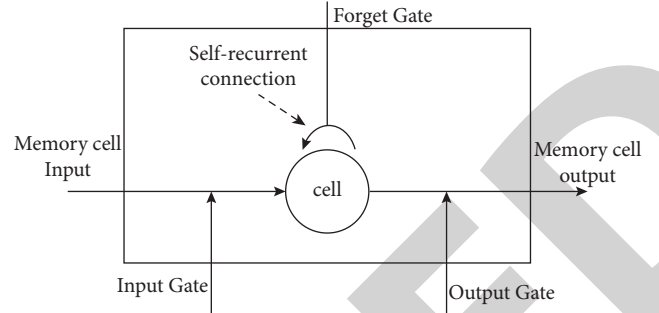


FIGURE 2: Internal structures of neurons in recurrent neural networks.

created to address the need for sequential inputs. Long Short-Term Memory (LSTM) is essentially a specific form of recursive neural network (RNN). In addition to containing a memory module, LSTM solves the RNN long-term dependency problem by adding a threshold (Gated RNN) to solve the problem that the LSTM adds input gate, output gate, and forget gate to the basic structure of RNN [15]. Each of these three logic control units is connected to a multiplication element (see Figure 2), and the input and output of the information flow and the state of the memory cell are controlled by setting the weights at the edges where the memory cell of the neural network is connected to the other parts. The specific structure is shown in Figure 2.

To note, the input gate denoted as  $i_t$  controls whether information flows into the memory cell whereas the forget gate controls whether the information in the memory cell at the previous moment accumulates into the memory cell at the current moment, and it is denoted as  $f_t$ . The output gate denoted as  $o_t$  controls whether the information in the memory cell at the current moment flows into the currently hidden state  $h_t$ . We recall also the cell "memory cell", which represents the memory of the neuron state and makes the LSTM cell have the ability to save, read, reset, and update the long history information, denoted as  $c_t$ . At moment  $t$ , the LSTM neural network is defined by the following equation:

$$\begin{aligned}
 f_t &= \text{sigmoid}(W_f \cdot [h_{t-1}, x_t] + b_f), \\
 i_t &= \text{sigmoid}(W_i \cdot [h_{t-1}, x_t] + b_i), \\
 o_t &= \text{sigmoid}(W_o \cdot [h_{t-1}, x_t] + b_o), \\
 \tilde{c}_t &= \tanh(W_c \cdot [h_{t-1}, x_t] + b_c), \\
 c_t &= f_t * c_{t-1} + i_t * \tilde{c}_t, \\
 h_t &= o_t * \tanh(c_t).
 \end{aligned} \tag{1}$$

The recursive neural network timing diagram is shown in Figure 3.

In addition to the previously mentioned  $i_t$ ,  $f_t$ ,  $o_t$ , and  $c_t$ ,  $W^*$  represent the recursive connection weights of their corresponding gates, and sigmoid and tanh are the two activation functions. In the training process of the LSTM neural network, firstly, the data features at moment  $t$  are input to the input layer and the results are output through the excitation function. The output results, the output of the hidden layer at moment  $t-1$ , and the information stored in

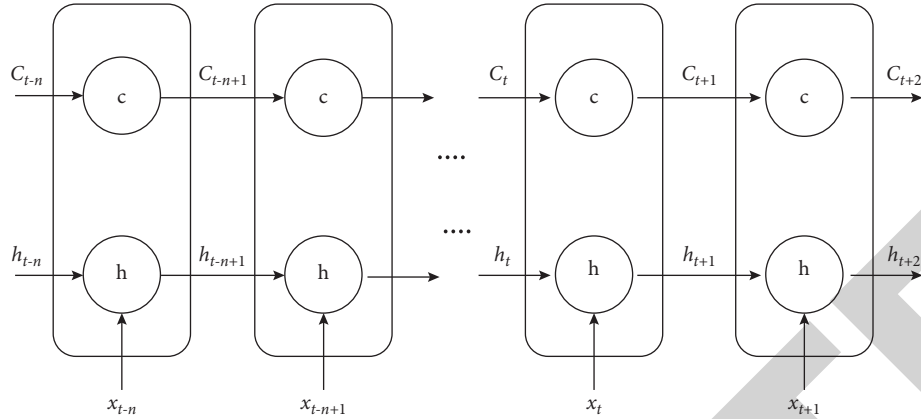


FIGURE 3: Recursive neural network timing diagram.

the cell unit at moment  $t-1$  are input into the nodes of the LSTM structure, and the data are output to the next hidden layer or output layer through the processing of input gate, output gate, forget gate, and cell units, the results of the nodes of the LSTM structure are output to the neurons of the output layer, and the calculation of backpropagation error updates each weight. The overall structure is shown in Figure 3.

A simple recursive neural network consists of an input layer, a hidden layer, and an output layer. For a given input sequence  $x = [X_1, X_2, \dots, X_t]$ , at moment  $t$ , the hidden layer state is  $s_t$  and the output value is  $z_t$ , as follows:

$$z_t = \sigma(V \cdot s_t), \quad (2)$$

$$s_t = \delta(U \cdot x_t + W \cdot s_{t-1}), \quad (3)$$

where  $V$  is the weight matrix of the output layer;  $\sigma$  is the output layer activation function;  $U$  is the weight matrix of the input  $x$ ;  $W$  is the weight matrix of the hidden layer state  $s_{t-1}$  at moment  $t-1$  as the input at moment  $t$ ;  $g$  is the hidden layer activation function. Looping equation (3) into equation (2), we get

$$z_t = V * \delta(U * x_t + W * \delta(U * x_{t-1} + W * \delta(U * x_{t-2} + W * \delta(U * x_{t-3} + \dots))))). \quad (4)$$

The LSTM differs from the RNN in that it adds a “processor” to the algorithm to determine whether the information is useful or not. A cell has three gates, called input gate, forget gate, and output gate. When a message enters the LSTM network, it can be judged as useful or not according to the rules. Only information that meets the algorithm’s certification is left behind, while information that does not match is forgotten through the forgetting gate. It is just a one-in-two-out working principle, but it can solve the long-standing big problems in neural networks with iterative operations. It has been shown that LSTM is an effective technique to solve the long-order dependence problem and the generalization of this technique is very high, leading to a great variety of possibilities brought about.

LSTM networks are trained using a backpropagation algorithm with the following steps: (1) forward computation of each neuron output value, for LSTM, i.e., five vectors  $i_t$ ,  $f_t$ ,  $o_t$ ,  $c_t$ , and  $h_t$ , which have been described in the previous section; (2) backward computation of the error term for each neuron; as with recursive neural networks, the backward propagation of LSTM error terms consists of two directions: the first is the backward propagation along time, i.e., calculating the error term at each moment starting from the current moment; the second is propagating the error term

one layer up; (3) calculating the gradient of each weight according to the corresponding error term.

## 4. Experimentation and Evaluation

**4.1. Datasets.** In this paper, the daily sales volume data of a brand company’s calligraphy exercise products in each market of a region within three consecutive years were selected, and the brand company had 78 retail stores in the region, and 78 sets of 1096 sales volume time series were obtained after statistical collation; one set of sales data and data format are listed in Table 1. The data in Table 1 can be used as a random time series for different outlets according to the synchronous series sorted from January 1, 2015, to December 31, 2017.

By observing the data characteristics of the sales volume of the enterprise’s products and then the above data as a unit of weekly statistics sales data, extracting the more representative three groups of data for comparative analysis shows the sales volume of the enterprise’s products in the period 2015–2017; there are obvious fluctuations; with time, sales data show a more obvious downward trend and a certain seasonal pattern and the existence of randomness, mainly as part of the seasonal trend and the overall decline in



TABLE 1: Daily sales volume statistics of calligraphy practice products of a company from 2015 to 2017.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	...
2015	6	8	11	7	4	5	6	6	5	4	11	6	10	4	...
2016	15	13	10	9	8	4	5	9	6	13	4	6	4	7	...
2017	13	15	5	5	7	3	8	16	7	5	11	9	5	6	...

sales volume of mixed trends, and the local existence of large fluctuation characteristics.

**4.2. Model Combinations.** In order to fully utilize the advantages of the Prophet model and LSTM neural network model, this paper proposes an optimal combined forecasting model based on Prophet and LSTM neural network for sales time series forecasting of calligraphy exercise products. In February 2019, Drotár et al. open-sourced a set of time series forecasting tools Prophet. Unlike traditional time series forecasting models (ARIMA, etc.), the Prophet model is essentially a curve fit to time series data, while having excellent adaptability to holiday effects and trend change points (change points) in the data, especially robust to missing values, shifts in trends, and a large number of outliers, and is currently mainly applied to traffic forecasting on Facebook social networking sites. Prophet itself is a model based on a self-additive model to predict time series data, the model as a whole consists of growth (trend term), seasonality (period term), and holidays (holiday term) 3 parts superimposed, and the basic form is as follows:

$$P(t) = g(t) + s(t) + h(t) + \varepsilon, \quad (5)$$

Here, the trend term  $g(t)$  is the core component of the whole Prophet model, containing parameters with different degrees of assumptions and adjusting smoothness, which is used to fit the nonperiodic changes in the time series and select the change point (change point) from the data to detect the trend direction. Firstly, the Prophet model and the LSTM network model with high prediction accuracy are constructed separately for the sales data, the prediction value of the Prophet model at time  $t$  is set as  $P(t)$ , the prediction value of the LSTM network model is  $L(t)$ ,  $t = 1, 2, \dots, N$ , and the two models are assigned dynamic weights  $w_1$  and  $w_2$ , respectively.  $t$ , this point, defines the integrated Prophet-LSTM combined prediction model as

$$Y(t) = w_1 P(t) + w_2 L(t), \quad w_1 + w_2 = 1, t = 1, 2, \dots, N, \quad (6)$$

where  $t$  is the time when the predicted value appears and  $Y(t)$  is the result of summing the predicted data of the Prophet model and LSTM network by weights. The Prophet-LSTM neural network sales volume forecasting model is obtained by calculating the optimal weights composed of the two models after integration. The Prophet model can transform the time series by certain functions into combined patterns of different time dimensions such as daily, weekly, quarterly, and yearly with overall trends. The Prophet-LSTM model is first initialized and empirically set change point = 0.15 to make the growth trend more sensitive to changes. The

forecast interval is specified as September 2017–December 2017, and the forecast frequency is “days”. In order to predict the value of sales change in the future period, the original sales volume time series data was divided into a training set and a test set according to 9 : 1 as a whole, the training set was input into the model for training, and the Prophet model was used to analyze and predict the results of the sales volume data, which will theoretically decline gradually in fluctuations over time. In order to optimize the update rate of the LSTM model parameters, the learning rate (Learning Rate) needs to be further controlled. The Adam algorithm combines the advantages of Ada Grad and RMS Prop algorithms to dynamically adjust the learning rate of each parameter by using the first-order moment estimation and second-order moment estimation of the gradient. It is an effective gradient-based stochastic optimization method, which makes the update of parameters smoother and takes less storage resources.

**4.3. Experimental Results.** In order to find the optimal weight coefficients  $w_1$  and  $w_2$  in the integrated model Prophet-LSTM model, we take the coefficients  $w_1$  to be 11 values in  $[0.0, 1.0]$  increments,  $w_1 + w_2 = 1$  and then the corresponding weight coefficients  $w_2$  to be 11 values in  $[1.0, 0.0]$  decrements and multiply the 11 sets of weight coefficients  $w_1$  and  $w_2$  with the sales volume forecasts of the respective models at each moment. After the above process, the 11 sets of weighted integrated sales forecasts are obtained as

$$Y(t_i), \quad i = 1, 2, \dots, 11, t_i = 1, 2, \dots, n. \quad (7)$$

In order to find the specific values of the weight coefficients  $w_1$  and  $w_2$ , the root mean square error equation (RMSE) and the mean absolute error (MAE) are used as the criteria to evaluate the effect of the Prophet-LSTM combined sales forecasting model for each group of weight coefficients, and the expressions are as follows: where  $x$  is the actual value of product sales in week  $i$ . According to Table 2, the root mean square error of the prediction results is minimized when the weight coefficients  $w_1 = 0.6$  and  $w_2 = 0.4$ , and the mean absolute error of the prediction results is minimized when the weight coefficients  $w_1 = 0.4$  and  $w_2 = 0.6$ . The results show that the prediction results of the Prophet-LSTM model are improved compared with the Prophet and LSTM models, and its prediction accuracy is generally better than the other two single prediction models, indicating that the prediction results of the Prophet-LSTM combined prediction model are relatively effective and more applicable than the single prediction model in the sales forecast of this enterprise. The weight coefficients corresponding to the evaluation metrics of the model are shown in Table 3.

In order to further verify the application performance of the Prophet-LSTM model, Holt-Winters (exponential smoothing model), ARIMA model, Prophet model, LSTM, and Prophet-LSTM combined model were used as comparison models in this paper to model the prediction of another new set of sales data, and the evaluation results of each model are listed in Table 3. The evaluation results show

TABLE 2: Comparison of the performance of different models.

Models	Evaluation metrics	
	RMSE	MAE
Holt–Winters	35.273	16.976
ARIMA	23.457	13.650
Prophet	3.465	2.143
LSTM	5.746	3.254
Prophet-LSTM ( $w_1 = 0.6, w_2 = 0.4$ )	2.645	1.645
Prophet-LSTM ( $w_1 = 0.4, w_2 = 0.6$ )	7.103	3.635

TABLE 3: The weight coefficients correspond to the evaluation metrics of the model.

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.0
$w_1$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.0
$w_2$	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.0
RMSE	3.700	3.427	3.274	3.153	3.059	3.022	3.010	3.050	3.139	3.253	3.490
MAE	2.514	2.380	2.300	2.274	2.269	2.297	2.351	2.453	2.524	2.605	2.778

that Prophet and LSTM single models have comparable forecasting performance, and both are significantly better than Holt–Winters and ARIMA classical time series models; Prophet-LSTM combined forecasting model has further optimized the forecasting accuracy based on the single model and has the best forecasting effect.

## 5. Conclusion

Calligraphy is the art of writing Chinese characters. The Chinese people love calligraphy and practice it. In a general sense, the art of calligraphy is the art of writing; writing can only meet the aesthetic requirements of the art of calligraphy if it is pursued in an aesthetically pleasing way and sublimated to art. From the practice of calligraphy education, learning calligraphy has many functions. The market for calligraphy practice products is vast, but in the face of a complex and dynamic market, it is important to predict the market demand for calligraphy practice products in a timely and accurate manner, to analyze the characteristics and patterns of sales volume data, and to improve the accuracy of sales volume forecasting, so that calligraphy practice product enterprises can develop timely and effective marketing strategies. This paper proposes a combined model prediction method based on recursive neural network model based on the pattern of sales volume time series data of a calligraphy practice product enterprise, constructs a weighted Prophet-LSTM combined prediction model, and conducts comparison experiments with the model under each weight coefficient, the single model before combination, and two classical time series models. The experimental results show that the forecasting performance of the Prophet and LSTM neural network models is significantly higher than that of the typical time series forecasting models, and the combined Prophet-LSTM model has better forecasting performance. Overall, based on the verification that the Prophet model and the LSTM model have obvious advantages in forecasting the sales volume of calligraphy practice products, this paper further improves the model prediction performance by weighted combination, maximizing the advantages of both prediction models. In this paper, only a combined

forecasting model combining two single forecasting models is designed, on which new forecasting models can be introduced for further combination in the future to pool the advantages of more models and thus obtain more accurate forecasting results. Besides, further experiments can be done on the parameter preferences of LSTM neural networks in the follow-up work to seek a better modeling method. In the future, in order to analyze the sales volume time series data more deeply, further research on the influencing factors of sales volume can be targeted.

## 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 that he has no conflicts of interest.

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