ISSN 2616-5775 Vol. 5, Issue 4: 75-78, DOI: 10.25236/AJCIS.2022.050414

Research on Financial Product Price Prediction Based on Grey Prediction and WOA-BP Neural Network

Man Jeoi Lau[1, 2], Shiyi Bai[1], Kevin Chan[1], Fang Lin[1, 3, *]

[1]Pittsburgh Institute, Sichuan University, Chengdu, Sichuan, 610065, China
[2]School of Economics, Sichuan University, Chengdu, Sichuan, 610065, China
[3]College of Physics, Sichuan University, Chengdu, Sichuan, 610065, China
**Corresponding author*

Abstract: *Quantitative trading is an emerging financial investment strategy. In this paper, based on the historical data prediction-guided trading strategy problem, small-sample prediction and machine learning are used to build a prediction trading model. To solve the problem of insufficient training samples in the early stage, we build a gray prediction model for small sample forecasting, and train the neural algorithm and use it for later predictions. In the gray prediction model, the optimal prediction parameters are obtained by tuning the parameters for the differential equation. The whale algorithm was introduced to optimize the BP neural network to obtain a threshold closer to the optimal solution, which accelerated the degree of threshold optimal approximation by reducing the mean absolute percentage error (MAPE) by 26%.*

Keywords: *Grey prediction; BP neural network; Quantitative trading*

1. Introduction

Quantitative trading is an emerging financial investment strategy that uses computer technology as a vehicle to replace traditional human subjective judgment with advanced mathematical models. Because it starts from probabilistic mathematics, it greatly reduces the losses caused by irrational investment decisions.[1] Today over 70% of the world's money is traded with computers or programs, half of which are operated by quantitative or programmed managers. Gold is considered one of the most classic international currencies due to its scarcity and ease of division and storage. Bitcoin, on the other hand, represents a cryptographic digital currency with anonymity, security and decentralization, and is one of the hottest new investment products in recent years.[2]

2. Price Forecasting Model Based on Grey Prediction and WOA-BP Neural Network

The GM (1,1) model is one of the most classic gray prediction models and is the basis for the study of gray prediction models. The gray prediction model first requires a cumulative generation process for the original data.[3]

The original sequence is known to be:

$$X^{(0)} = \left(x^{(0)}(1), x^{(0)}(2) \cdots x^{(0)}(n)\right) \tag{1}$$

Then the sequence generated by its first-order accumulation is:

$$X^{(1)} = X^{(0)}S \tag{2}$$

Thus, a completely new series is obtained as a way to reduce the uncertainty and perturbation of the original data, and then the GM (1,1) model is built using the generated data:

$$x^{(0)}(k) + az^{(1)}(k) = b \tag{3}$$

The GM (1,1) model is solved to obtain the time response series; finally, the first-order cumulative reduction is used to generate the series as:

$$X^{(0)} = X^{(1)}D \tag{4}$$

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In the above equation, D is a first-order cumulant generating operator, which can be used to process the time response series to obtain the reduced values, thus completing the prediction of the future.

The basic BP neural network model is mainly characterized by its wide application, complete theoretical foundation, clear learning mechanism and strong fault tolerance, self-learning ability and self-adapt ability.[4]

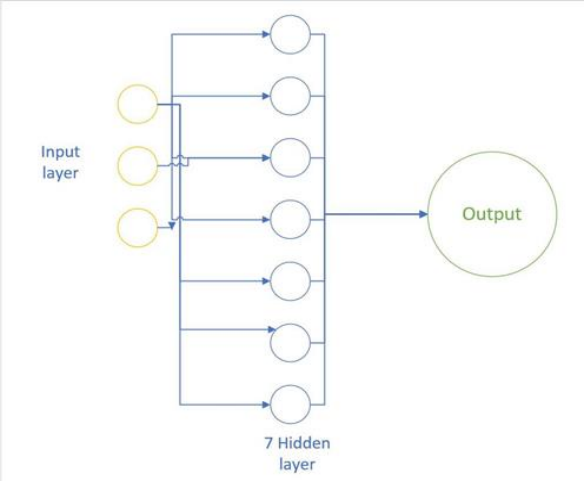

Figure 1: Schematic diagram of neural network

The model combines gray forecasting and BP neural network compared to the global forecasting using a traditional single model, taking into account the sample size applicable to both algorithms and segmenting the forecasting, which greatly improves the overall correctness of the sample size from small to large and makes the fitted results close to the true value.

First, the problem requires the model to forecast the future based on past data, and to convert dollar and gold or bitcoin holdings to each other based on the forecast to obtain returns. Since this model can only make predictions about the future based on sample data from the data file, the initial stage of prediction can only be based on a small number of samples. However, the training of BP neural network is the process of continuously adjusting the network weights by applying the error backpropagation principle so that the sum of squared errors between the output value of the network model and the known output value of the training samples is minimized or less than a certain expected value. Therefore, when the amount of sample data is small, using BP neural network to fit a small number of samples will lead to poor results because the network cannot find reasonable weights and thresholds. On the other hand, the method of using gray system for forecasting will not be able to make reasonable use of the past sample data when the volume of sample data becomes larger, and the gray forecast can only be fitted based on a small number of days of samples before the forecast.

Based on the above analysis of the shortcomings of the two traditional models, this model uses a combination of the two algorithmic models to solve the actual problem in stages, so that the two algorithms can complement each other and the model can be optimized from a global perspective.

For a small amount of sample data this model uses the gray prediction method for prediction, which requires less modeling information, is easy to operate, has high modeling accuracy, and has unique efficacy for analysis and modeling of time series segments, statistical data, and systems with incomplete information. At the same time, the BP neural network continues to receive more real values of gold and bitcoin price data as the number of samples gets larger, allowing it to perform machine learning. When the number of samples is sufficient, the model turns to the BP neural network for future prediction. Here, the model innovatively solves the problem of too many loops of the algorithm due to the daily input of new data to train the BP neural network, which is too complicated and cumbersome. Based on the relationship between the amount of sample data trained by the BP neural network and the amount of data that can be reasonably predicted within the error, the model sets the speed of updating the training data of the BP neural network, which greatly improves the operation efficiency of the model and keeps the error within an acceptable range, thus reducing the complexity of the model without compromising its accuracy and making it more adaptable and scalable.

In addition, this model innovatively introduces the whale optimization algorithm to find the optimal weight threshold for the BP neural network. The algorithm finds the threshold values of the neurons in

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the middle layers of the BP neural network and the weights from the input layer to the middle layer by establishing a spiral equation with the target and continuously updating the coordinate positions in the equation to shrink the envelope mechanism, and then the optimized neural network is trained. After comparing before and after optimization, the accuracy of the BP neural network after applying the whale optimization algorithm is significantly improved compared to the traditional BP neural network.[5]

Take the error analysis of Bitcoin as an example: by comparing the error values of BP neural network prediction and whale optimized BP neural network algorithm, we can conclude that the error value of WOA-BP algorithm is smaller.

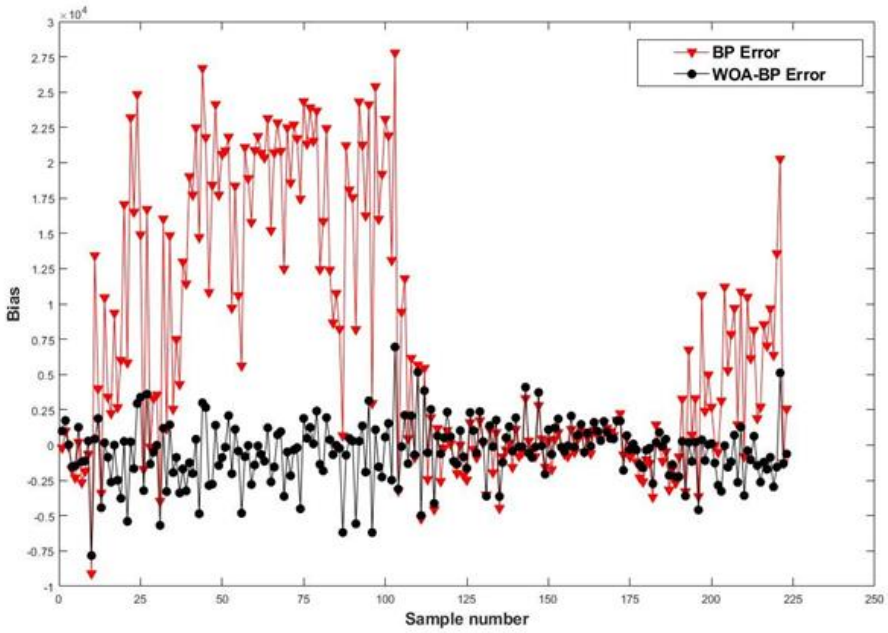

Figure 2: Comparison of the error between the predicted value and the actual value of the BP neural network before and after WOA optimization.

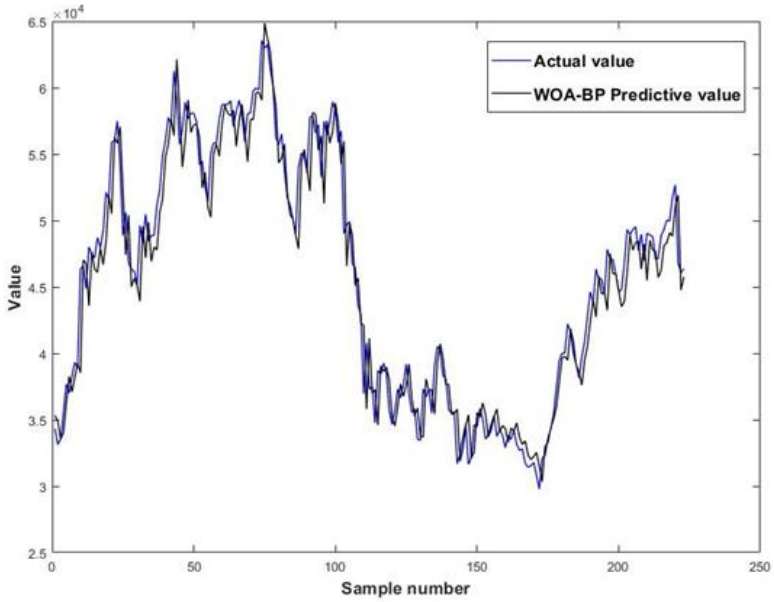

Figure 3: Comparison of predicted value and actual value of BP neural network before and after WOA optimization

By optimizing the model distribution prediction and the whale algorithm, the threshold value is no longer a random value generated by the system, but more effectively approximates the optimal value, and achieves a more desirable prediction effect. Mean absolute error (MAE), The mean square error (MSE), and Root mean square error (RMSE) all decreased significantly, while the average absolute

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percentage error (MAPE) was 5.1856%, which was 26% lower than the the average absolute percentage error (MAPE) is 5.1856%, which is 26% lower than the original BP neural algorithm.

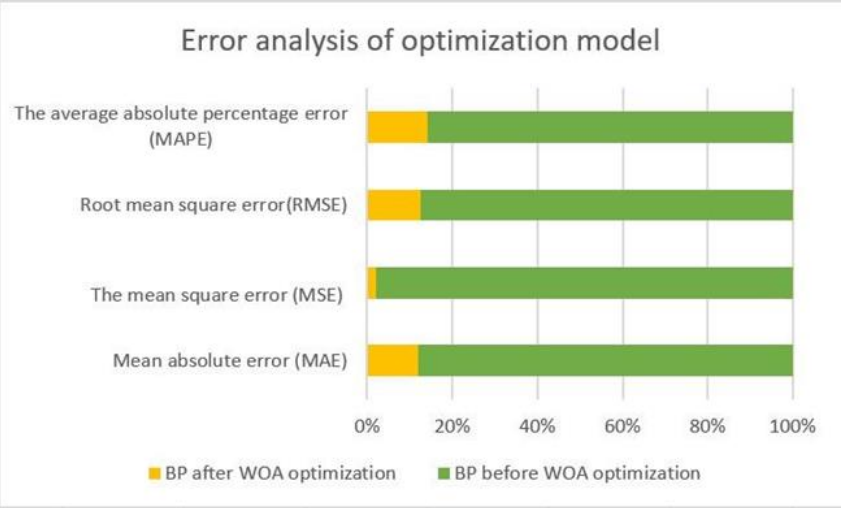

Figure 4: Error analysis of optimization model

3. Conclusion

This paper combines gray prediction with BP neural network algorithm and applies different algorithms to the prediction model for different time periods with full consideration of the condition of the amount of sample data required by the algorithm. In the initial stage, this model uses the gray prediction method based on small samples for prediction and gets better results. In this stage, the BP neural network continuously acquires data for machine learning.

When the number of samples is large enough, this model abandons the gray prediction method and changes to the WOA-BP neural network for prediction. It makes the deviation of the prediction decrease continuously with time. This model uses the whale optimization algorithm to help the neural network continuously find the optimal weights and thresholds, which reduces the number of iterations of the neural network and improves its accuracy. And the model uses segmentation to update data for the neural network, which reduces a large number of cyclic operations and optimizes the structure of the algorithm.

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