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New Neural Network Based on Ant Colony Algorithm for Financial Data Forecasting

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Abstract

The financial system is generally a very complicated system. So, it is very hard to predict its data. For example, it is a hard work to forecast the stock market. Here, from analyses the mathematic description of stock market system, a new forecasting method based on new evolutionary neural network is proposed here. In this new evolutionary neural network, the traditional BP algorithm and a new bionics algorithm-immune continuous ant colony algorithm proposed by author is combined. In order to verify this new prediction method, the stock market data of Shanghai market in 1996 is used. The results show that, our new method is very good to real practice.

1. Introduction

The stock market is a very complicated dynamic system. Big disturbance, serious non- linearity and blindness of investor all make the stock market prediction very complicated and very hard. So, how to forecast stock market very well is a very interesting problem for researchers and security analyzers.

To forecast stock market, we must acknowledge that, there are some basic laws that can be repeated in stock market [1]–[2]. And those laws are hided in history data. From mathematic aspect, those laws are function relationship. The object of prediction is to find those laws, and describe them. The prediction of non-linear dynamic system can be transformed to the problem of time series prediction. The previous studies show that, to forecast non-linear time series, the neural network is a very good method [3]. So, neural network is a very good method to forecast stock market. Nowadays, there are some researches on this field [4]–[6], but in those studies, the stock market can not be analyzed from mathematic aspects, and so the mathematic base of those the methods can not be revealed. So, to do this study better, firstly, the mathematic description of stock market has been founded. And based on this mathematic description, one new method with new evolutionary neural network is proposed. At last, this new method is applied in real stock market of Shanghai. And the results show that, this new method is a very good one.

2. Mathematic description of stock market

To a dynamic system, its evolvement can be described by differential equations.

$$\frac{d^p x}{dx^p} = f(x, x', \cdots, x^{(p-1)})$$

If one state variable of this process is the solution of above equation, then the dynamic system can be modeled by some time series of this variable.

$$\frac{d^2 x}{dt^2} = f(x, \frac{dx}{dt})$$

Supposing the solution of above equation is a time series with step h, $x(j), j = 1 \sim n$, and then the model of system can be made with the numerical solution of above ordinary differential equation.

The solution of differential coefficient at j in above equation is replaced by difference as follows.

$$\frac{d^2 x}{dt^2}\Big|_j = \frac{x(j+1) - 2x(j) + x(j-1)}{h^2} + o(h^2)$$

$$\frac{dx}{dt}\Big|_j = \frac{x(j) - x(j-1)}{h} + o(h)$$

So, we can get the follow function.

$$x(j+1) = h^2 f[x(j), \frac{x(j) - x(j-1)}{h}] + 2x(j) - x(j-1) + o(h^3)$$

The high order minim in above function is retrieved. The above function can be described as follow general function.

$$x(j+1) = F[x(j), x(j-1), h]$$

The above function is generalized to p-th order, the follow function can be gotten.

$$x(j+1) = F[x(j), x(j-1), \cdots, x(j-p+1), h]$$

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The main aspect of above function is to confirm the function relationship *F*. For the non-linear transferring function applied in neural network, the complicated non-linear problem can be solved very well by neural network.

3. Evolutionary neural network for stock market prediction

To construct a neural network model for stock market, the construction of neural network is the main problem to be solved. Because for this problem, the hidden layer construction and input layer construction all can be confirmed. This problem can be solved by evolutionary algorithm very well. Here, as a primary study, the evolutionary neural network which construction is confirmed by evolutionary algorithm and which weight is confirmed by MBP algorithm is proposed. To make problem simpler and generalization bigger, the three layers neural network is studied. So, here, only the number of input neuron and number of hidden layer neuron are to be confirmed. In MBP algorithm, there are two parameters, iterating step η and inertia parameter α, to be confirmed. And then, in evolutionary neural network, there are four parameters to be evolved.

Nowadays, a lot of evolutionary neural networks (ENNs) have been proposed [7]–[8], but in those ENNs, users must only use their experiences to estimate some parameters that have strong relation with the performance of ENNs, which makes the robustness of ENNs very poor.

To get a kind of good ENN, here the immune continuous ant colony algorithm [9] proposed by author is introduced and one new kind of ENN is proposed.

3.1. Immune continuous ant colony algorithm

Ant colony algorithm is a new evolutionary optimization algorithm from mimic the behavior of ant colony, and proposed by Italy scholar M. Dorigo in 1990's [10]. The original intention of ant colony algorithm is to solve the complicated combination optimization problems, such as TSP, so the traditional ant colony algorithm is a very good combination optimization method. According to the information cooperation of ant colony, the continuous optimization method based on principles of ant colony should be feasible. Based on above thought, some continuous ant colony algorithms have been proposed [10]–[12]. To improve the continuous ant colony algorithm, the immune continuous ant colony algorithm is proposed.

The main operations of immune continuous ant colony algorithm are as follows.

3.1.1. Probability move of ant individual. The probability move of ant individual is the key operation of algorithm. Its move probability can be expressed as follows.

$$P_{ij} = [\tau_j]^{\alpha}[\eta_{ij}]^{\beta} \Big/ \sum_k [\tau_k]^{\alpha}[\eta_{ik}]^{\beta}$$

where, τ_j is hormone intensity of ant individual. At initial stage, it is a constant, which is $\tau_0 = c$. In this study, we take $c = 0.001$. τ_j is related with $f(i)$ through $\Delta\tau$. $\eta_{ij} = f_i - f_j$, which express the modification quantity of objective function after the ant individual moves. When $f_i = f_j$ is occurred, the movement should be repeated, until they are not equal. The α and β are two variables, which ranges are as follows, $1 \le \alpha \le 5$, $1 \le \beta \le 5$. Here, we take, $\alpha = 1$ and $\beta = 5$.

3.1.2. Mutation operation and Selection operation. Here, adaptive Cauchi mutation and immune selection in reference [13] is used.

3.1.4. Hormone update operation. After the above operations, the hormone information of new ant colony must be updated. The method of hormone update can be expressed as follows.

$$\tau_j^{new} = \rho \cdot \tau_j^{old} + \sum_k \Delta\tau_j^k$$

where, ρ is volatile rate of hormone, which can be taken as about 0.3. $\Delta\tau_j$ is residual quantity of hormone. $\Delta\tau_j$ can be expressed as follows.

$$\Delta\tau = \begin{cases} Q & \text{ant moved along pathway } ij \\ 0 & \text{otherwise} \end{cases}$$

where, Q is a constant.

At start, the quantity of hormone is taken as a constant, which is *c*.

The optimal combination of parameters, which are Q, c, α, β, ρ, generally can be confirmed by trial method [10]. Apparently, these parameters can be confirmed by other optimization methods, such as evolutionary algorithm.

3.2. New evolutionary neural network

The details of new evolutionary neural network are as follows.

(1) The search range of input neuron and hidden layer neuron are given firstly. And also the search range of two parameters in MBP algorithm are given. And some evolutionary parameters, such as evolutionary generation stop criteria, individual number in one population, the error criteria of evolutionary algorithm, number of output neuron in neural network, iterating stop criteria and iterating error criteria in MBP algorithm are all given.

It must be pointed out that, to construct the suitable samples, the number of input neuron must be smaller than total number of time series.

(2) One network construction is generated by two random numbers in search range of input neuron and hidden layer neuron. And also, one kind of MBP algorithm is created by two random numbers in search range of parameters η and α . And then, one individual can be generated by the four parameters.

(3) To one individual, its fitness value can be gotten by follow steps.

a. The whole time series of stock market is divided to construct the training samples based on number of input neuron and number of hidden layer neuron. And also, the total number of samples is noted.

b. The whole learning samples are to be divided into two parts. One part is the training samples, which is to get the non-linear mapping network. The other part is the testing samples, which is to test the generalization of network.

c. The initial linking weights of network individual are generated.

d. The iterating step of MBP algorithm is taken as $j = 1$.

e. This network individual is trained by testing samples, and the square error *E*(*j*) is computed, and this error is taken as minimum error of the whole training, $\min E = E(j)$. If min*E* is smaller than the error criteria of evolutionary algorithm, then the fitness value is min*E*. And the computing process is changed to step (3).

f. This network individual is trained by training samples. If its training error is smaller than iterating error criteria of MBP algorithm, then the fitness value is also the min*E*. And the computing process is changed to step (3).

g. The whole linking weights are adjusted by MBP algorithm.

h. $j = j + 1$, and the computing process is changed to step *e*.

i. If *j* is lager than iterating stop criteria of MBP algorithm, then the fitness value is also the min*E*. And the computing process is changed to step (3).

(4) If the evolutionary generation reaches its stop criteria or computing error reaches error criteria of evolutionary algorithm, then the algorithm stop. At this time, the best individual in last generation is the searching result.

(5) The probability move operation is done to every ant individual.

(6) Every individual in population is mutated. For there are different data types in one individual, the different mutation types are used for each parameter. For numbers of input neuron and hidden layer neuron are integer number, the uniform mutation is used. For parameters η and α are real numbers, the adaptive Cauchi mutation is used. And then the offspring population is generated.

(7) The set of offspring population and parent population is selected by selection operation based on thickness, then the new offspring population is generated.

(8) The fitness value of each individual in offspring population is calculated by the method in step (3).

(9) The hormone update operation is implemented.

(10) The number of evolutionary generation increases 1, then the computing process is changed to step (4).

From the above algorithm, the four parameters, number of input neuron, number of hidden layer neuron, two parameters η and α in MBP algorithm can be confirmed. So, the optimization neural network for stock market forecasting will be gotten.

4. Real example

To verify the above algorithm, the stock market of Shanghai in 1996.3-1996.6 is used. In this example, the time series of 53 stock index and daily turnover is used, which is showed in follow figure 1 and 2.

The stock index data time series and daily turnover data time series are taken into our algorithm. In two time series, the 48 teams data is used for computation, and while 5 teams data is for forecasting. In the 48 teams computation data, 30 teams is training samples, and the other 18 teams is testing samples.

After computation, we will know that the best neural network construction for stock index forecasting is 7-13-1, and for daily turnover is 9-21-3. With those neural networks, the forecasting results are showed in figure 1 and figure 2.

From two figures, we can conclude that, using our evolutionary neural network algorithm for stock market forecasting, not only the approximation is good, but also the forecasting is satisfactory. So, our algorithm is a good method for stock market forecasting.

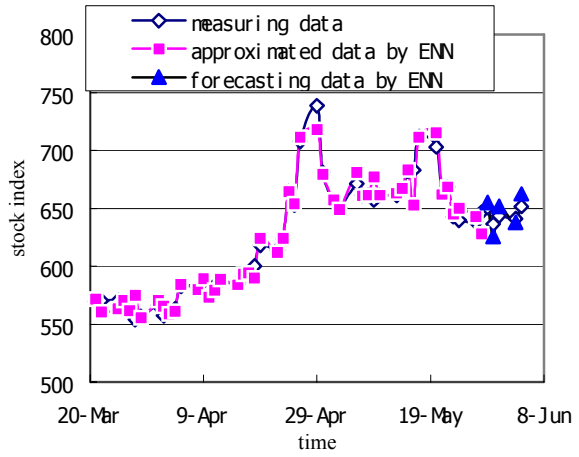

Figure 1. Stock index data time series

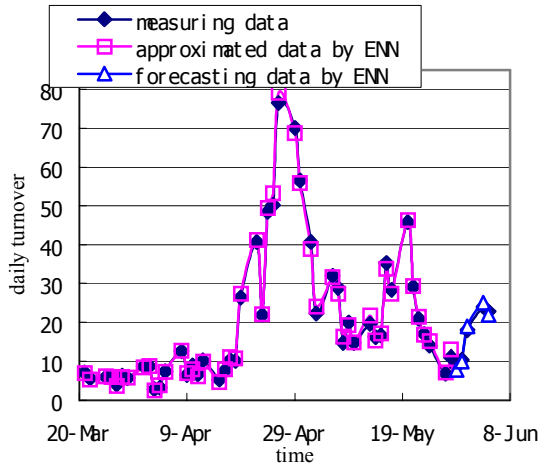

Figure 1. Daily turnover data time series

5. Conclusions

Stock market is a very complicated dynamic system affected by many factors. It has very important theory and real meaning for stock investment and market manage for stock market forecasting. In this paper, the development law of stock market is described mathematically, and one new method for stock market forecasting based on new evolutionary neural network is proposed. At last, this method is verified by real stock market data of Shanghai market in 1996. The results show that, our new algorithm is a very good method for stock market forecasting, and can be used in real practice.

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