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The Comparisons of Four Methods for Financial Forecast

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***Abstract* - With the development of economy and the change of people investing consciousness, financial investment has become an important issue currently. Therefore, the financial prediction becomes an important investment tool to financial investors. Stock prediction plays a crucial role in a wide range of forecast in the financial market. It can also be extended to other fields of the financial forecast. In this paper, current stock forecasting methods are introduced first. Then a variety of prediction models are mainly introduced, which are the current popular four kinds of methods: BPN (back propagation network), ELMAN, SVM (support vector machine) and WNN (wavelet neural network). The cross validation method is added to find the optimal parameters in these four methods. Experiments with three different kinds of stocks are conducted to verify these four methods. The advantages and limitations of these methods are given by analyzing and comparing the experiment results.**

Index Terms - Financial predictions*, *Stock forecasting, Neural network, Cross validation.

I. INTRODUCTION

There are different prediction aspects in financial fields. Stock forecast is one of the most popular and widely applied aspects currently. Because stock market has the characteristics of high risk and high payoff, many investors and researchers trend to find useful predication tools. However, along with the financial industry development and economic globalization intensifying, financial environment makes the influence factors of the stock price increasing explosively. In addition to the traditional factors such as stock market mechanism with supply and demand, stock prices are still affected by a lot of other factors, such as government regulation, overall economic conditions, industry development conditions, public opinion and news, etc. It is evident that the stock market is a chaotic system with nonlinear, much noise and uncertain characteristics. Because of these characteristics, the whole stock forecast is a complex system with difficulties: (1) It is hard to develop accurate mathematical model. (2) Multiple influence factors are difficult to distinguish. (3) Stock investment is too subjectivity to predict.

Even if there are lots of difficulties, various forecasting methods were proposed, which were mainly divided into several categories: *(1) Basic analysis*: people make use of the knowledge of finance, financial management, venture capital and other subjects, establish the artificial construct of economic model to forecast the stock trend manually. *(2) Statistical analysis*: After the practice and research for a long time, people summarized a lot of methods of technical analysis which base on the statistics, such as the moving average line method, the K-chart analysis method, the point chart method, and so on, using the statistical mathematics model to forecast the stock trend. *(3) The chaotic dynamics analysis*: in chaos theory, chaos is not chaotic, seemingly irregular and moving orderly in certain system. In other word, the external surface is disorderly while the internal structure is orderly. Usually, this method reconstructs the space of forecasting object, calculates the fractal dimensions and embedding dimensions, finds or confirms the existence of the chaos, and then makes a forecast through the Lyapunov exponent [1]. *(4) Artificially intelligence analysis*: with the development of modern science and technology, computer technology gets progress increasingly. Neural network technique applying to the prediction of stock market has become a hot spot. Artificial neural network is a nonlinear parallel processing dynamic system, with a lot of adjustable parameters, highly parallel mechanism. It can quickly process information and data with strong learning ability. Therefore, it is suitable to the nonlinear complex environments with much noise for predicting stock price.

In the four methods, artificial intelligence analysis has unique advantages, of which artificial neural network is the best one of them. With neural network methods, the prediction of future stock movements becomes possible only based on historical data as long as the data having enough. Therefore, Human can get rid of the complex and heavy mathematical models. Achievements of previous research confirmed this point [2-3]. Artificial neural network is introduced briefly as follows.

Artificial neural network is a new high-tech research area since 1980s, involving a variety of disciplines, attracting many neurophysiologists, psychologists, mathematician, computer and information scientists, engineers and entrepreneurs to research and apply. After the development process with ups and downs, neural network becomes an interdisciplinary research area, having an extensive application market. It plays an important and indispensable role in the field of financial markets, network security, and automatic control. For the aspect of predicting research, it has been used in water resource conservancy and electrical load prediction [4-5], traffic flow prediction [6], the stock market prediction [7], and many other fields. For the forecast method, neural network has stretched out to a variety of networks, such as BPN [8], SVM [9], WNN [10], ELMAN [11] and so on.

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In this paper, three quite representative neural network methods are selected to forecast the stock price comparing with SVM method. A brief introduction on the four network methods are given here first. Then the accuracy and performance of the predictions are studied with comparisons.

A. BP neural network

BP (Back Propagation) network is one of the most widely used neural network proposed by Rumelhart and McCelland in 1986. It is a kind of feed-forward network with multi-layers. A back propagation algorithm of error signal is used to train the network. BP network can learn and store a lot of mapping relationships between input and output layers without mathematical equations. The learning rule selects the steepest descent method and then constantly adjusting the network weights and thresholds by the back propagation algorithm to make the sum of the network error minimum. BP network mainly includes two processes, which are the forward propagation of the information and the back propagation of the error. The first process is to enter a known sample, and to calculate the outputs of the neurons through every layer of the network. The weights and thresholds are used in the calculation, which are from the initial setting or the results of the former iteration. The second process is to get the error by comparing the actual outputs and the desired outputs of the network, to get the change gradient of weights and thresholds from the output layer back to the input layer, and then to modify each of the weights and thresholds. The two processes are conducted alternately to complete the training of the whole samples until the neural network achieve a convergent situation [12].

B.ELMAN neural network

Based on the flow direction of the data and information in artificial neural network, neural network can be divided into feed-forward and feedback. Feedback neural network is also called regression network or recurrent network. ELMAN neural network is a kind of feedback neural networks proposed by Elman in 1990. This model introduced a undertake layer in its feed-forward network, which makes the output information feedback becoming possible. Comparing with BP neural network, the output value of ELMAN network only depends on the input value and the matrix of weights, instead of the previous outputs. The impact of previous outputs works in the Elman neural network by delaying the feedback. This network has not only the complex nonlinear mapping capability like feed-forward neural network, but also the memory capability to remember the previous outputs. Therefore, ELMAN network has the ability to adapt to time-varying and dynamic environments [13].

C. Wavelet neural network

Wavelet neural network (WNN) is a new neural network model based on wavelet analysis theory. Early study on WNN can be found from [14] by Zhang and Benveniste from Institute of information technology in France in 1992. It combines the theory of wavelets and neural networks. Therefore, it has the good localization ability of wavelet transform nature, and has robustness, fault tolerance, and generalization features existing in neural networks. The structure of Wavelet neural networks is similar to the BP neural network, generally consists of one input layer, one hidden layer, and one output layer. The activation functions on hidden layer are drawn from an orthonormal wavelet family instead of the common transfer functions (such as sigmoid functions). So Wavelet neural networks take advantage of wavelet transform, and still have the features of information forward propagation and error back propagation.

D. SVM

SVM (support vector machine) method is a model proposed firstly by Cortes and Vapnik in 1995. It is good at solving the classification problem with small, high dimension and nonlinear samples. This model is widely used in machine learning and other research areas. SVM has the theoretical basis according to the statistical learning VC dimension theory and structural risk minimization theory. The main idea of SVM is to establish an optimal hyper-plane as the decision surface which can divide all samples into two types and maximize the space between the edges of the two types. Although it does not use the knowledge of problem areas, it still shows good generalization performance on pattern classification problems, which is the unique property of SVM. Just like multilayer perception network and radial basis function network, SVM can be used for pattern classification and nonlinear regression [15].

II. EXPERIMENTAL METHODS

In this section, experimental methods are described in detail consisting of two subsections. The principles of four methods are introduced first in subsection A, including the topology structures of BPN, Elman, WNN, SVM, the models of input-output, the error calculation methods, and the self-learning models. In the second subsection, parameter optimization algorithms are described, and the different results of different algorithms on different parameters are shown.

A. Design of four different methods

1). BP neural network

BP neural network includes input-output model, transmission function model, error calculation model and self-learning model. In this paper, the structure of BP neural network model is designed as shown in Fig. 1. It includes one input layer, one output layer and one hidden layer. The number of nodes in the input layer is six, corresponding to the day's opening price, closing price, highest price, lowest price, trading volume and transaction volume. The number of nodes is one in the output layer, corresponding to the next day's opening price. The number of nodes in the hidden layer is η and learning rate is μ, which can be changed according to different situations.

The model of input and output is defined as:

$$a^1 = S_1 \left(W^1 P + b^1 \right) \tag{1}$$

$$a^2 = S_2 \left(W^2 a^1 + b^2 \right) \tag{2}$$

where S_1, S_2 are transmission functions, b^1, b^2 are thresholds, and W^1, W^2 are the matrix of weights.

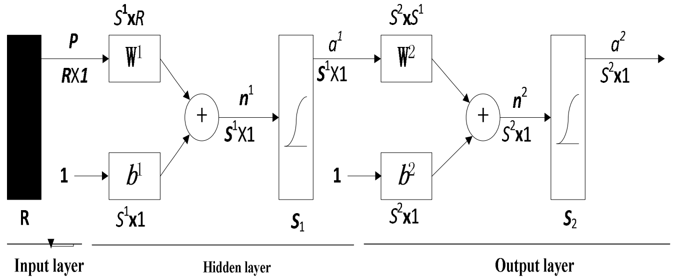

Fig.1 The structure of BPN, where S^1, S^2, R are the vector dimension, P, n^1, n^2, a^2 are vectors, S_1, S_2 are transmission functions, b^1, b^2 are thresholds, and W^1, W^2 are the matrix of weights.

The model of transmission is defined as:

$$f(x)=\frac{1}{1+e^{-x}} \tag{3}$$

The model of error calculation is defined as:

$$E=||\tilde{a}^2-a^2|| \tag{4}$$

where $\tilde{a}^2$ is desired output, and a^2 is actual output.

The model of self-learning is defined as:

$$w_{ij}^1(N+1)=w_{ij}^1(N)-\sigma\frac{\partial e}{\partial w_{ij}^1(N)}p,\ \ i=1,\dots s^1\ ;\ j=1,\dots R \tag{5}$$

$$w_{ki}^2(N+1)=w_{ki}^2(N)-\sigma\frac{\partial e}{\partial w_{ki}^2(N)}p, i=1,\dots s^1; k=1,\dots s^2 \tag{6}$$

$$b_i^1(N+1)=b_i^1(N)-\sigma\frac{\partial e}{\partial b_i^1(N)}\quad i=1,2,\dots s^1 \tag{7}$$

$$b_k^2(N+1)=b_k^2(N)-\sigma\frac{\partial e}{\partial b_k^2(N)}\quad k=1,2,\dots s^2 \tag{8}$$

where w_{ij}^1 is a element of weights matrix of W^1, w_{ki}^2 is a element of weights matrix of W^2, b_i^1, b_k^2 are thresholds.

2) ELMAN neural network

The structure of the Elman neural network is similar to the BP neural network, but a undertake layer is added with a feedback mechanism. The undertake layer inputs the previous outputs of the hidden layer to the hidden layer, which similar to a delay operator. In this paper, the structure of the ELMAN neural network model is designed as shown in Fig. 2. Similar to the structure of BP neural networks, the number of the nodes in the input, output, and hidden layers are the same as six, one, and η. The learning rate is also μ. The number of the nodes in the undertake layer is the same as the one in hidden layer. Because the Elman model of self-learning and transmission are similar to the BP neural network, only the input-output model and the error calculation are introduced as follows.

The model of input and output is defined as:

$$a^1(k)=S_1(IW^1a^1(k-1)+W^1P+b^1) \tag{9}$$

$$a^2(k)=S_2(W^2a^1(k)+b^2) \tag{10}$$

where $a^1(k)$ is the output vector of the hidden layer in the k^{th} operation; $a^2(k)$ is the output vector in the output layer in the k^{th} operation; $a^1(k-1)$ is the output vector of the undertake layer in the k^{th} operation; P, n^1, n^2, a^2 are the input and output vectors related to itself-layer; S_1, S_2 are transmission functions, b^1, b^2 are thresholds, and W^1, W^2, IW^1 are the matrix of weights.

The model of error calculation is defined as:

$$E=||\tilde{a}^2(k)-a^2(k)|| \tag{11}$$

where $\tilde{a}^2(k)$ is the desired output, and $a^2(k)$ is the actual output.

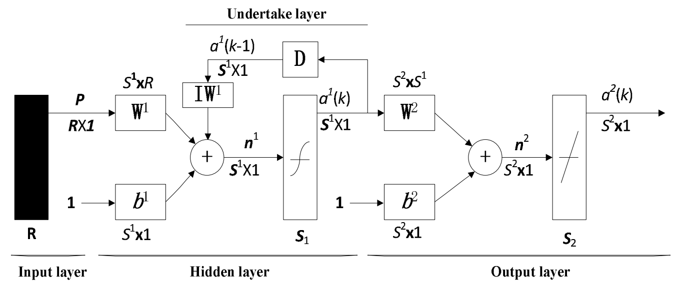

Fig.2 The structure of Elman, where $a^1(k-1)$, $a^1(k)$ and $a^2(k)$ are the outputs of layers; P, n^1, n^2, are the inputs of layers; S_1, S_2 are transmission functions, b^1, b^2 are thresholds, and W^1, W^2, IW^1 are the weights.

3) WNN

The structure of WNN is similar to the one of BPN. It has one input layer, one hidden layer and one output layer as shown in Fig. 3. All of the parameter settings are similar to the one of BPN described above. The wavelet basis function -- transmission is introduced as follows.

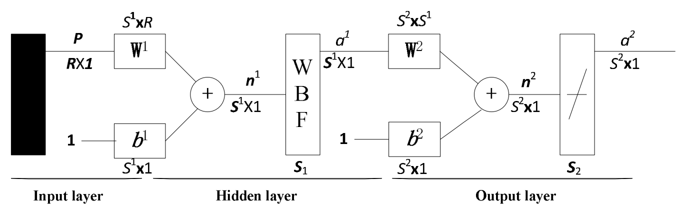

Fig.3 the structure of WNN, where P, n^1, n^2, a^1, a^2 are the inputs and output of layers, S_1, S_2 are transmission functions, b^1, b^2 are thresholds, and W^1,W^2 are weights.

The model of input and output is defined as:

$$a^2(k)=\sum_{j=1}^{l}W_{jk}\ \mathrm{hide}(j)\qquad k=1,2,\dots,S^2 \tag{12}$$

The model of transmission is defined as:

$$\mathrm{hide}(j)=\mathrm{hide}_j\left(\frac{\sum_{i=1}^{R}W_{ij}^1p_i-b_j}{a_j}\right)\quad j=1,2,\dots,S^1 \tag{13}$$

where p_i is a input vector, hide(j) is the j^{th} output function in the hidden layer, W_{ij} is the connection weight between the hidden layer and the input layer, b_j is the translation factor in wavelet basis function, a_j is the stretch factor in wavelet basis function, $hide_j$ is wavelet basis function, which conducts Morlet wavelet basis function. The formula of $hide_j$ is defined as follows：

$$y=\cos(1.75x)\,e^{-x^2/2} \tag{14}$$

The model of error calculation is defined as:

$$E=||\tilde{a}^2-a^2|| \tag{15}$$

where $\tilde{a}^2$ is desired output, and a^2 is actual output. The model of self-learning is defined as:

$$W_{xy}(i)=W_{xy}(i-1)+\Delta W_{xy}(i) \tag{16}$$

$$a_k(i)=a_k(i-1)+\Delta a_k(i)\quad k=1,2,\dots,S^2 \tag{17}$$

$$b_k(i)=b_k(i-1)+\Delta b_k(i)\quad k=1,2,\dots,S^2 \tag{18}$$

$$\Delta W_{xy}(i)=-\mu\frac{\partial e}{\partial W_{xy}(i-1)} \tag{19}$$

$$\Delta a_k(i) = -\mu \frac{\partial e}{\partial a_k(i-1)} \quad k = 1,2,\ldots,S^2 \tag{20}$$

$$\Delta b_k(i) = -\mu \frac{\partial e}{\partial b_k(i-1)} \quad k = 1,2,\ldots,S^2 \tag{21}$$

where $a_k(i)$, $b_k(i)$, $W_{xy}(i)$ are the stretch factor ,translation factor and weight in the i^{th} operation respectively; $\Delta W_{xy}(i)$, $\Delta a_k(i)$, $\Delta b_k(i)$ are incremental quality respectively; μ is the learning rate, and S^1, S^2 are the vector dimension.

4) SVM

Two different algorithms are used in SVM for pattern classification and nonlinear regression. Therefore, the predicting algorithm based on nonlinear regression is briefly introduced here: 1) Selecting training and testing sets respectively before data processing. 2) For getting the optimal parameters, the training set makes cross-validation by using different parameters from grid search. 3) Training the SVM network by using optimal parameters. 4) The trained SVM makes process of regression forecast by training set and getting forecast result.

B. *Parameters optimization*

There is no effective theoretical guidance on the selection of the node number in the hidden layer of BPN, WNN and ELMAN neural network methods. If the node number η is less, it will not make full use of the training set and the learning ability. The sequent problem is that the neural network method cannot complete the accurate stock prediction task. However, if the node number η is too large, the neural network will be trained over-action, and deteriorate the ability of generalization and stock prediction. In addition, the learning rate μ has a great influence on the performance of neural network. For example, it is difficult to converge to the acceptable extent if μ is large, and it is easy to converge to the local minima if μ is too small because of the mechanism of validation check.

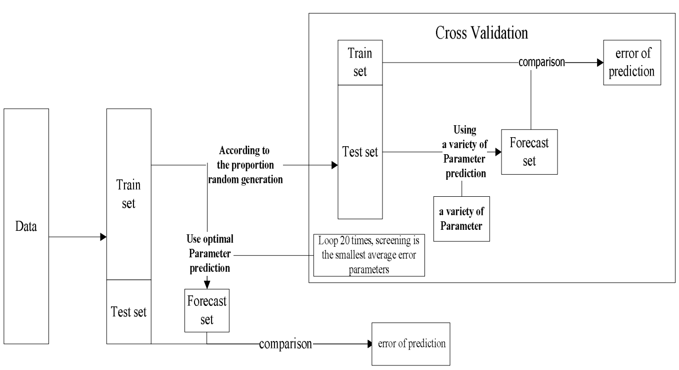

Fig.4 the process of optimization parameters

To deal with the above phenomenon, we will find the optimal parameters by using cross validation and grid search method during the experiments as shown in Fig. 4. The initial learning rate μ is set to the range [0.01, 0.1], while the node number η is set to the range [4, 12] in the hidden layer of neural networks. The data set is randomly divided into training set and testing set following by the process of the cross validation. The original training set makes the stock prediction by selecting different η and μ. And then get the right parameters η and μ with the smallest average error from above 20 processes.

Fig. 4 shows the algorithm in details about the process of parameter optimization in BPN, WNN and ELMAN. The result using BPN is shown as error surface diagram and error contour diagram in Fig. 5.

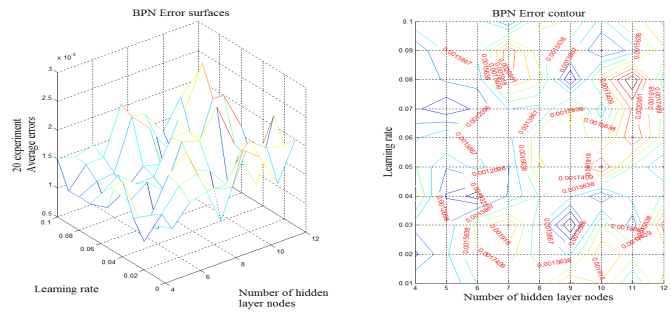

Fig.5 the result of BPN

In BP neural network, different learning rate μ and the nod number in the hidden layer conducts different corresponding error. Based on the data of stock (SANY 600031), the right parameters η and μ can be selected as 9 and 0.03, with which having the smallest error. The stock prediction results are given in Fig. 6 with three different parameters, with which get the best, ordinary, and worst prediction. In ELMAN and WNN neural networks, the learning rate μ and the nod number in the hidden layer have the same effect as in BP neural network. The explanation is omitted here.

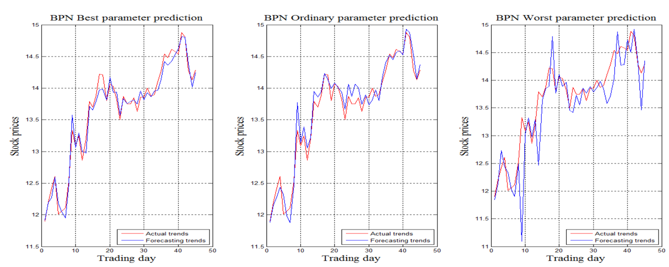

Fig.6 the result of different parameters in BPN

In SVM neural network, the optimization parameters on penalty parameter c and kernel function parameter g can be obtained by using the method described in Section II. 4).

During the parameter selecting process, in order to be sure the penalty parameter c being small enough to avoid the over learning of the neural network, two times of the processes are conducted with the rang $[2^{-5}, 2^{5}]$ first following by the rang $[2^{-3}, 2^{3}]$. Fig. 7 shows the training results as error surface diagram and error contour diagram using SVM. Based on the data of stock (SANY 600031), the right parameters c and g can be selected as 2 and 0.35335, with which having the smallest error.

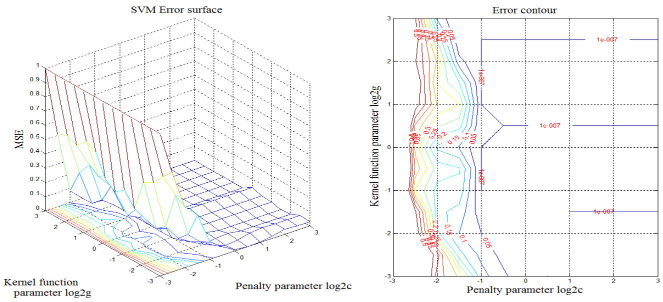

Fig.7 the result of SVM

The stock prediction results using SVM neural network are given in Fig. 8 with three different parameters, with which get the best, ordinary, and worst prediction.

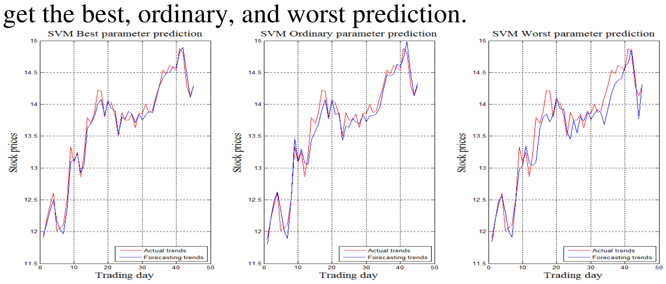

Fig.8 the result of different parameters in SVM

III. The Results and Analysis

In this section, the source of data used in the experiments, the experimental results, and the analysis of results are introduced.

A. *The source of data*

During the experiments, the data from three representative stocks are selected, including SANY Heavy Industry (SANY 600031), China Southern Airlines (CSA 600029) and Datang Telecom technology (DTT 600198). The period of data collection is from August 1, 2011 to March 9 2012 having 145 trading days from the website [16]. The data for every stock include the opening price, the highest price, the lowest price, the closing price, trading volume and transaction volume for every day as shown in Fig. 9.

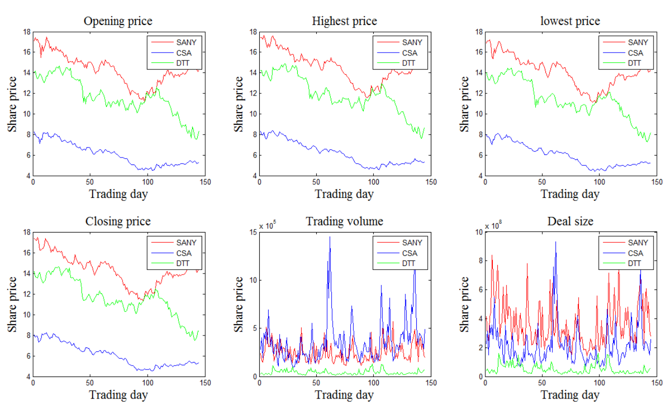

Fig.9 six index data for the selected three stocks

During the experiments, the data of one day for a stock, including the opening price, highest price, lowest price, closing price, trading volume and transaction volume are used to forecast the opening price of the next day. Therefore, the 145 sets of data are divided into two parts, one is the training group with 99 sets, and another is the test group with 45 sets. During the training process, the six index data from the 1-99 sets of a stock are used as the input data, while the opening price of the next day from the 2-100 sets are used as the desired output data. The data of the test group from the 101-145 sets are used to verify the experimental methods. The six index data from the 100-144 sets of a stock are used as the test input, and the opening price of the next day from the 101-145 set are used as the desired output, which can be used to compare with the actual output of the used methods.

B. *The results of experiments*

During the experiments, based on the data of the stock (SANY 600031), after the training process and the parameter optimization process, the optimal parameters of the different methods are given in Table 1.

Table 1. the optimal parameters of the different methods

Method	The number of nodes η（penalty parameter c）	Learning rate μ（kernel function parameter g）	The smallest average error
BP	9	0.03	6.7832e-004
Elman	8	0.04	3.3248e-005
WNN	11	0.02	3.6863e-005
SVM	2	0.35335	2.0181e-005

Four different methods (BPN, ELMAN, WNN, SVM) are checked using the test data from the 101-145 sets of three stocks (SANY, CSA, DTT). Fig. 10 shows the prediction results (blue lines) comparing with the desired results (red lines). The three lines of diagram represent the results for stock SANY, CSA, and DTT respectively. The four columns of diagram represent the used method BPN, ELMAN, WNN, and SVM respectively.

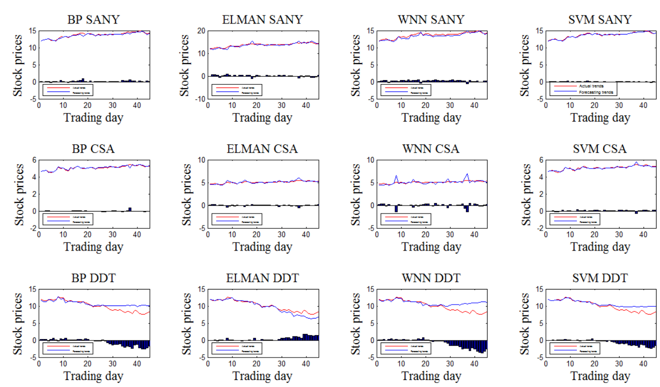

Fig.10 the predictions of different stock in optimal parameters

C. *The analysis of results*

Because the cross-validation method is used to get the optimal parameters, the influence of various parameters to the performance of neural networks is reduced. From the experimental results as shown in Fig. 10, it is obvious that four methods have good results to predict stocks SANY and CSA. Among these methods, SVM method is the best one for forecasting. WNN method has better results for stock SANY than that for stock CSA. Actually the price of SANY changes frequently while the price of CSA keeps smooth. This shows that WNN method is good at predicting the stocks, whose movement trend change frequently.

From the last line of the diagrams in Fig. 10, it can be seen that the four methods make poor performances on the forecasting for stock DDT, especially after the 25th trading day. After the carefully analyzing this situation, the reason is the training data not enough, and the data rang not covering the prediction area. To solve this problem, more training data with large range are required. Even in this situation, ELMAN method has a better result than other methods because of the existence of feedback mechanism.

Although SVM has outstanding performance on the prediction with regard to accuracy, the prediction on nonlinear regression takes long time. This is because that SVM must run the process of cross-validation and grid search to finish the optimization parameters, while other methods can select appropriate parameters based on experience. Usually, SVM method is the most time-consuming method especially with a large number of samples.

General speaking, for anyone of the four methods, the accuracy of predictions would be improved by changing the model of input using more than one day's data. However, to focus on the memory ability of the four methods, and to simplify the comparison standards, only one day's data are used in this paper.

IV. Conclusions and Future Work

In this paper, four neural-network-based models (BPN, ELMAN, SVM, and WNN) are introduced to predict stock price, while the cross validation method is combined to find the optimal parameters in these four methods. Experiments with three different kinds of stocks are conducted to verify these four methods. The comparing results between these methods are summarized here: SVM method has the best performance with regard to accuracy among the four methods, but it is the most time-consuming method. BPN method has simpler topology structure and transmission functions comparing with WNN and ELMAN methods, so it has higher efficiency. WNN method has high accurate result when the stock trend change frequently, and has some mistakes when the stock price keeping smooth. ELMAN method has better results than other methods when the training samples are limited.

The topology, learning algorithm and the transmission function play important roles in the prediction methods. Another important factor is parameter, which has great influence on the prediction performance. In this paper, the cross-validation and grid search methods are used in the network training process to get the optimal parameters. Using the prediction methods with optimal parameters, we can get much better prediction results.

The optimal parameters are obtained by the method of grid search and cross-validation. It is easy to search in the small-scale two-dimensional zone by this method, but it is impossible to search in a large-scale multi-dimensional zone. Therefore, the improvement on parameter optimization is the future work. Our study will focus on reducing the randomness of the parameters and making faster and more efficiently to find the optimal parameters.

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