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Stock price prediction model based on modified IWO neural network and its applications

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ABSTRACT

For the deficiency of easily trapping into a local optimum of neural network learning algorithm based on steepest descent method, we apply a new kind of optimization strategy called invasive weed optimization (IWO)algorithm, where the standard deviation of the distribution of offspring individuals adjusts dynamically, and a feed-forward neural network learning algorithm based on IWO is given. Considering the phenomena of optimization accuracy being not high and precocious in IWO algorithm, further we use IWO algorithm to search globally, meanwhile searching locally by utilizing reflection, extension and compression operation of complex to create a new solution for replacing the worst individual in current population, and propose a complex invasive weed optimization (CIWO) algorithm, which avoids precocious phenomenon, improves precision of optimization and increases the speed of convergence. On this basis, neural network prediction models based on IWO and CIWO algorithm are respectively established, the feasibility of IWO algorithm training the neural network and the validity of improving the IWO algorithm with complex method are verified by stock price forecasting.

KEYWORDS

Invasive weed optimization; Complex Invasive weed optimization; Feed-forward neural network; Prediction model.

INTRODUCTION

Currently, the stock is very close to human's daily life, how to predict stock prices exactly becomes a hotspot topic[1], however, traditional prediction methods were always based on linear model, and they couldn't analyze and fit stock price very well, leading to affection for accuracy of prediction[2]. With the development of modern intelligent prediction technology, the nonlinear fitting ability of neural network was widely used[3], but the standard BP neural network algorithm was based on local search algorithm of gradient descent, which could not be used to search the global minimum points of multimodal function, it had high requirements to the functions, the disadvantages of slow speed of convergence, easily trapping into local minimum and low robustness and so on[4,5]. In order to overcome these deficiencies, some intelligent optimization algorithm such as genetic algorithm, evolutionary algorithm, simulated annealing algorithm, particle swarm optimization algorithm, ant colony algorithm, chaos optimization algorithm, artificial immune algorithm were tried to train the feed-forward neural network.

IWO was a new intelligent optimization algorithm, which was evolved from the evolution principle of weeds in nature. This algorithm mimicked the basic process of spatial dispersal, growth, reproduction and competitive exclusion of weed colonizing and it had a strong adaptation and robustness[6]. In IWO, the group evolution was guided by the outstanding individual in the population, the offspring individuals were distributed around parent individuals with a normal distribution during the evolution process, and the standard deviation of normal distribution adjusted and changed dynamically with the evolution generation, and this had made the algorithm keep the diversity of population in the early and middle evolution period, and overcame the phenomenon of premature convergence. In the later period, the local search ability of outstanding individual became stronger and stronger, which ensured the algorithm approximate steadily the global optimal solution with higher accuracy. By comparing IWO algorithm with the simple particle swarm algorithm, IWO did not need too large storage space to save the track of particle; By comparing it with genetic algorithm, the structure of the algorithm was more simple and it was easy to realize, and it did not need the selection operator, crossover operator and mutation operator which were used in genetic operations, and could quickly and efficiently converge to the optimal solution of the problem. Therefore, IWO algorithm is tried to apply into the training of feed-forward neural network to solve the problems of basic BP algorithm and a neural network learning algorithm based on IWO algorithm is given, and then a practical simulation of stock price prediction is carried out, the feasibility and validity are verified by comparing it with the standard BP algorithm.

Nevertheless, as IWO algorithm itself also has defect of easily trapping into local optimum and low accuracy of optimization in later period, which greatly influences the speed and accuracy of forecasting. In view of the phenomena of optimization accuracy being not high and precocious in IWO algorithm, an algorithm with complex method guiding the search for IWO algorithm is proposed, which is called CIWO algorithm. After each iteration of IWO, the algorithm uses individuals which are about to enter the next generation to construct the complex, utilize the centroid of the complex to create a new solution for replacing the worst point in the complex through reflection, stretching and contraction operation, making the complex being near to the optimal point continuously. In this way, IWO ensures the species diversity of individuals in population, and the complex method improves the precision and speed of optimization, achieving the effect of complementary advantages. A neural network learning algorithm based on CIWO algorithm is given, and a neural network prediction model based on this learning algorithm is established. The validity of improving the IWO algorithm with complex method is verified by practical simulation of stock price forecasting.

IWO-NN PREDICTION MODEL AND CIWO-NN PREDICTION MODEL

Feed-forward neural network

The prediction refers to estimating values for unknown future data by some known historical data. Assuming that a time series $\{x_i\}$, among which the historical data is $x_n, x_{n+1}, \cdots, x_{n+m}$, we want to predict the value at time $n+m+k(k>0)$, namely predicting nonlinear function relationship x_{n+m+k} at time $n+m+k(k>0)$, where the function relationship is $x_{n+m+k}=f(x_n,x_{n+1},\cdots,x_{n+m})$.

We use the feed-forward neural network to predict, that is we use neural network to fitting function f by a set of data points $x_n,x_{n+1},\cdots,x_{n+m}$ and get the predicting value at future time $n+m+k(k>0)$.

The feed-forward neural network is a common artificial neural network model, which has processing units of several connected layers, where each neuron in one layer is connected to every neuron in next layer, and there is no feedback in the network. In this paper, a three layer network is considered, which is widely used, and the output layer is a linear layer, and the nonlinear effect function (the activation function) of neurons in hidden layer is a hyperbolic tangent function ($\tan-sigmoid$):

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

It is assumed that the output of neurons in input layer is $P^i=(p_1,p_2,\dots,p_R)$, $\{w1_{i,j}\}$ is the connection weights of input layer to hidden layer, $\{b1_{i,1}\}$ is the threshold value of neurons in hidden layer, $\{w2_{i,k}\}$ is the connection weights of hidden layer to output layer, and $\{b2_{i,1}\}$ is the threshold value of neurons in output layer. The mapping of input to output of network is:

$$y_k=\sum_{i=1}^{S_1}w2_{i,k}\sigma(\sum_{j=1}^{R}w1_{i,j}\,p_j+b1_{i,1})+b2_{i,1}\quad 1\le k\le S_2 \tag{2}$$

The training sample set of the feed-forward neural network is $A=\{(P^i,T^i)\,|\,i=1,2,\cdots,s\}$, where s is the number of training samples, $P^i\in R^R$ is the input of training data in the ith group, $T^i\in R^{S_2}$ is the expectation output of corresponding input of training data in the ith group, T_k^i is the expectation output of the kth neuron in output layer. Assuming that the actual output of training data in ith group is $Y^i\in R^{S_2}$, Y_k^i is the actual output of the kth neuron in output layer, and then the error function based on the training sample set is given by:

$$E=\frac{1}{2}\sum_{i=1}^{s}\sum_{k=1}^{S_2}(Y_k^i-T_k^i)^2 \tag{3}$$

The function is a nonlinear function with various multiple minimum points, and the training process for this feed-forward neural network is adjusting the connection weights and threshold value of $\{w1_{i,j}\},\{b1_{i,1}\},\{w2_{i,k}\},\{b2_{i,1}\}$ until the error function E to minimum[7].

IWO algorithm

The convergence is one of the most important characteristics of intelligent optimization algorithm, IWO algorithm relies on the guiding information of outstanding individual for the reproduction technique in development process, which is the foundation of convergence of algorithm. The dynamic adjustment of standard deviation in offspring distribution is the key point of the convergence of algorithm. The offspring individuals are distributed around parent individuals in normal distribution, making the algorithm achieve both selection and diversity of population, and avoid the local maximum points availably so that it can ensure the stability of global convergence. The value range of the parameters is very wide, and the parameters do not highly depend on initial population. The steps of algorithm are listed below:

step1 Initialization of a population, we need determine the size P_{size} of initial population P (part of ethnic groups) and the size Q_{size} of ethnic groups Q, maximum number of iterations $iter_{\max}$, dimension of solving the problem $\dim$, maximum generated seed number $s_{\max}$, minimum generated seed number $s_{\min}$, nonlinear modulation index n, initial value of interval step σ_{init} and final value of interval step σ_{final}, $x_{\min}$ and $x_{\max}$ respectively represent minimum value and maximum value of initial search space of independent variable.

step2 Randomly generate the initial solution by initial population, initial search space of independent variable and dimension of solving the problem.

step3 Refresh the iterations and the standard deviation of normal distribution of offspring, which is calculated by

$$\sigma_{cur} = \frac{(iter_{\max} - iter)^n}{(iter_{\max})^n}\left(\sigma_{init} - \sigma_{final}\right) + \sigma_{final} \tag{4}$$

where $iter$ is current number of iterations.

step4 Reproduction. The offspring are randomly distributed around parent by normal distribution $N(0,\sigma^2)$. The calculation of the offspring individual (seed number) depends on the fitness value of offspring. The number of offspring allowed by optimal fitness individual is $S_{\max}$, and the number of offspring allowed by worst fitness individual is $S_{\min}$, other number of offspring allowed obeys a round down linear relationship with their fitness. The above reproduction technique is similar to the mechanism of weed colony in nature, and the formula of generating seeds is

$$weed_n = \frac{f - f_{\min}}{f_{\max} - f_{\min}}(s_{\max} - s_{\min}) + s_{\min} \tag{5}$$

step5 Check whether the population number is the maximum. If the population number is not the maximum, return step4.

step6 If the number of population individuals is greater than the maximum population number, compete and eliminate, the fittest is survival. Save the least fitness individuals what we mentioned above, and the specific operation is rank the parent individuals and offspring individuals according the fitness value, keep individuals with excellent fitness value to make the size of population within the maximum number of population. The operation that excellent individuals will be kept to the next generation ensures the convergence of the algorithm.

step7 Check whether the population number is the maximum. If not, repeat step4 to step6, otherwise, output the individual with the best fitness as the optimal solution.

Neural network learning algorithm based on IWO algorithm

Basic idea of training neural network based on IWO algorithm

Assuming that X is a feed-forward neural network $X = \{X_i \mid i = 1,\cdots,p\}$, where X_i is the individual in population X, and p is the number of the individuals. Every individual X_i consists of two weight matrices $\{w1_{i,j}\},\{w2_{i,k}\}$ and two threshold matrices $\{b1_{i,1}\},\{b2_{i,1}\}$, the algorithm is to find the optimal X_i in $X = \{X_i \mid i = 1,\cdots,p\}$ and the optimizing function $\min F(x)$ is the error function E (its expression is given in equation (3)). Then the error function E is optimized by IWO algorithm until satisfying the given stopping conditions[7,8].

Steps of training neural network based on IWO algorithm

step1 Randomly generate the initial solution, namely, population X, where each individual in the population is $X_i = [w1_{i,1}, w1_{i,2},\cdots, w1_{i,n}, b1_{i,1}, w2_{i,1}, w2_{i,2},\cdots, w2_{i,m}, b2_{i,1}]$[9], $n = R \times S_1$, $m = S_1 \times S_2$, R is the number of inputs neuron, S_1 is the number of neuron in hidden layer, and S_2 is the number of neuron in output layer. The initial individual number of the population is P_0, and the maximum number is Q. Calculate the fitness for each individual X_i.

step2 For the initial solution X, we determine the generated seed numbers allowed by individual X_i in equation (5), where f is the fitness, thus the evaluation function $f = \min F(x)$.

step3 According to equation (4), a new solution X_i is generated by adding a value D to the solution in each dimension, and calculate fitness for new individual, where $D \in [-\sigma, \sigma]$;

step4 If the number of the existing solution is less than Q, go to step2; otherwise, go to step5;

step5 According to the mechanism of competitive exclusion, choose Q numbers of the best fitness solutions;

step6 If $iter < iter_{\max}$, jump to step2; otherwise, exit implementation process of the algorithm and output the optimal solution, and find the individual $X_i = [w1_{i,1}{}^*, w1_{i,2}{}^*, \cdots, w1_{i,n}{}^*, b1_{i,1}{}^*, w2_{i,1}{}^*, w2_{i,2}{}^*, \cdots, w2_{i,m}{}^*, b2_{i,1}{}^*]$ with minimum fitness value in the optimal solution.

CIWO algorithm

Optimization strategy of basic IWO is just randomly initializing the individuals, generating new individuals with random step in a certain range, and then selecting individuals with good fitness. In basic IWO, individuals don't utilize the information of contemporary population, and there is no communication between individuals. In order to speed up the optimization, complex method for solving constrained optimization problems is used to deal with weeds in the iterative process. After each iteration of IWO, the algorithm uses individuals which are about to enter the next generation to construct the complex, utilizes the centroid of the complex to create a new solution for replacing the worst point in the complex through reflection, stretching and contraction operation, making the complex being near to the optimal point continuously. In this way, IWO ensures the species diversity of individuals in population, and the complex method improves the precision and speed of optimization, achieving the effect of the complementary advantages. This algorithm is called complex invasive weed optimization (CIWO) algorithm.

Complex method

In 1965, Box applied simplex method for solving unconstrained optimization problems into solving the constrained optimization problems, and the new method was called complex method[10]. Assuming that the ascending order of fixed-point of complex is $(x_1, x_2, \cdots, x_n)$, the main steps of the complex method are as follows:

step 1 Calculate the centroid x_c of complex:

$$x_c = \frac{1}{n-1}\left(\sum_{i=1}^{n} x_i - x_n\right) \tag{6}$$

step 2 Calculate the reflection point x_r:

$$x_r = x_c + \rho(x_c - x_n) \tag{7}$$

Where ρ is reflection factor, generally take $\rho = 1.3$. Whether x_r is better than x_n, and if so, replace x_n with x_r, execute extended operation (step 3); otherwise, perform contract operation (step 4).

step 3 Extended operation.

$$x_e = x_r + \gamma(x_r - x_c) \quad (8)$$

Where γ is the given coefficient of elongation, take $\gamma = 0.5 - 0.8$. Whether x_e is better than x_n, and if so, replace x_n with x_e, execute step 1; otherwise, perform shrink operation (step 4).
step 4 Shrink operation.

$$x_s = x_n + \beta(x_c - x_n) \quad (9)$$

Where β is the given contraction coefficient, take $\beta = 0.7$. Whether x_s is better than x_n, and if so, replace x_n with x_s, execute step 1; otherwise, reconstruct the complex.

Mixed strategy of complex method and IWO

Based on their respective characteristics of the complex method and IWO algorithm, the mixed strategy can be summarized as follows:

In IWO, weeds produce seeds by certain step length according to their own fitness value. In this way, individuals with poor fitness also have chances to survive and reproduce. Fitness value of weed is high (low), while fitness value of seed may be low (high). Seeds randomly distribute around the weeds in normal distribution. Weeds and seeds will compete and survive when the maximum number of individuals in the colony is reached, and the individuals of good fitness value will be saved to the next generation. We can see IWO ensures the diversity of the individuals in a colony, making poor individuals also have a chance to reproduce.

The complex method uses individuals which are about to enter the next generation to construct the complex, calculates the centroid of the complex, then utilizes the centroid to create a new solution of better fitness value for replacing the worst point in complex, and so forth, making the complex being near to the optimal solution continuously. It can be seen that the complex method has a characteristic of making use of the information of population, which guarantees the convergence and optimization precision of the algorithm. In addition, one of the advantages of complex method is that it only adds a new point in each generation, which is a small amount of calculation, making the calculation being not significantly increased when the dimension of the problem increases, and the higher dimension of complex method is, the more superior. Mixing complex method and IWO algorithm is advantageous to enrich search behavior of optimization, enhance the search efficiency of CIWO, and get high quality solutions at the same time. Thus CIWO algorithm which is produced by combination of the complex method and IWO algorithm will play a complementary role.

CIWO algorithm

The first problem is structuring the complex when using the complex method in IWO. In the experiment, after every generation of evolution of weed, we utilize the individuals which are about to enter the next generation to construct complex (the former), instead of constructing complex before the next generation of evolution (the latter), of which the purposes are below: Firstly, the former optimization precision is much higher than the latter; Secondly, prematurely iterating weeds reduces the diversity of weeds individuals, which is not conducive to local search of the algorithm in early stage, and that is why the experimental results of the former is better than the latter. In addition, in the experiments, we carry out five iterations after structuring the complex for weeds, which ensures the diversity of weeds individuals and does not increase a large number of calculation. Experimental result shows that this method is effective.

To illustrate the process of CIWO, the steps of CIWO algorithm is given below.

step1 Initialization of a population, the control parameters of IWO includes: the size P_{size} of initial population P (part of ethnic groups) and the size Q_{size} of ethnic groups Q, maximum iteration numbers

$iter_{\max}$, dimension of solving the problem $\dim$, maximum generated seed number $S_{\max}$, minimum generated seed number $S_{\min}$, nonlinear modulation index n, initial value of interval step σ_{init} and final value of interval step σ_{final}, $x_{\min}$ and $x_{\max}$ respectively represent minimum value and maximum value of initial search space of independent variable; the control parameters of complex method includes: reflection factor ρ, coefficient of elongation γ, contraction coefficient β. Randomly generate the initial solution by initial population, initial search space of independent variable and dimension of solving the problem.

step2 Evaluation of individuals, calculate the fitness value for each individual $f(X)$.

step3 Each individual produces offspring seeds which is calculated by the formula (5).

step4 Refresh the iterations and the standard deviation of offspring normal distribution, which is calculated by formula (4).

step5 Offspring produce. Join the descendants into the current population and evaluate new individuals.

step6 Determine whether the number of individuals reach maximum size Q_{size} of population, if not, turn to step 3; otherwise, compete and survive, rank the population individuals according to their fitness value, select the best Q_{size} individuals.

step7 Make the number of iterations $t=0$.

step8 Structure the complex with Q_{size} individuals, calculate the centroid x_c of the complex by formula (6).

step9 Calculate the reflection point x_r by formula (7). Whether x_r is better than x_n, and if so, replace x_n with x_r, execute extended operation (step 10); otherwise, perform contract operation (step 11).

step10 Carry out the extended operation by formula (8). Whether x_e is better than x_n, and if so, replace x_n with x_e, execute step 8; otherwise, perform contract operation (step 11).

step11 Carry out the shrink operation by formula (9). Whether x_s is better than x_n, and if so, replace x_n with x_s, turn to step 8; otherwise, reconstruct the complex, turn to step 7.

step12 If $iter < iter_{\max}$, turn to step2; otherwise, exit implementation process of the algorithm and output the individual with the best fitness value in the colony.

Feed-forward prediction model respectively based on IWO algorithm and CIWO algorithm

Firstly, the historical time-series data for network is collected. In order to remove the dimensional level which has an impact on the training of neural network, and to increase the training speed, we should normalize all the input variables and the original input data to the range of $[-1,1]$. The normalized training input is $P^i=(p_1,p_2,\dots,p_R)^T$, the training target data is $T^i=(t_1,t_2,\dots,t_{S_2})^T$, the prediction input is $pX^i=(p_1^*,p_2^*,\dots,p_R^*)^T$, and the actual target value is $pY^i=(t_1^*,t_2^*,\dots,t_{S_2}^*)^T$.

Secondly, input the normalized training input $P^i=(p_1,p_2,\dots,p_R)^T$ and the training target data $T^i=(t_1,t_2,\dots,t_{S_2})^T$ to the network, and the optimal individual X_i is obtained by training, the prediction models are obtained respectively based on IWO algorithm and CIWO algorithm by assigning the optimal individual X_i to weight matrices $\{w1_{i,j}^*\},\{w2_{i,k}^*\}$ and threshold matrices $\{b1_{i,1}^*\},\{b2_{i,1}^*\}$.

$$y_k=\sum_{i=1}^{S_1} w2_{i,k}^*\sigma\Big(\sum_{j=1}^{R} w1_{i,j}^* p_j + b1_{i,1}^*\Big)+b2_{i,1}^* \quad 1\le k\le S_2 \tag{10}$$

Finally, input the input variable $pX^i = (p_1^*, p_2^*, \ldots, p_R^*)^T$ to the prediction model, we need inverse normalize the prediction result $y_j = p_{j+1}$, and then the prediction true value is obtained.

SIMULATION ANALYSIS

Original data

The stock market is a nonlinear system with unstable dynamic changes. The economic factors at home and abroad, human factors and government's macro-control and so on, all these factors can affect the future of the stock market. Therefore, the stock sample data must be collected under the normal operation; otherwise, special data extracted will reduce the forecasting ability of the network.

In order to verify the validity of IWO-NN and CIWO-NN prediction model proposed in this paper, the stock prices of enterprise in China are taken as the predict object. Based on the stable development of SANY Heavy Industry in recently years, since the company shares listed on the Shanghai stock exchange, it does not appear too large oscillation, which guarantees the prediction accuracy, so we select SANY Heavy Industry (stock code: 600031)as the stock price prediction object. 300 sets of historical samples are collected from 2005.6.30 to 2006.9.22 as the network training input samples, 300 sets of history samples are collected from 2005.7.7 to 2006.9.29 as the training target samples, 20 sets of data from 2006.9.25 to 2006.10.27are taken as the prediction input samples, and 20 sets of data from 2006.10.9 to 2006.11.3 are taken as the actual target samples. We select 300 groups of data to train the network, and then use the rest 20 groups of data to evaluate its performance. For the sake of research, the period of 5 days is taken as one analysis period for prediction, which means the historical trading data in 5 days is taken as the prediction evidence, including opening price, highest price, lowest price, closing price and trading volumes. In turn order five days of data is input data for network, and the data in the last day is the target data, and the training samples of neural network are obtained by this arrangement of rolling method. Part of the historical stock prices of SANY Heavy Industry is shown in TABLE 1 and TABLE 2[1].

TABLE 1 : 300 samples of network training input/target data.

Sequence	Opening price	Volume (shares)	Highest price	Lowest price	Closing price
1	7.74/7.16	3277048/2932205	7.95/7.29	7.60/7.11	7.69/7.16
2	7.60/7.13	7850876/4350030	7.61/7.22	7.00/6.8	7.00/6.85
⋮	⋮	⋮	⋮	⋮	⋮
300	14.01/15.6	2595016/4516485	14.38/16.8	13.75/15.5	14.26/16.3

TABLE 2 : 20 samples of network prediction input/actual value.

Sequence	Opening price	Volume (shares)	Highest price	Lowest price	Closing price
1	14.21/16.35	2972750/3353063	14.30/17.36	13.6/16.01	13.98/16.71
2	13.96/16.50	1342635/3446818	14.26/17.08	13.75/16.2	14.18/17.02
⋮	⋮	⋮	⋮	⋮	⋮
20	18.00/18.30	2713835/1123350	19.19/18.88	18.0/18.15	19.12/18.47

Analysis of prediction results

Firstly, before the training, in order to improve the training speed, reduce the error and avoid paralysis of network, the function mapminmax in neural network toolbox in Matlab is used to normalize the original sample data to obtain 300 sets of training inputs data P^i, 300 sets of training target data T^i, the last 20 sets of prediction inputs are pX^i, and actual target value are pY^i.

Secondly, train the feed-forward neural network respectively using IWO algorithm and CIWO algorithm.

In the feed-forward neural network, there are three layers, including input layer, one hidden layer and output layer, the corresponding nodes in each layer are $R=25$, $S_1=16$ and $S_2=1$, and $\tan-sigmoid$ function is used as excitation function.

Set the parameters in IWO neural network (IWO-NN): The initial population is $P_{size}=10$, the maximum of population is $Q_{size}=15$, the maximum iterations is $iter_{\max}=300$, the maximum and minimum of generated seed number are $S_{\max}=3$ and $S_{\min}=0$, the nonlinear modulation index is $n=3$, the initial value of interval step is $\sigma_{init}=1$ and the final value of interval step is $\sigma_{final}=0.01$, the minimum of initial search space is $x_{\min}=-0.1$ and the maximum is $x_{\max}=0.1$.

Set the parameters in CIWO neural network (CIWO-NN): The initial population is $P_{size}=10$, the maximum of population is $Q_{size}=15$, the maximum iterations is $iter_{\max}=300$, the maximum and minimum of generated seed number are $S_{\max}=3$ and $S_{\min}=0$, the nonlinear modulation index is $n=3$, the initial value of interval step is $\sigma_{init}=1$ and the final value of interval step is $\sigma_{final}=0.01$, the minimum of initial search space is $x_{\min}=-0.1$ and the maximum is $x_{\max}=0.1$, set reflection factor $\rho=1.3$, coefficient of elongation $\gamma=0.5$, contraction coefficient $\beta=0.7$.

The training is carried out by inputting P^i and T^i to the network, and the optimal individual X_i is obtained. By assigning X_i to weight matrix $\{w1^*_{i,j}\},\{w2^*_{i,k}\}$ and threshold matrix $\{b1^*_{i,1}\},\{b2^*_{i,1}\}$ in the feed-forward neural network, the prediction model based on IWO algorithm and CIWO algorithm are obtained,

$$y_k=\sum_{i=1}^{S_1} w2^*_{i,k}\,\sigma\Big(\sum_{j=1}^{R} w1^*_{i,j}\,p_j+b1^*_{i,1}\Big)+b2^*{}_{i,1}\quad 1\le k\le S_2 \tag{11}$$

In the IWO-NN prediction model, where the connective weights of input layer to hidden layer $\{w1^*_{i,j}\}$ is $W1=\begin{pmatrix}1.1398 & 0.7676 & \cdots & -0.4716\\ -0.3010 & -0.3596 & \cdots & -0.1997\\ \vdots & & & \vdots\\ -0.3433 & 0.1020 & \cdots & -0.4934\end{pmatrix}$ the connective weights of hidden layer to output layer $\{w2^*_{i,k}\}$ is $W2=\begin{pmatrix}0.0539 & -0.0400 & \cdots & 0.2042\end{pmatrix}_{1\times16}$; the threshold matrix $\{b1^*_{i,1}\}$ of neurons in hidden layer is $B1=(-0.7240 \quad -1.7566 \quad \cdots \quad 0.4423)^T{}_{16\times1}$; and the threshold matrix $\{b2^*_{i,1}\}$ of neurons in output layer is $B2=\left(0.6626\right)_{1\times1}$.

In the CIWO-NN prediction model, where the connective weights of input layer to hidden layer $\{w1^*_{i,j}\}$ is $W1=\begin{pmatrix}-0.0497 & 0.2533 & \cdots & -0.0923\\ 0.4324 & 0.0015 & \cdots & 0.0187\\ \vdots & & & \vdots\\ 0.2217 & 0.1173 & \cdots & 0.3384\end{pmatrix}$ the connective weights of hidden layer to output layer $\{w2^*_{i,k}\}$ is $W2=\begin{pmatrix}0.2308 & -0.0449 & \cdots & -0.1830\end{pmatrix}_{1\times16}$; the threshold matrix $\{b1^*_{i,1}\}$ of neurons in hidden layer is $B1=(-0.1938 \quad -0.3317 \quad \cdots \quad -0.2134)^T{}_{16\times1}$; and the threshold matrix $\{b2^*_{i,1}\}$ of neurons in output layer is $B2=\left(-0.2826\right)_{1\times1}$.

Finally, input the last 20 prediction inputs pX^i to the prediction model (10), and then the final prediction true values are obtained by inverse normalization using postmnmx function in neural network toolbox in Matlab.

The prediction of stock price is carried out by IWO-NN neural network, and the results are shown in TABLE 3 and Figure 1, and the best fitness changes are shown in Figure 2.

TABLE 3 : The predicting stock price based on IWO-NN model.

Trading day	Actual	IWO-NN	Trading day	Actual	IWO-NN
06.10.09	16.71	15.65	06.10.23	17.06	18.86
06.10.10	17.02	16.31	06.10.24	17.72	16.40
06.10.11	17.55	17.07	06.10.25	18.56	16.41
06.10.12	17.27	16.80	06.10.26	18.30	17.64
06.10.13	16.84	19.74	06.10.27	19.12	21.37
06.10.16	17.40	18.98	06.10.30	19.00	18.99
06.10.17	17.95	17.79	06.10.31	19.09	20.69
06.10.18	17.97	16.76	06.11.01	18.69	20.66
06.10.19	17.65	20.68	06.11.02	18.56	20.88
06.10.20	17.71	20.02	06.11.03	18.47	19.33

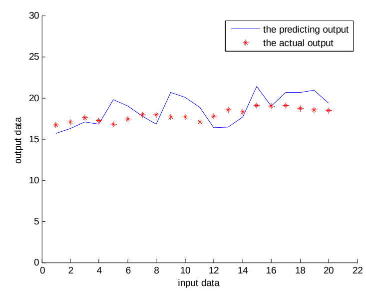

Figure 1 : Predicting the stock price based on IWO-NN

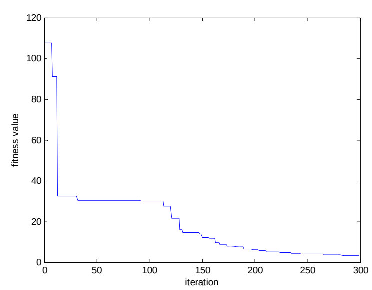

Figure 2 : Change of best fitness based on IWO-NN

From the comparison of prediction results between BP neural network and IWO-NN prediction model shown in Figure 5, we can see that the prediction curve of prediction model trained by IWO is more approximate to actual value. The change curve of best fitness of IWO-NN model is shown in Figure 2, the optimal solution is obtained by 300 iterations by IWO algorithm, which is increased significantly than the standard BP model. The comparison on the predicting closing price and actual closing price in different trading day, error of mean square between neural network based on BP algorithm and IWO algorithm are shown in TABLE 5, it shows that the feed-forward neural network trained by IWO algorithm reflects a better tendency of network prediction changes, and the accuracy of the prediction is improved.

From above analysis, IWO algorithm can find global initial connection weights and threshold value, improve the fitting ability and generalization ability of feed-forward neural network, thus improving the prediction accuracy of the network, therefore, it is an effective feed-forward prediction method.

The prediction of stock price is carried out by CIWO-NN neural network, and the results are shown in TABLE 4 and Figure 3, and the best fitness changes are shown in Figure 4.

TABLE 4 : The predicting stock price based on CIWO-NN model.

Trading day	Actual	CIWO-NN	Trading day	Actual	CIWO-NN
06.10.09	16.71	16.40	06.10.23	17.06	17.56
06.10.10	17.02	16.62	06.10.24	17.72	17.13
06.10.11	17.55	16.63	06.10.25	18.56	17.67
06.10.12	17.27	16.92	06.10.26	18.30	17.98
06.10.13	16.84	17.28	06.10.27	19.12	17.78
06.10.16	17.40	16.48	06.10.30	19.00	18.21
06.10.17	17.95	17.42	06.10.31	19.09	18.72
06.10.18	17.97	17.35	06.11.01	18.69	18.27
06.10.19	17.65	17.25	06.11.02	18.56	18.36
06.10.20	17.71	17.45	06.11.03	18.47	18.17

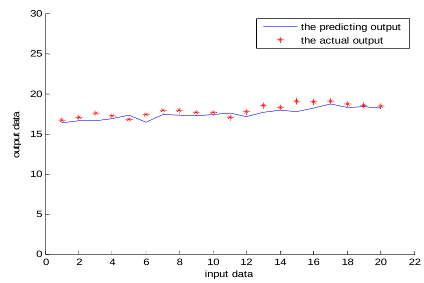

Figure 3 : Predicting the stock price based on CIWO-NN

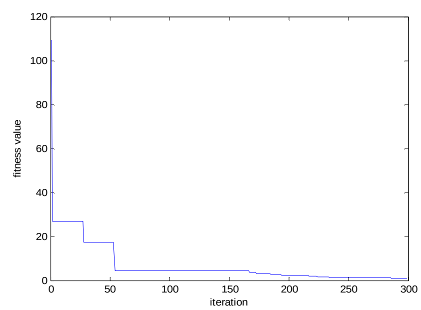

Figure 4 : Change of best fitness based on CIWO-NN

TABLE 5 : Comparison on the predicting results and errors about three predicting models.

Trading day	Actual	CIWO-NN	IWO-NN	BP	Trading day	Actual	CIWO-NN	IWO-NN	BP
06.10.09	16.71	16.40	15.65	15.29	06.10.24	17.72	17.13	16.40	14.18
06.10.10	17.02	16.62	16.31	14.98	06.10.25	18.56	17.67	16.41	10.97
06.10.11	17.55	16.63	17.07	14.09	06.10.26	18.30	17.98	17.64	15.42
06.10.12	17.27	16.92	16.80	16.05	06.10.27	19.12	17.78	21.37	14.41
06.10.13	16.84	17.28	19.74	16.38	06.10.30	19.00	18.21	18.99	18.56
06.10.16	17.40	16.48	18.98	15.26	06.10.31	19.09	18.72	20.69	15.72
06.10.17	17.95	17.42	17.79	12.55	06.11.01	18.69	18.27	20.66	17.76
06.10.18	17.97	17.35	16.76	15.21	06.11.02	18.56	18.36	20.88	15.45
06.10.19	17.65	17.25	20.68	16.14	06.11.03	18.47	18.17	19.33	11.26
06.10.20	17.71	17.45	20.02	17.34	Mean				
06.10.23	17.06	17.56	18.86	13.94	square error		0.3759	2.8345	12.3701

From the comparison of prediction results between IWO-NN neural network and CIWO-NN prediction model shown in Figure 5, we can see that the prediction curve of prediction model trained by CIWO is more approximate to actual value. Comparing the change curve of best fitness of CIWO-NN model shown in Figure 4 with the change curve of best fitness of IWO-NN model shown in Figure 2, we can see that CIWO-NN has a faster speed of convergence. The comparison on the predicting closing price and actual closing price in different trading day, error of mean square between neural network based on IWO algorithm and CIWO algorithm are shown in TABLE 5, it clearly shows that the feed-forward neural network trained by CIWO algorithm has higher accuracy of convergence than that of IWO algorithm.

From above analysis, it can be seen that CIWO is better than the IWO in accuracy of optimization, speed of searching optimization and robustness, which justify improving IWO with complex method is effective.

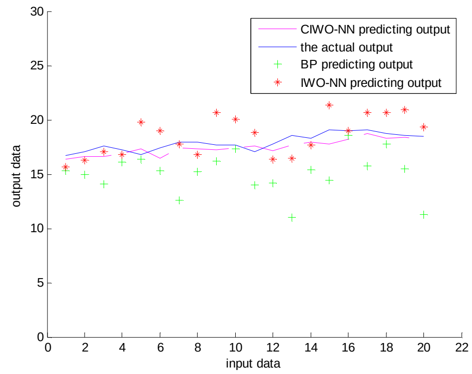

Figure 5 : Comparison on predicting stock price about three predicting models

CONCLUSIONS

Firstly, the training approach of three layers feed-forward neural network based on IWO algorithm is given to make the network training simple and reduce the calculation complexity, the global search and local search are coordinate by the dynamic adjustment of standard deviation of offspring individuals' distribution, which ensures that the optimal solution is obtained accurately, the defect of trapping into local optimization is reduced and the convergence speed is improved. IWO-NN prediction model is established. From the prediction results of stock price, the convergence speed and prediction accuracy of feed-forward trained by IWO algorithm are better than that of the standard BP neural network, and feasibility of the prediction method is verified.

Secondly, aiming at the characteristics of optimization accuracy being not high, slow speed of optimization, easily trapping into local optimum of IWO, on the basis of without changing the pattern of normal space diffusivity of IWO, a CIWO algorithm is proposed, which utilizes traditional complex method to improve IWO, it not only does not reduce the diversity of individuals, but also makes full use of the characteristics of simple calculation and guiding of complex method. Train the feed-forward neural network by CIWO algorithm, and establish a prediction model. Feasibility of the prediction method is verified by the instance simulation of stock price prediction, thus it suggests that CIWO algorithm have higher accuracy of optimization, speed of optimization and better robustness.

Finally, IWO-NN and CIWO-NN prediction model can also be applied to the prediction in other areas by adjusting the training parameters, so they have a certain continuation.

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