

## Retraction

# Retracted: Interbank Offered Rate Based on Artificial Intelligence Algorithm

## Mathematical Problems in Engineering

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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

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

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

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

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

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

## References

- [1] W. Xie, "Interbank Offered Rate Based on Artificial Intelligence Algorithm," *Mathematical Problems in Engineering*, vol. 2021, Article ID 9931539, 11 pages, 2021.

## Research Article

# Interbank Offered Rate Based on Artificial Intelligence Algorithm

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Interbank offer rate is the interest rate at which banks lend money to each other in the money market. As a market-oriented core interest rate, Shibor can accurately and timely reflect the capital supply and demand relationship in the money market, and its changes will quickly transmit and affect China's financial market. Therefore, the purpose of this paper is to predict and study the fluctuation and trend of Shibor. In this paper, the overnight varieties of Shibor were studied and predicted from two time dimensions, namely, daily fluctuation and monthly trend. In the prediction of overnight Shibor daily data, a comparison prediction model based on BP neural network algorithm was first established, and then WNN was applied in the prediction, and the effect was found to be better. When predicting the monthly mean value of overnight Shibor, nine indicators were selected and tested for correlation based on the factors affecting the trend of interest rate, and a regression model of support vector machine was established. Particle swarm optimization algorithm was used to improve the SVR algorithm, and the PSO-SVR prediction model was established to improve the prediction accuracy. The model could basically predict the trend of overnight Shibor. Furthermore, a prediction model of WNN based on cuckoo search (CS) optimization was proposed, which improved the prediction accuracy by 78% and fitted the daily fluctuation of overnight Shibor well.

## 1. Introduction

As China's economic situation continues to improve, the importance of establishing and improving a strong financial market has become increasingly obvious. In particular, the gradual introduction of market interest rates is the top priority of the reform of the financial sector, which directly affects the stability of China's financial market and its position in the international financial market [1, 2]. The key to interest rate liberalization is to establish benchmark interest rate [2, 3]. Benchmark interest rate refers to the interest rate with general reference significance in the money market. Pricing or rate of return of other financial products in the financial market can be determined based on this benchmark interest rate, and monetary authorities can also make and implement monetary policies based on this interest rate [4, 5]. Interbank offered rate, also known as inter-bank offered rate, is the rate at which commercial banks finance funds in the money market. Compared with other interest rates, the open, market-oriented, and transparent interest rate formation mechanism enables it to accurately and

timely reflect the capital supply and demand relationship in the money market. In view of the importance of Libor, it is usually selected as the benchmark interest rate internationally, such as Libor [6–8].

Ivanov, Ivan T, studied how the introduction of market pricing, which links lending rates to credit default swaps, affected bank funding. Ivanov, Ivan T, found that market-based pricing was associated with lower interest rates, both at the beginning of the loan and over the life of the loan. Ivanov and Ivan T's results also show that banks have simplified market-based loan pricing contracts, suggesting that the decline in bank debt costs can be explained, at least in part, by a fall in monitoring costs. Therefore, in addition to reducing the cost of bank debt, market pricing may also have adverse consequences due to the reduction of bank monitoring [9]. Gianfranco Giulioni analyzed how changes in policy rates affect bank-related variables by changing the composition of loan portfolios. Using a calculation that takes full account of the heterogeneity of borrowers, Gianfranco Giulioni shows how the diversity of bank customers has changed and how this has affected the bank's cash inflows,

making them more volatile. Gianfranco Giulioni also shows how the composition of loan portfolios is affected by the rise in policy rates when policy rates remain low. Safer borrowers were the first to exit the loan portfolio, leading to a gradual increase in the risk of the loan portfolio. As riskier borrowers pay less, interest payments flow in less. In addition, we find that the shortening of loan term will increase the volatility clustering of bank interest payment inflow [10]. A stock loan is a loan secured by shares [11]. They are modern financial products designed for investors with large equity holdings. Mathematically speaking, stock loan can be regarded as an American call option with time-effective strike price. Wenting Chen's research is the first study in the literature to consider equity loan value under the framework of stochastic interest rate. Based on portfolio analysis, the partial differential equation of stock loan value is established. An appropriate set of boundary conditions, especially in the interest rate direction, is proposed to close the pricing system. The reasonable mathematical and financial proofs are provided for the proposed boundary conditions. For the proposed nonlinear PDE system, the predictive-corrected finite difference method is used. Wenting Chen adopts alternating directional implicit method to improve computing efficiency. Numerical results show that this method is reliable, and the stochastic interest rate makes the optimal execution price of stock loan relatively high [12].

Based on an in-depth study of existing literatures, Shibor was determined as the research object in this paper, mainly because since the official operation of the interbank lending market in 2011, the transaction volume of the lending market has dramatically increased, from over 2 trillion yuan in 2010 to over 10 trillion yuan in 2011, and continued to grow rapidly thereafter. Among the eight types published by Shibor, overnight varieties had the largest trading volume, and commercial banks used them more, which had the greatest impact on the interest rate market. Therefore, this paper studies the overnight Shibor prediction model based on artificial intelligence algorithm.

## 2. Artificial Intelligence Algorithm

### 2.1. Overnight Shibor Prediction Based on Artificial Intelligence

**2.1.1. BP Neural Network Prediction Model.** Traditional time series models, such as ARMA model and VAR model, basically assume that the research objects are linear [13, 14]. However, most of the research objects in the economic market are difficult to meet the assumption that the Shanghai interbank offered rate is a chaotic, high-dimensional nonlinear time series data. The prediction of the daily data time series of the interest rate is based on the data analysis and the rule of fluctuation, and the scientific research method is used to measure the fluctuation and predict the level of the interest rate on the next day. With the rapid development of artificial intelligence, neural network has been applied in many researches due to its excellent performance in dealing with high-dimensional nonlinear problems. Among them, BP network is the best, most

essence, and core part of the forward neural network. Data shows that more than 80% of the networks are using BP network or its related deformation and optimization. The related deformation and optimization are different in different research objects and purposes. The research object of this chapter is the overnight variety day data of Shibor, and the research method is artificial neural network. Therefore, BP neural network prediction model is firstly established as the basic model, so as to serve as the reference standard for the model performance in further studies.

BP network is a kind of multilayer feedforward neural network [15]. In its network training process, the signal is transmitted forward. The most critical step is to adjust the weight of the network through error backpropagation. BP neural network can learn and remember a large number of pattern mapping patterns between input and output, but it does not need to explicitly express the mathematical equation of such pattern mapping pattern in advance. In the forward signal transmission, the input signal from the input layer passes through the hidden layer to reach the output layer. Neurons in each layer are not connected to each other, and the state of neurons in the lower layer is affected by the way of full interconnection. If the desired output cannot be obtained by the output layer, the backpropagation process based on gradient descent is carried out to update the network weight and prediction and continuously improve the network performance, so that the output gradually approximates the desired output. The topological structure of BP neural network (a hidden layer) is shown in Figure 1, and the algorithm training process is shown in Figure 2. The relevant expression is as follows.

(1) The hidden layer excitation function  $f$  is as follows:

$$f(x) = \frac{1}{1 + e^{-x}}. \quad (1)$$

(2) The hidden layer output  $H$  is as follows:

$$H_j = f\left(\sum_{i=1}^n \omega_{ij} x_i - a_j\right), \quad j = 1, 2, \dots, l. \quad (2)$$

(3) The predicted  $O$  output is as follows:

$$O_k = \sum_{j=1}^l H_j \omega_{jk} - b_k, \quad k = 1, 2, \dots, m. \quad (3)$$

(4) Calculate the prediction error  $e$ ;  $Y$  is the expected output:

$$e_k = Y_k - O_k, \quad k = 1, 2, \dots, m. \quad (4)$$

(5) Weight  $\omega_{ij}$ ,  $\omega_{jk}$  is updated as follows:

$$\begin{aligned} \omega_{ij} &= \omega_{ij} + \eta H_j (1 - H_j) \times (i) \sum_{k=1}^m \omega_{jk} e_k, \quad i = 1, 2, \dots, n, \\ \omega_{jk} &= \omega_{jk} + \eta H_j e_k, \quad j = 1, 2, \dots, l, k = 1, 2, \dots, m. \end{aligned} \quad (5)$$

(6) Update thresholds  $a$  and  $b$ :

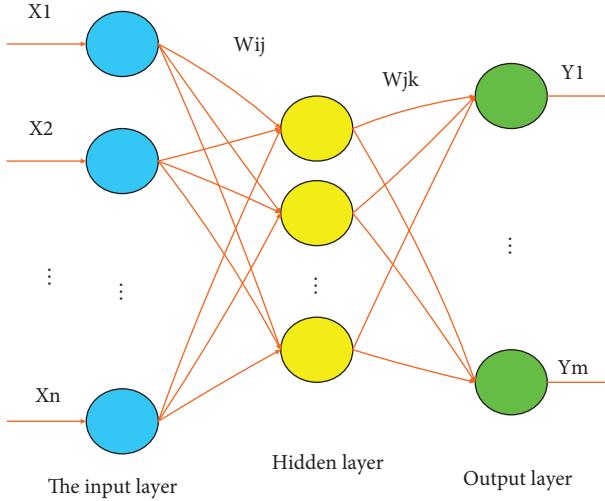


FIGURE 1: Topology structure diagram of BP network.

$$\begin{aligned} a_j &= a_j + \eta H_j (1 - H_j) \sum_{k=1}^m \varpi_{jk} e_k, \\ b_k &= b_k + e_k. \end{aligned} \quad (6)$$

In the previously mentioned expression, \$n\$ is the number of nodes in the input layer, \$m\$ is the number of nodes in the output layer, and \$l\$ is the number of nodes in the hidden layer.

**2.1.2. WNN Prediction Model.** The continuous wavelet coefficients of CWT neural networks are especially suitable for prediction or classification due to their redundancy and strong anti-interference ability.

(1) *Basic Principle of WNN.* In the WNN structure based on the BP network topology principle, the transfer function of its hidden layer node is used to replace the wavelet basis function. The basic principle is the same as that of the BP network. Although its signal transmission will cause error back propagation, the use of gradient correction method and wavelet basis function of the network weights and parameters can make WNN prediction gradually achieve the expected output effect.

Assuming that the hidden layer output value is \$y\$, the output layer \$y\_n\$ is the desired output, \$\varpi\_{ij}\$ represents the weight value connecting the input layer and the hidden layer, \$\varpi\_{jk}\$ represents the weight of the hidden layer to the output layer, \$h\_j\$ is the wavelet basis function, \$b\$ is the conversion factor, and \$l\$ is the number of hidden layer nodes, \$m\$ is the number of output layer nodes, \$e\$ is the prediction error, \$n\$ is the learning rate, and the related expressions are as follows:

The wavelet basis function is as follows:

$$y = \cos(1.75x)e^{-x^2/2}. \quad (7)$$

Calculate the output value of the hidden layer:

$$h(j) = h_j \left[ \frac{\sum_{i=1}^k w_{ij} x_i - b_j}{a_j} \right], \quad j = 1, 2, \dots, l. \quad (8)$$

Calculate the output layer of the predicted output:

$$y(k) = \sum_{i=1}^l \omega_{ik} h(i). \quad (9)$$

The prediction error is as follows:

$$e = \sum_{k=1}^m y_n(k) - y(k), \quad k = 1, 2, \dots, m. \quad (10)$$

Algorithm training steps overview is as follows.

*Step 1.* Network initialization: random initial assignment was made to the scaling factor and translation factor of the wavelet base function and the link weight between the network layers, and the learning rate of the network was selected, and the number of nodes in the input layer, output layer, and hidden layer were set according to the task situation.

*Step 2.* Sample classification: the dataset is properly divided into two parts for training and testing. The training set is used for network training, and the test set is used to verify the training effect of the network.

*Step 3.* Predicting the output: the training data is input into the network, the predicted value is calculated according to the output expression of the output layer, and the error value is obtained by comparing with the expected output.

*Step 4.* Weight correction: according to the error value, the weights of the network and the parameters related to the wavelet basis function are modified again and again.

*Step 5.* Judge whether the algorithm has stopped running according to the set error value. If not, return to step 3 to continue iteration.

**2.1.3. Cuckoo Optimization of WNN Prediction Model.** WNN training is an optimization process with multiple local extreme values, which makes the network eventually converge to the local optimal rather than the global optimal. The effect and performance of network training are greatly affected by the primary value. In this paper, a prediction model of cs-WNN is established, which is based on the meta-heuristic algorithm cuckoo search optimization wavelet network. In cs-WNN, each egg represents the initial weight and threshold of the wavelet network. In the iterative process, CS algorithm is used to continuously update the position, optimize the initial weight and threshold, and satisfy the adaptive value function until the optimal. During the training of WNN, the cuckoo search algorithm continuously optimizes the weights and thresholds of the network until the convergence condition is satisfied (when the number of iterations or MSE meets the set condition). The empirical analysis of the cs-WNN prediction model shows

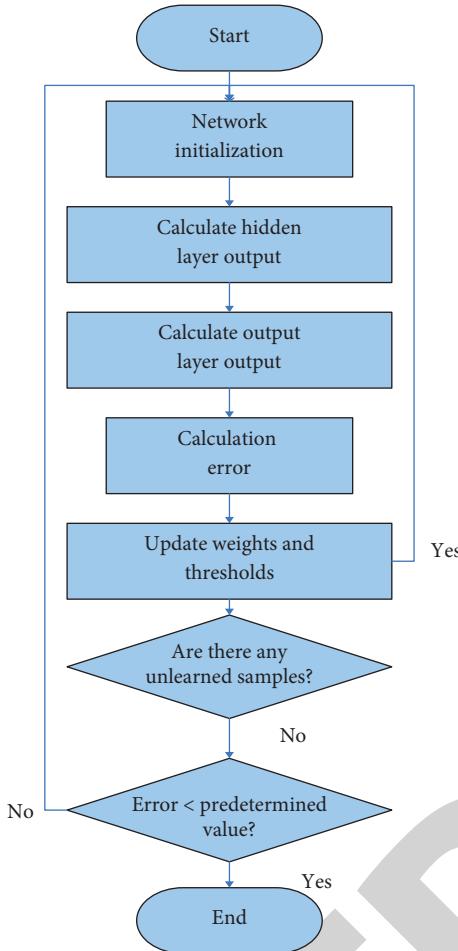


FIGURE 2: BP algorithm training flow chart.

that the optimization model overcomes the local minimum problem and has good generalization ability.

(1) *Theoretical Basis of Cuckoo Search (CS)*. Cuckoo search (CS) is a new optimization metaheuristic algorithm constructed on the basis of swarm intelligence technology, which simulates cuckoo's nest parasitism and flight behavior of other host birds. In this bionic optimization algorithm, cuckoo eggs are mapped into solutions to actual problems, with each egg in the nest representing a potential solution and the next generation of cuckoo eggs representing a new solution, with the goal of replacing the worse solution in the nest with a better solution. The process of updating the solution is carried out through the flight behavior of levy. The actual algorithm operation makes three idealized assumptions as follows: first, each cuckoo can lay only one egg at a time and then randomly put it into a nest to hatch, second, high-quality eggs from randomly selected nests survive into the next generation, third, the number of nests that can be used as parasitic nests is fixed, and the probability of parasitic cuckoo eggs being identified and picked out by the host bird is  $P_a \in [0, 1]$ . If found, the host bird can either discard the cuckoo's eggs or simply abandon its nest and find a new location to build a new nest.

*Definition 1.* The update of the equation of cuckoo bird's nest selection process is as follows:

$$X_i^{(t+1)} = X_i^{(t)} + \alpha \oplus \text{Levy}(\lambda), \quad i = 1, 2, 3, \dots, n, \quad (11)$$

where  $X_i^{(t)}$  is the position of the nest in the  $t$ -th search;  $\oplus$  stands for point-to-point multiplication;  $\alpha$  is a step factor;  $\text{Levy}(\lambda)$  is a random search vector generated by a Levy distribution with a compliance parameter of  $\lambda$  ( $1 \leq \lambda \leq 3$ ).

To sum up, the cuckoo optimization iteration mode is as follows.

Step 1: randomly initialize the positions of nests, determine the optimal adaptive value of the algorithm, and set the maximum number of iterations and the probability of being discovered by the host bird and other parameters.

Step 2: calculate the fitness value of each nest, and record the current best solution and the corresponding nest location

Step 3: learn how Levy flies, update the position of the nest with the update equation, and test and record the nest in the new position with the objective function.

Step 4: compare the newly produced bird's nest position with the optimal bird's nest position of the previous generation, and according to the elite selection rule, keep the optimal bird's nest to the next generation.

Step 5: randomly generate a number from 0 to 1, compared with the probability of cuckoo bird eggs being found by the host. If the random number is larger, then randomly generate a group of nest positions. Otherwise, the nest location with the optimal test results is still retained.

Step 6: when the recorded result of the best nest location has met the set accuracy requirements or reached the number of iterations, then the nest is the global optimal location, and the search process is over; otherwise, return to step 2.

2.2. *Daily Fluctuation of the Lending Rate*. The prediction process of the model is based on the daily data time series of the interest rate, starting from the fluctuation of the interest rate level itself, without involving other relevant factors, which is similar to the technical analysis in the financial market. The assumption contained in this paper is that all the influencing factors will eventually be reflected in the change of interest rate level. In the study of interest rate fluctuation with "daily" as the time dimension, this assumption is basically satisfied.

- (1) For interbank interest rates such high-dimensional nonlinear time series data, the overall prediction effect of the BP neural network prediction model is average. In the test set fitting process, once the inflection point is variable, it will greatly affect the prediction effect of the test sample after the turning point, and the prediction accuracy will be greatly reduced as a whole.

- (2) Using the cuckoo search algorithm to optimize the WNN parameters, its prediction effect on loan interest rate fluctuations is quite good, and the prediction accuracy of the prediction model is significantly improved. The optimized prediction model shows excellent performance in the prediction of overnight Shibor daily data, which is of great help to decision-making assistance.
- (3) The error of BP neural network, WNN, and cs-WNN for overnight Shibor prediction is shown in Table 1.

### 3. Experimental Research on the Interbank Offered Rate Based on Artificial Intelligence Algorithm

*3.1. Experimental Data Sources.* Before establishing the model, Shibor related variables were preselected in this paper. As economists have different understandings of the determinants of interest rates and the ways in which these determinants affect interest rates, different theories of interest rate determination have been formed. According to the research results of relevant theories and the current situation of China's financial environment, there are many factors that affect the interest rate, such as a country's economic situation and economic policies, the supply and demand of money, savings and investment, price level, international interest rate level, and average profit rate. According to the available data and the main acquisition of money supply (M2), the dollar is equal to the average value, the trading volume of the China Stock Exchange, the RMB deposits and loans of non-performing financial institutions, the consumer price index (CPI), the purchasing managers index (PMI) bank pledged repo rate, new credit data, foreign direct investment (FDI) these nine indicators, the relevant analysis is as follows:

- (1) Money supply (M2): "liquidity preference" is the tendency of investors to hold the same amount of cash currency based on the portfolio framework. Economic equilibrium theory points out that the interaction of money supply and demand determines the level of interest rates. Considering the size of opportunity cost, the holding of money by rational economic man is mainly driven by three factors: prevention, speculation, and trading. The quantity of money supply is an exogenous variable determined by the monetary authority. When the two are equal, it is the equilibrium interest rate. For the purpose of macromonitoring and regulation, the central bank divides the money supply into three levels according to the size of liquidity, namely, M0 (cash in circulation), M1 (narrow sense of money supply), and M2 (broad sense of money supply). With the rapid development of the economy, the money supply of our country has been increasing, and the return on capital has been declining on the general trend, and whether the growth of the money supply is consistent with the growth of the economy is the most critical. Therefore, M2 is selected as the preselected

TABLE 1: Comparison of model prediction errors.

The evaluation index	Prediction model		
	BP neural network	WNN	cs-WNN
MAPE	2.3978	1.8689	1.4072
MAE	0.0388	0.0281	0.0216
MSE	0.0028	0.0017	0.0012

variable in this paper, and the data is from the official website of the People's Bank of China.

- (2) Consumer price index (CPI): there is a strong correlation between changes in the price level and changes in interest rates. On the one hand, the high and low prices affect the amount and cost of social funds absorbed by commercial banks through affecting enterprises and individuals and ultimately affect the source and amount of bank credit funds. On the other hand, since price and currency depreciation are often mutually causal relations, when currency depreciation takes place, banks must take into account the actual value of the currency rather than the nominal value when taking deposits and issuing loans. The problem of currency preservation also exists on the other side of the credit relationship, where people are more concerned about the real interest rate. Therefore, the market-oriented interest rate will make corresponding adjustments according to the changes in the price level to ensure that both credit parties will not suffer losses due to price changes. Consumer price calculation of China's social products and services activities, measuring China's price situation, not only is closely related to the people's living costs but also has an important position in the domestic production price system. CPI index is an important index for judging economic situation, testing, and controlling price level. The rate of change in the CPI index largely reflects the extent of deflation or inflation. Therefore, CPI is selected as the preselected variable in this paper, and the monthly data is from the official website of the People's Bank of China.
- (3) Turnover of the stock exchange: the stock market is an important bridge connecting the real economy and the financial market. A large number of empirical studies and relevant theories have shown that the stock market situation of a country is closely related to the country's economic situation, and it also reflects the level of listed enterprises financing for wealth creation and appreciation. The effect of the stock market on the interest rate is based on two considerations: on the one hand, the situation of the stock market is related to the economic prosperity degree, and the economic prosperity degree is related to the level of interest rate; on the other hand, the attractiveness of the stock market is essentially determined by a firm's return on capital, which is closely related to the level of interest rates in the market. According to statistics, the turnover of our

- country's Shanghai and Shenzhen stock exchanges is basically the same. As an important indicator to measure the stock market, turnover reflects both the corporate popularity index and capital status. Therefore, this article chooses the stock exchange turnover as the main variable to analyze the monthly data of the stock exchange website.
- (4) Purchasing managers' index (PMI): the expected return on funds in the macroeconomy largely determines the level of interest rate, while the return on funds is directly determined by the economic conditions of a country. Normally, when the economic cycle is in a boom stage, people and enterprises are full of confidence in the development of the economy, the money market is in short supply, the expected rate of return on capital is rising, and the interest rate of interest will rise with the prosperity of the economy. On the contrary, when the economic cycle of a country is in a depression, people and companies are pessimistic about the prospect, people and companies will be more cautious when they engage in investment, savings will increase, borrowing costs will be lower, money market shows a phenomenon of oversupply, and interest rates will usually fall. GDP growth rate is an accepted indicator to measure economic conditions from a macro-perspective. Relevant empirical analysis shows that PMI is highly correlated with GDP, and it is a leading indicator in economic monitoring. The inflection point of its trend change is often ahead of the GDP growth rate for a period of time. Considering that the monthly data of relevant indicators are used as the dependent variable in this paper to predict the level of the interest rate of the next month, it is more appropriate to preselect PMI index as the variable in this paper. The monthly data are from the official website of the People's Bank of China.
- (5) Foreign direct investment (FDI): with the continuous progress of economic globalization, as well as the deepening of China's reform and opening up and market economy, the cross-border investment of foreign investors in order to obtain investment returns has a growing impact on China's economic environment. Relevant studies show that a large amount of international hot money enters China through foreign direct investment, which has a huge impact on the fluctuation of China's real economy and financial market, thus affecting the level of interest rate. In this paper, foreign direct investment (FDI) is selected as the preselected variable, and the monthly value is from the official website of the People's Bank of China.
- (6) New credit data: credit refers to credit loans, during which the debtor does not need to provide capital guarantee and the creditor issues funds according to the credit of the demander. Credit loan has always been the most commonly used loan method by Chinese commercial banks. The change of new credit data indicates that the demand level of money market for funds is rising or falling. On the one hand, it will affect the relationship between capital supply and demand; on the other hand, it will affect the cash reserves of commercial banks and then indirectly affect the level of interest rate through interbank lending market. In this paper, the monthly data of new credit was selected as the preselected variable, and the data came from oriental fortune.
- (7) Interbank pledged repo rate: in bond repo transactions, buyers and sellers agree to carry out reverse transactions of bonds at a certain time in the future when buying and selling bonds, which is essentially a financing behavior with bonds as collateral. Pledge-type repo and interbank disconnection are the main channels for commercial banks to maintain cash liquidity. Since these two channels can replace each other to some extent, there is a direct interaction between the repo rate and the open and release rate. In this paper, the one-day weighted average interest rate of nationwide interbank pledge-type repo is selected as the preselected variable. The relevant data are from the official website of the People's Bank of China.
- (8) Difference between deposits and loans of financial institutions in RMB: during the period when the average profit rate remains certain, the level of interest rate in the financial market is basically determined by the supply and demand of borrowing funds in the money market. This is because interest rates are essentially the time cost of borrowing money and the pricing of risk. In general, interest rates fall when there is a surplus of cash and rise when there is a shortage of cash. Of course, the interest rate also acts against the supply and demand of funds. When the interest rate rises, the increase in borrowing costs reduces the demand, and when the interest rate falls, the decrease in borrowing costs also increases the demand. According to the classical interest rate determination theory, savings and investment are the two main determinants of the interest rate level. Therefore, when studying the interest rate level, it is inevitable to choose relevant indicators that can reflect savings and investment. Savings can be reflected through deposits, while investment is closely related to the loan scale. Based on the previously mentioned analysis, the difference between deposit and loan is an important variable that affects the level of interbank lending rate. In this paper, the difference between deposit and loan of financial institutions is selected as the preselected variable, and the monthly value is from the official website of the People's Bank of China.
- (9) Us dollar equivalent to the average of RMB: with the progress of China's interest rate liberalization and the approval of the inclusion of RMB into the SDR, China's monetary policy will increasingly need to pay attention to the impact of the exchange rate in

the future. In the international financial market, the relative change of interest rates between the two countries reflects the relative change of returns between the two countries, which naturally has an impact on the change of exchange rate. At the same time, the fluctuation of exchange rate will also have a certain impact on the level of interest rate. The exchange rate has an indirect effect on interest rates, mainly through unbalanced changes in global transactions. The balance of capital account and the balance of current account are the two major components of the balance of international payments. When a country has a persistent surplus under its current account and a large amount of foreign exchange inflows, the local currency will continue to appreciate externally. On the one hand, in order to cope with the continuous pressure of appreciation, the monetary authorities tend to lower the interest rate and reduce the domestic foreign exchange supply through capital outflow under the capital account so as to divert the upward pressure. On the other hand, the appreciation of the local currency leads to the contraction of net exports and the expansion of the supply of goods in the domestic market. The price of goods and the interest rate fall. In addition, in order to stabilize the domestic currency, the balance of payments surplus is converted into foreign exchange reserves. Once the foreign exchange reserves increase, a corresponding amount of local currency must be released. The monetary policy is too loose, and the money supply increases, resulting in the decrease of interest rate. The US dollar is the most important currency in the international currency market and is the main part of China's foreign exchange reserve structure. Therefore, this paper selects the average value of US dollar converted into RMB as the preselected variable, and the monthly data comes from the official website of the People's Bank of China.

**3.2. Selection of Experimental Variables.** Based on the theory of interest rate determination and the availability of monthly data, nine indicators of interest rate impact have been pre-selected. Correspondingly, overnight Shibor prediction model is based on interest rate as an influencing factor, because this article focuses on the overnight interest rate in a longer time dimension because this article mainly deals with data such as the trend of overnight interest rates in a longer time dimension, we will use the overnight Shibor quotation algorithm to calculate the monthly average, the average represents Shibor overnight interest rates in this month. Thus, during the nine years from 2011 to 2019, data of 108 months of overnight Shibor were obtained, and the preselected variables also selected the data of 108 months.

Pearson correlation test was conducted on nine indicators and 10 variables of overnight Shibor monthly data, and the results were shown in a table. Since the predicted time indicators correspond to overnight Shibor with a one-month lag, Pearson

correlation test was conducted on nine indicators and the monthly data of overnight Shibor (with a one-month lag), and the results are shown in Table 2.

According to the correlation of the test results in Table 2, the monthly average of the overnight Shibor and the 9 preselected indexes at the 0.01 level show a significant correlation. The Pearson correlation coefficients of M2, FDI, deposit/loan difference, and exchange rate are  $-0.884$ ,  $-0.545$ , and  $-0.833$ , respectively, all of which are strongly correlated. Therefore, the repo rate, exchange rate, and CPI were finally selected as the input variables affecting the interest rate.

## 4. Analysis of Results

**4.1. BP Neural Network Prediction Model Analysis.** The evaluation of measurement performance error is as follows. In the process of establishing the prediction model of the Shanghai interbank offered rate, in addition to the comparison and analysis of the figures, an intuitive and quantifiable evaluation standard of prediction accuracy is also required. The evaluation system should be able to simply measure the predictive performance of the model. For different models, due to the difference of research object and research purpose, there is no unified system for prediction evaluation at home and abroad. Combined with the research purpose and method in this paper, mean absolute error (MAE), mean square error (MSE), and mean percentage error (MAPE) are selected as the indicators to measure the prediction error.

From 2011 to 2019, a total of 2248 days of overnight Shibor data were generated. The first 2100 days of overnight Shibor data (January 4, 2011, to May 29, 2019) were taken as training samples, and the remaining 148 days (January 1, 2019, to June 31, 2019) were taken as test data. According to the implementation steps of BP neural network, the number of nodes in the hidden layer is firstly determined. The number of nodes in the input layer is five, and the number of nodes in the output layer is one, which means that, in the training of mapping, the first to the fifth data of the time series are used to predict the sixth data, the second to the sixth data correspond to the seventh data, and the remaining data are similarly recurred. Figure 3 is the prediction effect of BP neural network on overnight Shiobr.

It can be seen from Figure 3 that, in the prediction of Shiobr's time series overnight, the first 60 data points of BP neural network fit the fluctuation of the interest rate well in the stable stage, and the fitting performance was average when the fluctuation was large. When the prediction is deviated, the fitting of nearly 90 data points in the future is deviated greatly. On the whole, the BP neural network prediction model has basically fitted the fluctuation trend of the interest rate, but the error is still relatively large. Among them, the value of MAPE is 2.3978, MAE is 0.0388, and MSE is 0.0028.

**4.2. Analysis of Prediction Effect of WNN.** Similarly, the first 2100 (January 1, 2019, to June 31, 2019) daily data points of

TABLE 2: Correlation test (a).

		Supply of currency (M2)	Consumer price index (CPI)
Overnight Shibor	Pearson correlation significance (bilateral) N	0.318 0.001 0.108  Purchasing managers' index (PMI) -0.213 0.027 0.108  Weighted average interest rate of nationwide interbank pledged repo (one day) 0.989 0 0.108	0.362 0 0.108  Foreign direct investment data (FDI) 0.3500  The difference between deposit and loan of RMB in financial institutions 0.289 0.002 0.108
Overnight Shibor	Pearson correlation significance (bilateral) N	Correlation test (b)	Consumer price index (CPI)
Overnight Shibor (lag)	Pearson correlation significance (bilateral) N	Supply of currency (M2) 0.315 0.001 0.107  Purchasing managers' index (PMI) -0.088 0.369 0.107  Weighted average interest rate of nationwide interbank pledged repo (one day) 0.712 0 0.107	0.373 0 0.107  Foreign direct investment data (FDI) 0.3600  The difference between deposit and loan of RMB in financial institutions 0.296 0.002 0.107
Overnight Shibor (lag)	Pearson correlation significance (bilateral) N		

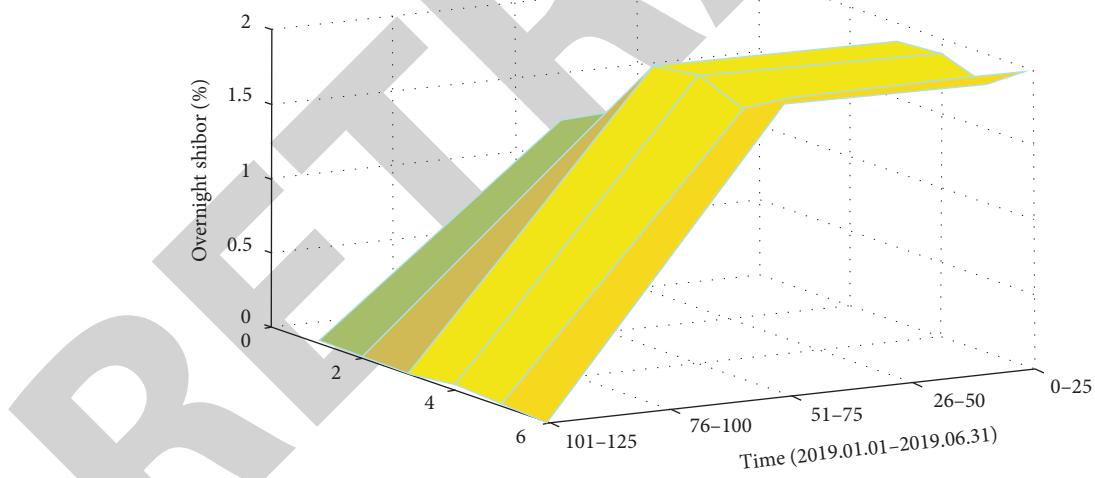


FIGURE 3: Prediction effect drawing: BP network model.

2248 overnight Shibor's time series were taken as training samples, and the remaining 148 (June 1, 2011, to December 31, 2011) data points were taken as test data.

According to the implementation steps of the WNN, the structure of 5-9-1 is adopted in this paper. There are five nodes in the input layer, representing the corresponding interest rate level of the first five time points of the predicted time node, nine nodes in the hidden layer, and only one node in the output layer of the predicted interest rate output from the network. The wavelet basis function and the network weight are obtained randomly

when initializing the parameters, and the number of iterations of the algorithm is 180. The trained WNN is used to predict the interest rate of the test set. Figure 4 is the prediction result of the WNN on the overnight varieties of interbank offered rate.

It can be seen from Figure 4 that the 50-75 data points in the time series prediction of the overnight Shibor by the WNN are relatively large, and the accuracy of the prediction in the other 100 or so data points is very high, the relative error is small, and it is basically in line with the daily actual data of the actual interest rate.

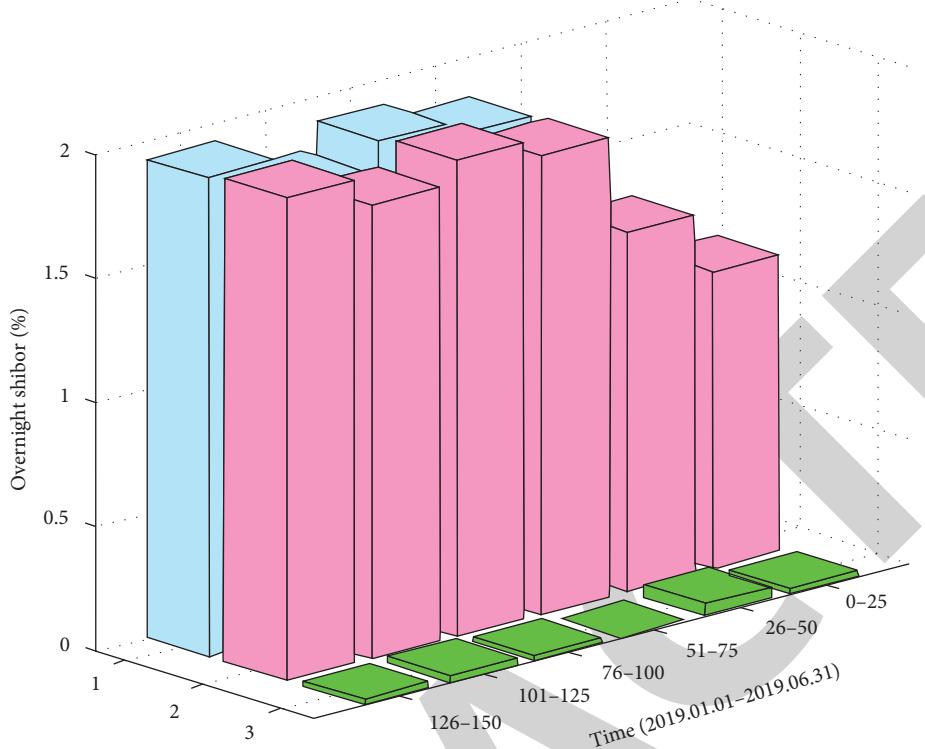


FIGURE 4: Prediction effect diagram: WNN model.

**4.3. Analysis of Cuckoo Optimization of WNN Prediction Model.** Similarly, the statistics of the test data can be obtained, the input layer has five nodes, which represent the corresponding overnight Shibor interest rate level five time points before the predicted time node. The hidden layer has nine nodes, and the predicted overnight Shibor is the output layer of one node. The well-trained cs-WNN is used to predict the opening and release rates of the test set. Figure 5 is the prediction result of cs-WNN on Shibor overnight.

It can be seen from the Figure 5 that, compared with WNN, cs-WNN model has a better fitting effect in the prediction of the data of the first 25 days. The fitting of the data of 25 days, between 50 and 75, is better than that of WNN. The extreme points of the catch and the strong ability of fitting and the deviation and lag appear less, which further improved the ability to predict.

**4.4. Regression Support Vector Machine (SVR) Prediction Model.** Shibor has only been in operation since 2011, and monthly Shibor data overnight are very limited. In view of the situation of the data in the prediction task and the characteristics of the research object, the support vector machine for regression (SVR) was selected to establish the prediction model in this paper. This is because support vector machine (SVM) has obvious advantages in solving small sample, nonlinear, nonstationary, and high-dimensional tasks, with the following significant advantages.

- (1) The principle of structural risk minimization, a statistical learning theory, has a solid theoretical foundation.
  - (2) The algorithm is put forward specifically for the small sample of the research problem, which is finally reduced to a quadratic programming problem. Theoretically, the global optimal solution can be obtained under the condition of limited samples, which improves the local extremum problem of the traditional neural network.
  - (3) Support vector determines the topology structure of SVM and avoids the excessive dependence of traditional neural network on user's trial-and-error network topology structure.
  - (4) SVM maps the actual problem data to the high-dimensional feature space through the nonlinear transformation. Then, in the high-dimensional feature space, the linear function realizes the processing function of the nonlinear function of the original space and avoids the "dimension disaster," and the model has strong generalization ability.

In solving practical problems, SVM is first used for classification and pattern recognition and other fields, while regression support vector machine (SVR) introduces an insensitive loss function into the SVM classification process, which often achieves good performance and effect in the application of regression problems. When SVM is used for classification problems, an optimal classification surface is constructed to separate the two samples. When we use SVM for regression fitting, the idea is to construct the optimal

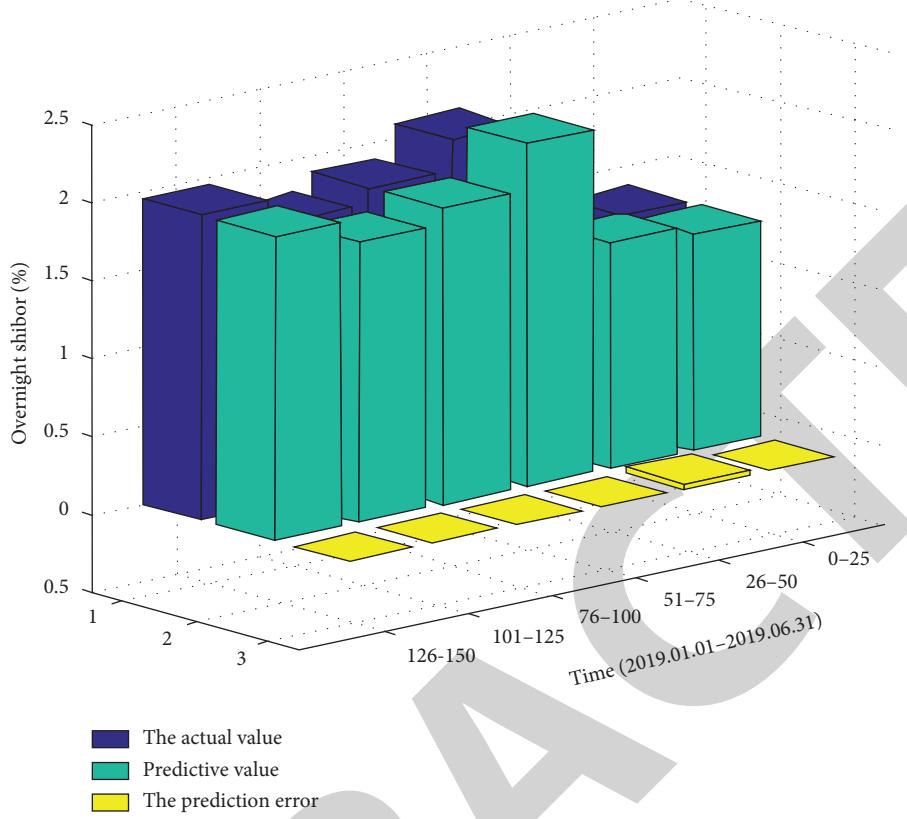
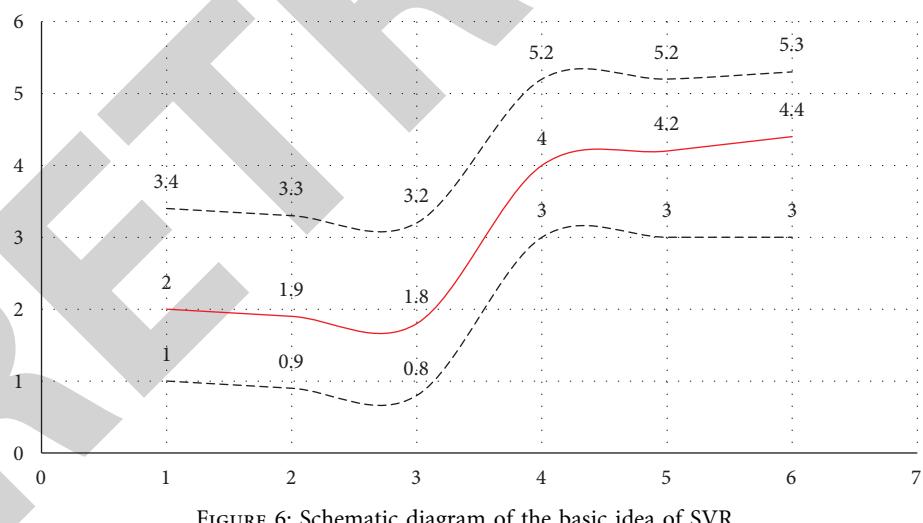


FIGURE 5: Prediction effect diagram: cs-WNN model.



classification surface that minimizes the distance of all training samples from this classification surface and convert the nonlinear regression task into linear regression in high-dimensional space, so as to approximate the input and output. The basic idea of SVR is shown in Figure 6.

## 5. Conclusions

The prediction process of the model is based on the daily data time series of the interest rate, starting from the

fluctuation of the interest rate level itself, without involving other relevant factors, which is similar to the technical analysis in the financial market. The assumption contained in this paper is that all the influencing factors will eventually be reflected in the change of interest rate level. In the study of interest rate fluctuation with “daily” as the time dimension, this assumption is basically satisfied.

In this paper, the overnight varieties of Shibor were studied from two time dimensions. When the research focus is the short-term fluctuation of overnight Shibor, we directly

model the daily time series data through an artificial intelligence algorithm. In terms of the selection of algorithm, this paper first applied BP neural network as the basic prediction model algorithm and then proposed applying WNN algorithm to overnight Shibor prediction and further proposed a prediction model based on cuckoo search optimization, based on WNN, which improved the prediction accuracy. When the research focuses on the long-term trend of overnight Shibor, we start from the factors affecting the trend of interest rate, select CPI, quarter-on-quarter growth rate of pledge-type repo rate, quarter-on-quarter growth rate of exchange rate, and last month value of overnight Shibor as independent variables to establish the SVR prediction model and further improve the SVR algorithm with PSO to improve the prediction effect.

The prediction model has markedly improved the prediction precision and the optimized prediction model in overnight Shibor. Data prediction shows good effect and can forecast the auxiliary decision-making. In the trend study of Shibor, the regression support vector machine (SVR) algorithm was selected for the feature that Shibor was officially launched only in 2011 and monthly data was very limited. By analyzing the performance of the SVR prediction model established by the influencing factors of the interest rate on overnight Shibor monthly data, it can be found that the model has a general prediction effect on the monthly average value of overnight Shibor, and the predicted value fluctuates too much. The prediction algorithm of particle swarm optimization (PSO) is used to optimize the extreme value of nonlinear function in solvable space through dynamic adjustment of particles. In the empirical analysis of overnight Shibor prediction based on interest rate influencing factors, PSO-SVR prediction model shows better prediction ability than SVR model. In the short-term daily data forecast of the interest rate, the prediction model performs very well and can basically be used to predict the volatility. In the long-term monthly data prediction of the interest rate, the monthly data points of the interest rate influencing variable showed a relatively average performance in the prediction of the overnight Shibor monthly mean value of the next month, which were unable to reflect the response of the interest rate to some emergencies. Therefore, emergency observation was added into the framework design of the decision-making system to assist decision-making.

## Data Availability

No data were used to support this study.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding this paper.

## Authors' Contributions

All authors have read and approved the manuscript for publication.

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