Short-term Prediction for Opening Price of Stock Market Based on Self-adapting Variant PSO-Elman Neural Network

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Abstract—**Stock price is one of intricate non-linear dynamic system. Typically, Elman neural network is a local recurrent neural network, having one context layer that memorizes the past states, which is quite fit for resolving time series issues. Given this, this paper takes Elman network to predict the opening price of stock market. Considering that Elman network is limited, this paper adopts self-adapting variant PSO algorithm to optimize the weights and thresholds of network. Afterwards, the optimized data, regarded as initial weight and threshold value, is given to Elman network for training, accordingly the prediction model for opening price of stock market based on self-adapting variant PSO-Elman network is formed. Finally, this paper verifies that model by some stock prices, and compares with BP network and Elman network, so as to draw the result that shows the precision and stability of this predication model both are superior to the traditional neural network.**

Keywords—Self-adapting variant PSO；Elman network；stock market prediction；MATLAB

I. INTRODUCTION

In the financial world, stock market prediction is an unfailing research subject. Meanwhile, the opening price always fluctuates significantly due to many factors. Thus, the stock market can be considered as an intricate non-linear dynamic system as well, which is hard to reveal the inherent law by traditional methods. However, the modeling approach of Artificial Neural Network (ANN) built by black box theory has great non-linear mapping capability, so that this approach is well suited for analyzing and predicting the stocks.

Taking no account of external factors, this paper predicts the next stock price by using the short-term stock price of the past, this is equivalent to a dynamic time series problem, but the static feed forward neural network is not appropriate for resolving these problems.[1]

Elman neural network has a context layer, and it is a dynamic system with feedback ability. This kind of network can reflect the change of dynamic system directly and also has strong computing power. For this reason, this paper decides to use Elman network to predict the opening price of stock market. However, traditional Elman network trains the network by utilizing gradient-descent algorithm, so the convergence velocity is slow, which causes defects occur, like local minimum. That is to say, if self-adapting variant PSO is used, deficiencies of Elman network can be made up by global optimization.[2] Eventually, the self-adapting variant PSO-Elman neural network model is built to forecast the short-term opening price of stock market.

II. ELMAN NEURAL NETWORK

Elman neural network is divided into 4 layers: input layer, hidden layer, context layer and output layer. The structure figure of network model is shown as Figure 1. Three layers of Elman network, including input layer, hidden layer and output layer, have similar connection mode to feed forward neural network, and both have same function too. The context layer can be considered as a one-step time-lapse operator, mainly used for memorizing.

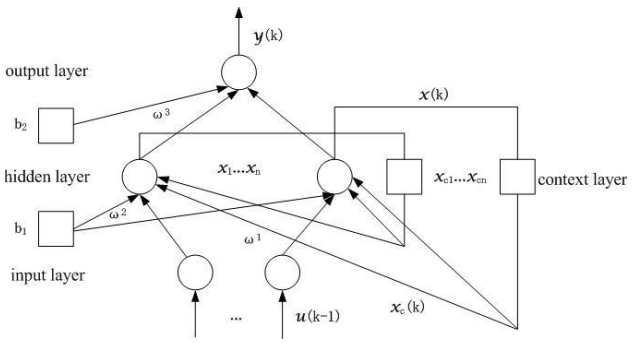

Fig.1. Structure of Elman Network Model.

In non-linear state space, formulas of Elman network are：

$$\boldsymbol{y}(k) = g\left(\omega^3 \boldsymbol{x}(k)\right) \quad (1)$$

$$\boldsymbol{x}(k) = f\left(\omega^1 \boldsymbol{x}_c(k) + \omega^2\left(\boldsymbol{u}(k-1)\right)\right) \quad (2)$$

$$\boldsymbol{x}_c(k) = \boldsymbol{x}(k-1) \quad (3)$$

u is r-dimensional input vector, x is vector of n-dimensional hidden layer, y is m-dimensional output node vector, x_c is n-dimensional feedback vector, ω^3 is the connection weight from

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hidden layer to output layer, ω^2 is the connection weight from input layer to hidden layer, ω^1 is the connection weight from context layer to hidden layer; $g(*)$ is the transfer function of output neurons, it is linear combination of output from hidden layer, and $f(*)$ is the transfer function of neurons hidden layer neurons, generally, Sigmoid function is used.[3]

Elman neural network's feedback system differs from static feed-forward neural network's. To put it simply, its output from hidden layer is sent back to the input of hidden layer via the delay and storage of context layer, the whole process makes the system sensitive to historical data. This paper actually forecasts the opening price of stock market according to the historical data, so that this characteristic matches the modeling method this paper proposed very much.[4] Furthermore, the dynamic information processing capacity of network is heightened after internal feedback network added, which achieve the purpose of dynamic modeling. All these situation show Elman network is good to predict the short-term opening price of stock market.[5] Besides that, Elman network can approach arbitrary nonlinear mapping with arbitrary precision. It models the system when the input and output data of system are given.

III. SELF-ADAPTING VARIANT PSO

In a D- dimensional searching space, If n particles form a species $\mathrm{X} = (\mathrm{X}_1, \mathrm{X}_2, \ldots \mathrm{X}_\mathrm{n})$, the position of i^{th} particle is represented by a D-dimensional vector $\mathrm{X_i} = [\mathrm{x_{i1}}, \mathrm{x_{i2}}, \ldots \mathrm{x_{iD}}]^\mathrm{T}$, meanwhile, this means one potential solution of problem. The i^{th} particle's velocity is $\mathrm{V_i} = [\mathrm{V_{i1}}, \mathrm{V_{i2}}, \ldots, \mathrm{V_{iD}}]^\mathrm{T}$, its individual extremum is $\mathrm{P_i} = [\mathrm{P_{i1}}, \mathrm{P_{i2}}, \ldots, \mathrm{P_{iD}}]^\mathrm{T}$, and global extremum of species is $\mathrm{P_g} = \left[\mathrm{P_{g1}}, \mathrm{P_{g2}}, \ldots, \mathrm{P_{gD}}\right]^\mathrm{T}$.[6]

When optimizing every time, particle has to update its velocity and position by individual and global extremum, and the update formulas are:

$$V_{id}^{k+1} = \omega V_{id}^{k} + c_1 r_1 \left(P_{id}^{k} - X_{id}^{k}\right) + c_2 r_2 \left(P_{id}^{k} - X_{id}^{k}\right) \quad (4)$$

$$X_{id}^{k+1} = X_{id}^{k} + V_{id}^{k+1} \quad (5)$$

in formula: k is the number of iterated times; ω means inertia weight; $\mathrm{d} = 1,2, \ldots, \mathrm{D}$; $\mathrm{i} = 1,2, \ldots \mathrm{n}$; $\mathrm{V_{id}}$ means particle velocity; c_1 and c_2 is non-negative constant that is called acceleration factor, generally obtained in accordance with the actual situation; r_1 and r_2 is random number among interval$[0,1]$.[6-7]

When algorithm is operating, some of particles may find the suspected optimal position, enabling the other particles draw closer to them fast, which causes algorithm is trapped in local optimum and premature convergence probably occur, as the result, the algorithm cannot re-search in searching space. Taking example by the variant thought emerged from genetic algorithm (GA), introduced variant operation in the PSO algorithm, two formulas of particles updating their velocity and position tell that the next particle position is be determined by both the current position and velocity, displacement distance depends on the velocity, and moving direction of particle is based on the speed direction. That means the velocity is main influenced by factor ω, so that these variables will be reinitialized with certain probability. When iterating, the algorithm narrow the searching space of species, while the variant operation can jump out of the optimal position it searched before, and start to search in bigger space, increasing the chances that the algorithm finds out better value. Therefore, after simple variant operator is introduced based on general PSO algorithm, the self-adapting variant PSO algorithm is formed.[6]

IV. BUILD THE SELF-ADAPTING VARIANT PSO-ELMAN MODEL

Without the other economic indicators, this paper forecasts the opening price of stock market only based on the short-term opening price of the past, the next opening price is predicted by the previous N periods of the opening price.[1] Thus, it can be represented as a mapping function:

$$x_n = f(x_{n-1}, x_{n-2}, x_{n-N}) \quad (6)$$

As for the 340 given data, all of them are divided into the training samples and test samples at first, the measure of division is: extract $x_1 \sim x_N$ to form the 1st sample. In this sample, its independent variable is $(x_1, x_2, \ldots, x_{N-1})$, objective function value is $\mathrm{x_N}$; and to extract $x_2 \sim x_{N+1}$ to form the 2nd sample, and its independent variable is $(x_2, x_3, \ldots, x_N)$ while the objective function value is x_{N+1}; finally, the following matrix is formed:

$$\begin{bmatrix} x_1 & x_2 & \cdots & x_i \\ x_2 & x_3 & \cdots & x_{i+1} \\ \vdots & \vdots & & \vdots \\ x_{N-1} & x_N & \cdots & x_{N+i-2} \\ x_N & x_{N+1} & \cdots & x_{N+i-1} \end{bmatrix}$$

every column is considered as a sample, the last row is considered as expected output. This paper set N=8, so a 9×322 matrix is generated, and selected 273 columns as the training data, and the last 59 columns are set as the test data.

The method of building a Self-adapting Variant PSO-Elman Neural Network Model:

Step 1: Standardize the input and output samples of neural network;

Step 2: Confirm Elman network structure according to the output and input parameters, after that the particle length of PSO algorithm is ascertained.

Step 3: Encode all the weights and thresholds in the Elman network structure. If the network contains X weights and thresholds, at the same time, the initial particle swarm will be represented by X-dimensional vector composed of X weights and thresholds.

Step 4: Set the sum of predicted error absolute values as the value of individual fitness, then, the individual and global extremum are obtained according to the fitness value;

Step 5: Judge whether the global extremum meet the end conditions of PSO algorithm or not. If it meets, then quits the PSO optimizing and goes to Step 6; if not, it updates the speed and position of particles and goes back to Step 4.

Step 6: Decode the particle of global extremum, and take that as Elman network's weights and thresholds. Re-train the network model, and use the trained one to run prediction operation.[8-9]

Due to N=8, that means the next opening prices is predicted by the opening prices of previous 8 terms, thus, neurons number of input layer is set as 8, and neurons number of output layer is 1; after multiple tests, it finds that when neurons number of hidden layer is set as 20, the mean square error of system is minimum. Therefore, the neurons number of hidden layer is 20.

Because Elman network structure is 8-20-1, it has $8\times20+20\times1=180$ weights, and $20+1=21$ thresholds, so that the particle length of PSO algorithm is $180+21=201$, and the species scale is set as 30, iterative times of algorithm is 1000, $c_1=c_2=2$, $V_{max}=1$, $V_{min}=-1$, the individual maximum value $pop_{max}=1$, the individual minimum value $pop_{min}=-1$.

When confirmed the condition that Elman network structure is 8-20-1, this paper uses the optimization algorithm of self-adapting variant particle swarm to optimize the weights and thresholds of network. The optimized best weights and thresholds is given to Elman neural network, which are regarded as the initial values to train the network. Afterwards, the short-term prediction model of opening price based on the self-adapting variant PSO-Elman neural network is going to be built.

V. Network Predictive Result

The model is verified by software MATLAB 2014b.[10] The mean square error between network predictive output and true value of share price is mse= 0.0879615 and the comparison of predicative results are shown as Figure 2.

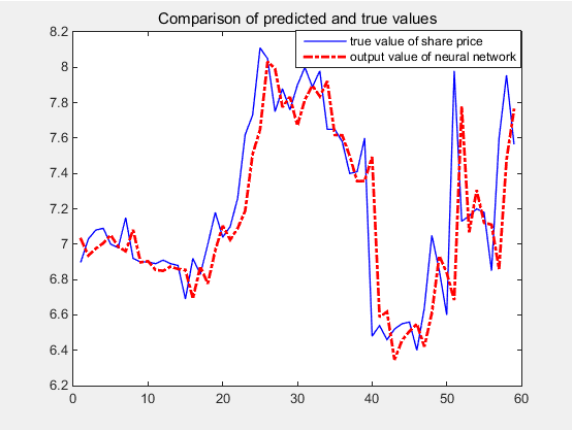

Fig.2. Comparison of Predicative Result.

As shown in Figure 2, basically network predictive value and the true value of share price show the same change trend; and predictive curve relatively fits the true value curve, this situation means precision of predictive result is high, and the network performance is great.

The error between the network predictive output and the true value of share price is shown as Figure 3. As shown in Figure3, except that a few of result errors are larger, the other shows smaller errors. Compared with Figure 2, it is easier to find that the point with larger error always exists at the part of share price trend changing greatly.

For comparing the performance of self-adapting variant PSO-Elman neural network model, this paper also adopts BP neural network and Elman network to predict the same samples at the same time. The Mean Square Error (MSE) and mean absolute error (MAE) of 3 network models are shown in the Table 1.

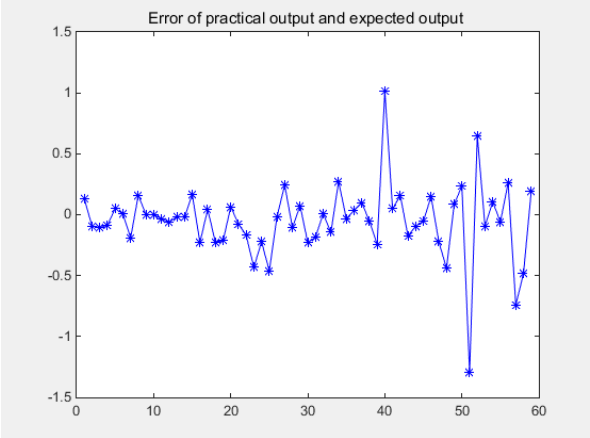

Fig.3. Prediction Result Errors.

TABLE I. Error Comparison of 3 Networks

Network Model	Mean Square Error	Mean Absolute Error
BP Network	0.0947893	2.951521
Elman Network	0.0893256	1.599670
PSO-Elman Network	0.0879615	1.541107

It can be seen from the table that the MSE and MAE of the self-adapting variant PSO-Elman neural network model are less than the BP neural network and the Elman neural network, and compared with the BP network, the superiority of this model is obvious. The MSE and MAE of this model meets the requirements of practical application, the experimental results are relatively ideal.

VI. Conclusions

This paper uses the self-adapting variant PSO-Elman neural network to predict the short-term opening price of stock market. If this model is used to predict when there are no significant fluctuations in stock market, the result is quite accurate. This shows that the performance of this model is good. This paper also brings BP network and Elman network to predict the same data set and compare its results. It turns out that the error of BP network is large, the error of the Elman network is slightly larger than the model this paper proposed, but the advantage is not obvious, it means that the complexity of this data set is low, the advantages of this model cannot be fully demonstrated. If the data sets with more independent variables are used, the superiority of the self-adapting variant PSO-Elman neural network model can be fully proved.

The experiments have proved that self-adapting variant PSO-Elman neural network has good fault tolerance, which provides great predictive effect for the opening price of stock market. Therefore, it has good guiding significance for practical application.

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