ISSN: 2664-9640

RMB Exchange Rate Forecast Based on PSO Optimized SVR Algorithm

Xu Dong[1], Xiang Meng[2], Jingkai Yang[1]

[1]School of Management Science and Engineering, Anhui Finance and Economics University, Bengbu 230030, China

[2]School of statistics and applied mathematics, Anhui Finance and Economics University, Bengbu 230030, China

Abstract

As an important factor influencing domestic prices and foreign import and export trade, the fluctuation of Renminbi exchange rate has been significantly enhanced with the deepening of global economic integration. At the present time when the new pattern of development is proposed in China, it is of great significance to rationally control the exchange rate. In view of the randomness and non-linearity of exchange rate prediction, traditional econometrics methods show instability and low accuracy in predicting exchange rate. This paper presents a support vector machine regression (PSO-SVR) model based on particle swarm optimization, and uses particle swarm algorithm to optimize two parameters g and C that have a significant impact on the performance of the algorithm. The PSO-SVR model is re-established with the optimized parameters, and finally compared with the unoptimized SVR model, which proves that the accuracy and stability of the prediction results have been improved. It has practical significance for the prediction of the exchange rate of Renminbi and the proposition of future policies.

Keywords

Exchange rate, Support vector machine regression, Particle swarm optimization, parallel ensemble learning.

1. Introduction

With the rapid development of economic globalization and financial market, exchange rate has become a key issue of global concern. In recent years, the trade imbalance between China and the United States has been aggravating. The U.S. government attributes its huge trade deficit in China to the underestimation of the value of the Renminbi currency, and considers the exchange rate of the Renminbi to the United States dollar as a key issue affecting the economic and trade relations between the two countries. On the one hand, the exchange rate affects the stability of a country's import and export trade and prices, on the other hand, the exchange rate issue is also a financial means for a country to achieve certain political and military objectives. Therefore, in order to maintain the sustainable and stable development of the economy, it is of great practical significance to accurately predict the exchange rate of US dollar to Renminbi.

At present, many scholars at home and abroad have explored and studied the exchange rate data, and formed a variety of exchange rate prediction methods, which can be summarized into traditional econometrics methods and emerging machine learning methods. At present, the application field of machine learning and expanding to all walks of life, has been favored by more and more scholars in recent years, and has been applied to such fields as education, industry, finance, and has shown outstanding results. Similarly, the prediction of exchange rate is one of the fields applied by machine learning methods.

Traditional econometric methods mainly include GARCH model, ARIMA model [1] and so on. It is found that the short-term forecast effect of the traditional model on exchange rate is not ideal, mainly due to the non-linearity and high fluctuation of exchange rate data. The intelligent prediction model based on artificial neural network, support vector machine and other machine learning methods can better solve the prediction problem of non-linear data. At present, the application field of machine learning and its expansion to all walks of life have been favored by more and more scholars in recent years. It has been applied to fields such as education [2], industry [3], finance [4] and so on, and has shown outstanding results. Similarly, the prediction of exchange rate is also one of the application fields of machine learning methods.

For example, Liu [5] used BP neural network to predict the RMB exchange rate, and verified the superiority of BP neural network in forecasting performance. Li Lin et al [6]. used the gray model GM(1, 1) to predict and analyze the trend of the RMB exchange rate, and proved that the gray prediction model It is effective for exchange rate forecasting. Yang Xinchen et al [7]. used the support vector machine to predict the exchange rate data of Japanese yen, pound sterling and Canadian dollar. And found that the support vector machine method has a good direction prediction performance, and the prediction results can be used as the basis for investment decision-making. Li Qiumin et al. [8] used the improved least squares support vector machine (LSSVM) to predict the exchange rate. The empirical results show that the prediction accuracy of this improved model has been significantly improved.

As a commonly used optimization method, the swarm intelligence algorithm has many applications in the optimization of traditional algorithms. For example, Liu et al. [9] used genetic algorithm (GA) to optimize the BP neural network to predict the life of the circuit breaker. Yildiz et al. [10] used Swarm algorithm (ABC) optimizes extreme learning machines to predict the power generation of hydropower stations. In addition, algorithms such as firefly (GSO) [11], ant colony (ACO) [12], particle swarm (PSO) [13] and other algorithms have also been applied to optimize traditional machine learning algorithms to improve their performance and stability.

This paper first analyzes that the prediction effect of the traditional support vector machine regression model is greatly affected by the initial radius parameter g and the error penalty parameter C. Inappropriate parameters will lead to problems of low accuracy and low stability. Therefore, we choose The parameters g and C of the support vector machine regression are optimized by particle swarm algorithm, and the parallel integration algorithm of PSO-SVR is constructed to predict the exchange rate of RMB against the US dollar. The experimental results show that the optimized PSO-SVR algorithm has better prediction accuracy. It has been greatly improved and has strong practical significance. Finally, in light of the current situation, relevant suggestions are put forward on the adjustment and control of the RMB exchange rate, so as to promote the stable development of the domestic economy and reduce the probability of foreign exchange risks.

2. Methods

2.1. Support Vector Regression(SVR)

The principle of support vector machine regression is similar to that of support vector machine. The main difference is that there is only one kind of sample points in SVR, and the purpose of finding the optimal hyperplane is to minimize the overall deviation of all sample points from the hyperplane:

The following training data sets are given: $D=\{(x_1,y_1),(x_2,y_2),\ldots,(x_i,y_i)\}$, $x_i \in R$, $y_i \in R$, i is the number of training samples, by nonlinear mapping φ converts the input into high-dimensional space, and perform linear regression in high-dimensional space, which is expressed as follows:

$$f(x) = \omega \cdot \varphi(x) + b \tag{1}$$

Where, $\varphi(x)$ is a mapping function, ω is the weight coefficient, b is the offset term; according to the principle of structural risk minimization, the parameters are determined ω and b, the corresponding optimization objective function is:

$$D(x) = \frac{1}{2}\|\omega\|^2 + \frac{1}{l}\sum_{i=1}^{l}|f(x_i) - y_i|_\varepsilon \tag{2}$$

Where $|f(x_i) - y_i|_\varepsilon$ is the loss function, by introducing relaxation variables $\xi_i \geq 0, \xi_i^* \geq 0$ and penalty factor $C > 0$ to solve the problem of fitting error, the final objective function and constraints are summarized as follows:

$$\begin{gathered} \min \frac{1}{2}\|\omega\|^2 + C\sum_{i=1}^{l}(\xi_i + \xi_i^*) \\ s.t. \begin{cases} y_i - \omega \cdot \varphi(x) - b \leq \varepsilon + \xi_i \\ \omega \cdot \varphi(x) + b - y_i \leq \varepsilon + \xi_i^* \\ \xi_i, \xi_i^* \geq 0, \quad i = 1,2,\ldots l \end{cases} \end{gathered} \tag{3}$$

The above formula is introduced into Lagrange function, and the duality principle and Lagrange multiplier are used a_i, a_i^* to solve the objective function, according to the theory of universal function, the kernel function conforming to Mercer condition is introduced $K(x_i, x)$, finally, it is transformed into a linear problem in high-dimensional space through nonlinear transformation, which is expressed as follows:

$$f(x) = \sum_{i=1}^{l}(a_i - a_i^*)K(x_i, x) + b \tag{4}$$

For support vector machine, the selection of kernel function also has a great impact on the performance of the algorithm. At present, several commonly used kernel functions and their expressions are as follows. In this paper, the following kernel functions are selected for testing, and then the kernel function with the smallest error is selected for the final prediction and analysis of RMB exchange rate:

(1) Linear kernel function

$$K(x, x_i) = x^T x_j \tag{5}$$

(2) Polynomial kernel function

$$K(x, x_i) = (x^T x_j)^d \tag{6}$$

(3) RBF kernel function (Gaussian kernel function)

$$K(x, x_i) = \exp(-\frac{\|x - x_i\|^2}{2\sigma^2}) \tag{7}$$

2.2. Particle Swarm Optimization(PSO)

Particle swarm optimization algorithm (PSO) is inspired by imitating the movement of bird population. Each bird is regarded as a particle carrying candidate solutions. In this paper, it is expressed as parameters g and C to be optimized. By constantly updating the position and speed of iterative particles, the optimal solution is searched in the solution space, so that the whole particle swarm is close to the optimal solution from the initial position, and finally the required optimal value or optimization parameters are obtained [14].

The speed and position iteration formula of PSO algorithm is as follows:

$$v(d) = wv(d-1) + c_1 r_1 (pbest(d) - x(d)) + c_2 r_2 (gbest(d) - x(d)) \tag{8}$$

$$x(d) = x(d-1) + v(d-1) \tag{9}$$

Where, D is the current number of iterations, pbest is the current optimal particle position, W is the inertia weight, which is used to maintain the influence of particle velocity, gbest is the historical optimal particle position, c1 and c2 are individual learning factors and social learning factors respectively, v(d-1) is the particle velocity of iteration d-1, x(d) is the particle position of iteration d, and r1 and r2 are random numbers in (0,1).

The operation process of particle swarm optimization algorithm is to continuously update the position and speed of each particle and the whole particle swarm, calculate the fitness value according to the given fitness function, compare the current optimal value and the historical optimal value of individual or population, end the algorithm process after reaching the maximum number of iterations, and output the final recorded optimal value and optimal individual position.

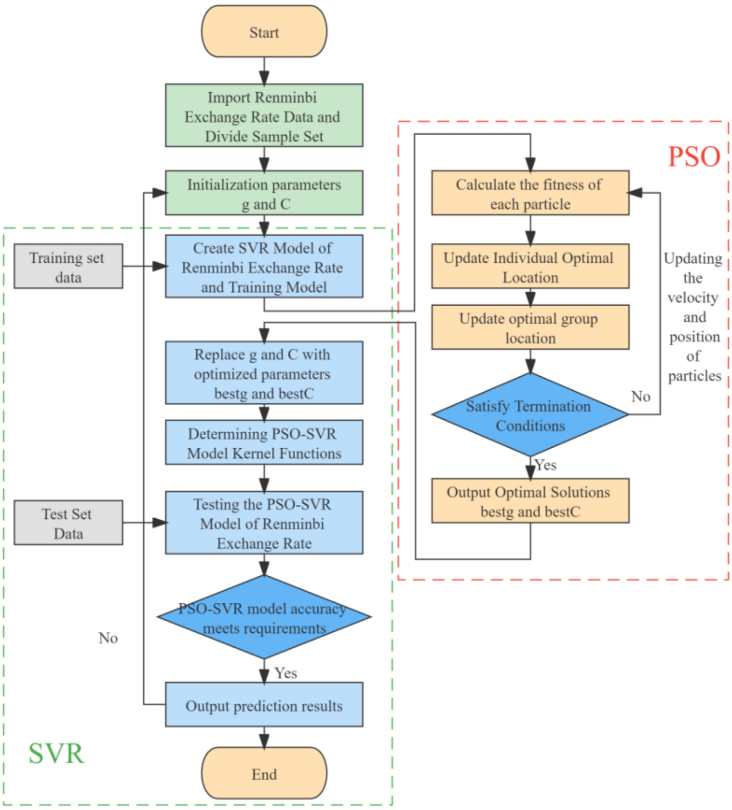


Figure. 1 Flow chart of PSO-SVR algorithm

2.3. Particle swarm optimization support vector machine regression(PSO-SVR)

The algorithm process of using particle swarm optimization to optimize support vector machine regression (PSO-SVR) to predict the RMB exchange rate is shown in the Figure.1 below:

Step1: import 5189 time series data of RMB / US dollar exchange rate into the model, the input and output are exchange rates, and divide the training set and test set;

ISSN: 2664-9640

Step2: initialize the parameters of SVR model and set the initial radius parameter g and error penalty parameter C to be optimized, (select the appropriate kernel function, if we choose Linear kernel, then there is no optimization of parameter g);

Step3: initialize PSO parameters: determine the maximum number of iterations N, population size n, individual learning factors and social learning factors C1 and C2, and randomly generate the speed and position of a group of particles;

Step4: particle swarm optimization algorithm starts iterative optimization, continuously updates the optimal position of individual and group until the number of iterations ends or reaches the predetermined accuracy, and outputs the optimized bestg and bestC parameters;

Step5: use the optimized initial radius parameter g and error penalty parameter C to replace the original parameters, and start training and forecasting the RMB exchange rate;

Step6: generate and compare the prediction results of SVR algorithm and PSO-SVR algorithm, and the process ends.

3. Experimental content

All experiments in this paper are carried out in the environment of MATLAB r2020b. The experimental data used are from CSMAR guotai'an financial research database. The experimental data are the exchange rate of RMB against the US dollar for 5189 days from January 2, 2001 to April 2, 2022.

Table 1 Historical data of RMB / US dollar exchange rate

Time	Exchange Rate	Time	Exchange Rate
2001-01-02	8.2774	2022-03-17	6.3406
2001-01-03	8.2779	2022-03-18	6.3425
2001-01-04	8.2773	2022-03-21	6.3677
2001-01-05	8.2781	2022-03-22	6.3664
2001-01-08	8.2775	2022-03-23	6.3558
2001-01-09	8.2778	2022-03-24	6.364
2001-01-10	8.2771	2022-03-25	6.3739
2001-01-11	8.2769	2022-03-28	6.3732
2001-01-12	8.2767	2022-03-29	6.364
2001-01-15	8.2768	2022-03-30	6.3566
2001-01-16	8.2767	2022-03-31	6.3482
2001-01-17	8.2766	2022-04-01	6.3509
…		…	

When the PSO-SVR model is used to predict the RMB exchange rate data, 75% of the data is selected as the training set and 25% of the data is selected as the test set. At the same time, a rolling sequence is established for the time series prediction, that is, the M + 1 data is predicted with 1 to M data, and then the M + 2 data is predicted with 2 to M + 1 data.

For PSO-SVR model, the choice of kernel function will also affect the accuracy of algorithm prediction. We use three different kernel functions: linear kernel, polynomial kernel and RBF kernel. By selecting different kernel functions to run on SVR and PSO-SVR model, we compare the accuracy of the results.

When measuring the accuracy of the prediction results, we choose MSE (mean square error), MAE (mean absolute error) and MRE (mean relative error). By measuring the performance of different kernel functions in SVR algorithm and PSO-SVR algorithm, we select the appropriate kernel function, and then use it as the prediction of RMB exchange rate.

The following table shows the performance of SVR and PSO-SVR models with different kernel functions on the test set:

Table 2 Algorithm performance comparison

Type	MSE		MAE		MRE	
	SVM	PSO-SVM	SVM	PSO-SVM	SVM	PSO-SVM
Linear	5.9896e-04	2.2241e-04	0.0182	0.0110	0.0027	0.0016
Polynomial	5.1674e-04	2.1991e-04	0.0168	0.0109	0.0025	0.0016
RBF	7.9919e-04	2.2459e-04	0.0218	0.0112	0.0033	0.0017

It can be seen that among the three different kernel functions, the error of each evaluation index of the polynomial kernel is the smallest, which proves that the polynomial kernel prediction result is the most accurate in the prediction of RMB exchange rate. Therefore, we choose the polynomial kernel as the final kernel function to predict the exchange rate of RMB against the US dollar.

Because the polynomial kernel is chosen as the kernel function, we need to optimize the radius parameter g and error penalty parameter C. First, we need to set the initial parameter values, so that g=10, C=0.001, is used to represent the unoptimized initial SVR model, and then use the particle swarm algorithm to optimize these two parameters.

The following figure shows the iterative curve of the parameter optimization process of particle swarm optimization algorithm. The fitness function is selected as the mean square error of RMB exchange rate. It can be seen that the algorithm converges after the 13th iteration, which proves that the optimal parameter combination has been found at this time. Finally, the optimal parameter combination obtained by optimization is g = 9.4239, C = 6.0738.

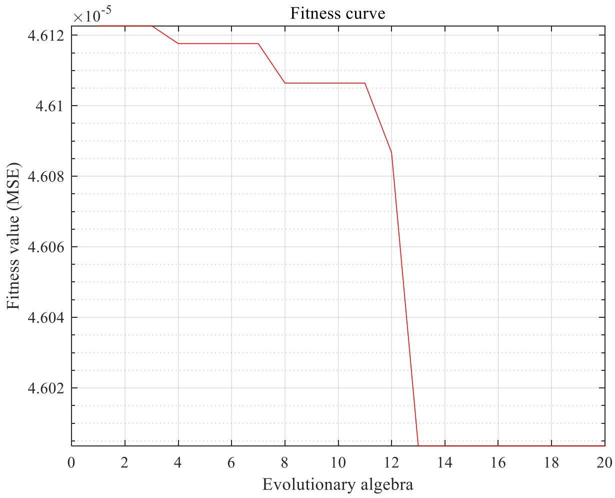


Figure. 2 Fitness iteration curve

When using polynomial kernel to predict the RMB exchange rate, PSO algorithm is used to optimize the SVR model, and the optimal parameter combination is input into the support vector machine regression model. The comparison of prediction results and prediction errors is shown in the figure. It can be seen that the accuracy of PSO-SVR model is improved compared with SVR model, and the actual output results are more consistent with the expected output value.

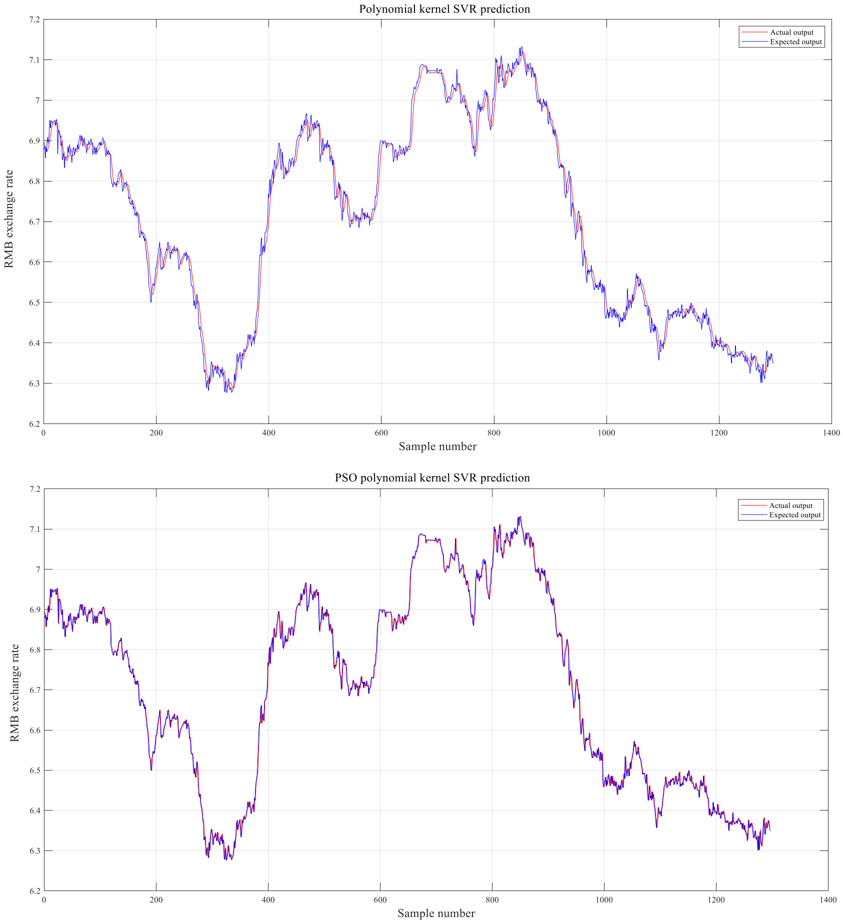
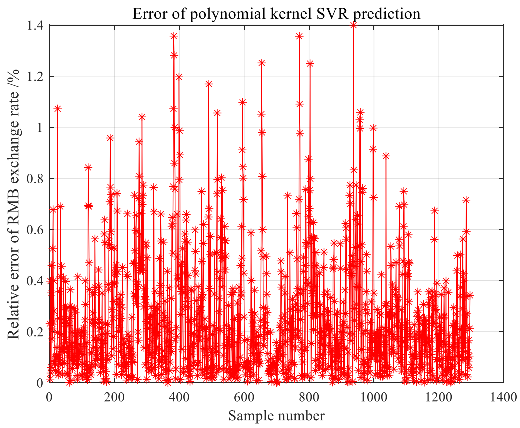


Figure. 3 Comparison of predicted values before and after algorithm optimization

The following is a comparison of the prediction errors between the SVR algorithm and the PSO-SVR algorithm. It can be seen that the prediction errors of the SVR model optimized by the particle swarm optimization algorithm are more accurate and more stable than those of the unoptimized SVR algorithm. The optimized PSO-SVR algorithm is concentrated in 0-0.4% error interval, which proves that the performance of the optimized PSO-SVR algorithm is better.



ISSN: 2664-9640

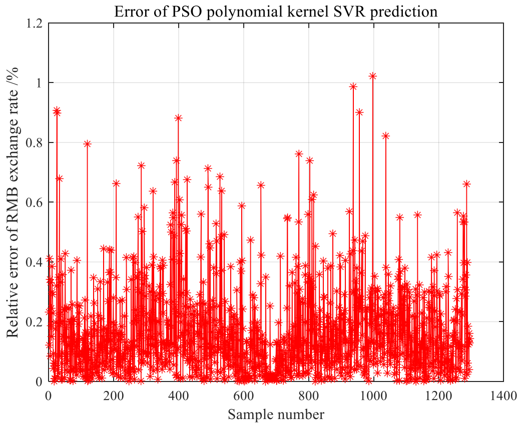


Figure. 4 Comparison of prediction errors before and after algorithm optimization

4. Conclusion

In this paper, the particle swarm optimization support vector machine regression model (PSO-SVR) is used to predict the exchange rate of Renminbi against the US dollar. Firstly, an appropriate kernel function is selected, based on the principle of minimum error, and finally a polynomial kernel is selected as the kernel function. Then, the PSO algorithm is used to optimize the initial radius parameter g and error penalty parameter C of the SVR model. By comparing the performance before and after the optimization of the algorithm, the experimental results show that the prediction accuracy of the SVR model optimized by the PSO algorithm is improved, and the prediction error is reduced while more stable, which can effectively predict the exchange rate of Renminbi and US dollars, and has some practical significance.

The exchange rate of Renminbi represents the external value of China's major currencies, and has a direct regulatory effect on China's import and export trade, as well as maintaining stable economic development and resisting economic risks brought by foreign funds. Based on the current international situation, the following conclusions and suggestions are put forward for the adjustment and fluctuation of the exchange rate of Renminbi:

1. The appreciation of Renminbi is an inevitable trend, but it is not achieved overnight; The currently most used currencies in the world are still US Dollar, Pound Sterling and Euro. The medium-term and long-term appreciation of Renminbi is also a policy for international financial risk. Rapid appreciation or depreciation will have a huge impact on the domestic economy. By properly controlling the trend and extent of the appreciation of Renminbi, the economic risk of large cross-border capital flows can be effectively reduced.

2. In recent years, affected by internal and external uncertainties such as epidemic prevention and control, economic recovery, export prospects, US dollar index, financial risk, big country game, etc., multiple factors should be taken into account in the prediction and analysis of the exchange rate of Renminbi. It is clear that factors affecting the exchange rate appreciation and depreciation coexist. Prepare in advance can react promptly in the face of risks.

3. The arrival of the big data era has made the machine learning method applied in many fields. Using the machine learning angle method to predict the exchange rate of Renminbi can help the government departments to formulate related policies. However, while the accuracy and stability of the prediction results have been improved, there is also a problem of explanatory decline. How to combine the accuracy and explanatory ability organically is also a subject worth exploring.

ISSN: 2664-9640

References

[1] Metsileng, L.D. , Moroke, N.D. , & Tsoku, J.T. . (2020). The application of the multivariate garch models on the brics exchange rates. Academic Journal of Interdisciplinary Studies, 9(4), 23.

[2] Guobadia, E.K. , Onyedikachi, I.P. , & Kevin, U.K. . (2021). Short Term Modeling of the Nigerian Naira/United States Dollar Exchange Rate Using ARIMA Model.

[3] Wang, J. , & Hu, S. . (2022). Research on the construction of intelligent media ideological and political learning platform based on artificial intelligence technology. Journal of Mathematics, 2022.

[4] Webert Heiko,Döß Tamara,Kaupp Lukas & Simons Stephan.(2022).Fault Handling in Industry 4.0: Definition, Process and Applications. Sensors(6).

[5] Feng Yuan & Souri Alireza.(2022).Bank Green Credit Risk Assessment and Management by Mobile Computing and Machine Learning Neural Network under the Efficient Wireless Communication. Wireless Communications and Mobile Computing.

[6] Liu, J. (2017). Prediction of Short Term Exchange Rate Using BP Neural Network. 2017 International Conference on Education Science and Economic Management (ICESEM 2017).

[7] Li Lin, pan Fuchen & Wang Chaobo (2018). Prediction of RMB exchange rate trend based on GM (1,1) model Contemporary economy (21), 40-41.

[8] Yang Xinchen & Wu Yangru (2010). Nonlinear exchange rate forecasting analysis based on support vector machine Statistics and decision making (18), 13-16.

[9] Li Qiumin, Tian Yixiang & Zhang gaoxun (2013). LSSVM prediction model based on GMDH and its demonstration Practice and understanding of Mathematics (06), 62-68.

[10] Liu, G. , Miao, J. , Zhao, X. , Wang, Z. , & Li, X. . (2022). Life prediction of residual current circuit breaker with overcurrent protection based on bp neural network optimized by genetic algorithm. Journal of Electrical Engineering & Technology.

[11] Yildiz, & Aikgz. (2021). Forecasting diversion type hydropower plant generations using an artificial bee colony based extreme learning machine method. Energy Sources.

[12] Liu, T. , Fan, Q. , Kang, Q. , & Niu, L. . (2020). Extreme learning machine based on firefly adaptive flower pollination algorithm optimization. Processes, 8(12), 1583.

[13] Stighezza, M. , V Bianchi, & Munari, I. D. . (2021). Fpga implementation of an ant colony optimization based svm algorithm for state of charge estimation in li-ion batteries. Energies, 14.

[14] Zhang, M. . (2021). Prediction of rockburst hazard based on particle swarm algorithm and neural network. Neural Computing and Applications, 1-11.

[15] Wang, W.J. , & Gang, L.I. . (2017). Greed particle swarm optimization based database optimal resource allocation in cloud computing. Control Engineering of China.