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The Research on the Inventory Prediction in Supply Chain based on BP-GA Chaos Prediction Algorithm

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Abstract

In the modern supply chain management, optimizing supply chain can reduce the cost of the enterprise. In the optimization of supply chain, the inventory optimization is a very important part. Through forecasting the inventory amount, we can reduce the cost of the inventory. And we also can optimize the supply chain. Because the supply chain network is complex, we use the chaos theory to study and predict the inventory. In this paper, we put forward a chaotic forecasting method which is based on the BP neural and genetic algorithm. This new method is BP-GA chaos prediction algorithm. We use the method to predict the inventory amount. The experiment shows that the method has achieved good forecasting effect.

Keywords: *Supply chain network; The inventory prediction; The chaos theory*

1. Introduction

Since the idea of supply chain management is proposed, many enterprises have applied the idea of supply chain management to the daily management. Since then, the management mode of the enterprise enters a new stage. The optimization of the supply chain is an important optimization job for reducing the cost and improving the work efficiency. Among them, the inventory optimization is a very important part in the optimization of supply chain. According to optimizing the inventory of the enterprise, we can reduce the inventory cost. If we find out a good method to forecast the inventory, we can control the inventory amount better and optimize the supply chain.

Many scholars have studied the inventory prediction [1-2]. Agus Mansur and Triyoso Kuncoro used the market basket analysis approach to predict the small medium enterprise inventory [3]. They understood the behavior of consumers in purchasing the products so it can be used to predict the purchasing for the next period. Later, the prediction was used as a decision support in determining the appropriate amount of inventory for each product. They use the Market Basket Analysis (MBA) and Artificial Neural Network (ANN) Back propagation to study this question. Wang Xu and Wang Hong applied the artificial intelligence into the inventory management and security inventory forecast [4]. Aiming to the security inventory, Wang Dongxu and other people established B-P neural network model. Then they trained, studied and forecasted the actual problem. They achieved better results than the traditional method [5]. Xuan Chaoting and other people summarized systematically the applications of the neural network technology in the supply chain management. Then they introduced the five applications about the neural network technology in the supply chain management in detail. They were the optimization, prediction, decision support, modeling and simulation. Finally, they applied BP neural network to forecast the demand for Shanghai bicycle market and achieved good results [6]. Liu Yang and Li Zhen added the influence factor to the BP neural network model. And they used the method to forecast the inventory amount. Then they also used the traditional forecast method. According to comparing the forecast results, it showed that

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the BP network model had the higher accuracy [7]. Jeong, Bongju and other people put forward a new supply chain optimization model and constructed a generalized genetic algorithm. Then they used the algorithm to solve this problem. This algorithm integrated special evolution rules, overcome the defect of the local convergence for the genetic algorithm and improved the ability of the global convergence. The experiment results showed that the solving of the supply chain optimization problem was better than the traditional algorithm [8]. Lu Qinghou put forward a kind of genetic algorithm which was based the minimum gene fragment encoding and the two generation competition. They used the algorithm to solve the best volume assignment and the optimal joint order point. It achieved the more scientific management and control for the warehouse resources and the capital in order to use effectively the inventory resources. Then it reduced the operating cost and the inventory cost [9]. P.Radhakrishthinan established the higher supply chain material demand forecast model and used the genetic algorithm to optimize. Then he compared the optimized model with the traditional algorithm and proved that the genetic algorithm can achieve the good effect [10].

Since the chaos produced, it infiltrated to many other interdisciplinary fields and got the widely applied. The modeling of the chaotic time series and prediction had the practical significance. Hima Nikafshan Ra,d Zakaria Jalali and Hossein Jalalifar proposed a hybrid nonlinear Chaotic and Neuro-Fuzzy system modeling for the basic RMR system uncertainty based on continuous functions. This model also proved the theory of Bieniawski that is based on nonlinear systems by using chaos theory and mathematical relations. The main advantage of proposed model was to directly predict output of RMR system classification system without considering the input parameters so that it leads to better results and a higher level of prediction rock quality [11]. Ehsan Maani Miandoab, Hossein Nejat Pishkenarib, Aghil Yousefi-Koma, Farid Tajaddodianfar proposed a new method that can avoid the chaotic motion affect the resonator performance in different nonlinearities. The novel method was proposed for prediction of the chaos in the micro- and nano-electro-mechanical resonators. Based on the proposed method, first an accurate analytical solution for the dynamics behavior of the nano-resonators was derived using the multiple scales method up to the second order [12]. Tang Yangshanetc used the chaotic method to study the traffic conflict flow. Using the chaotic forecast method, the author studied the traffic conflict of the intersection. And he evaluated the forecast method and result according to the gray error test method. It showed that the chaotic forecast method was an effective method for the traffic conflict flow [13]. Deng Zhongyi studied the chaotic forecast method and the applied study [14]. The author analyzed in detail the current commonly used chaotic forecast methods. It contained the main thoughts of the chaotic time series. This paper gave several representative prediction examples. And it pointed out the wide application and the applied direction of the chaotic prediction. Besides, many other authors studied the chaos prediction and obtained the dramatically achievements [15-20].

Using the chaotic theory to forecast the inventory of the supply chain can control the inventory cost and reduce the burden of the enterprises better. At the same time, according to forecasting the inventory amount, it can better meet the demand of customers. Therefore, this paper put forward the chaotic forecast method which is based on the BP neural and genetic algorithm. The method is BP-GA chaos prediction algorithm. We use this method to forecast the inventory of the enterprises. The structure of this paper is as follows. The first part is the instruction. In this part, we introduce the research status of the inventory forecast and the chaotic theory. The second part is the chaotic prediction method. In this part, we introduce the chaotic forecast methods. The third part is the new chaotic forecast method-BP-GA chaos prediction algorithm which is based on the BP neural network and the genetic algorithm. In this part, according to the defects of the traditional chaos prediction algorithm, we combined the chaotic forecast method, BP neural with genetic algorithm. And we put forward the improved BP-GA chaos prediction algorithm. The fourth part is the numerical analysis. In the fourth part, we forecast the inventory amount. The fifth part is the conclusion.

2. The Chaotic Prediction Method

We assume that the chaotic time series is

$$x(1), x(2), \cdots, x(t), \cdots \tag{1}$$

The time series reflects a state of one thing. It is not only a result of one thing, but also the information of the future development. According to the research of the ancient scholars, constructing a state space can reveal the information association rules among these motion states.

$$Y(t) = (x(t), x(t+\tau), \cdots, x(t+(m-1)\tau)) \in R^M, (t = 1, 2, \cdots, N) \tag{2}$$

Where, $Y(t)$ is the state space vector. $x(t), x(t+\tau), \cdots,$ are the components of the state space vector. τ is the sequence delayed time. m is the dimension of the state space. In general, the sequence delayed time τ is given by the subjective. τ is not too small in order to prevent the linear correlation among the components of the vector. τ is not too big in order to prevent that the nonlinear correlation range of the components of the vector is beyond the information. The dimension of the state space m depends mainly on the attractor fractal dimension d of the sequence.

Forecasting the future state of the time sequence is to determine the function relationship $f_L(\cdot)$ between the current state $Y(t)$ and the future state $Y(t+L)$.

$$Y(t+L) = f_L(Y(t)) \tag{3}$$

The method which is according to the attractor method in the fitting phase space to find the nonlinear function $f_L(\cdot)$ can be divided into the global chaotic prediction method and the local chaotic prediction method.

The global chaotic prediction method is to make the all points in the locus as the fitting object. According to the polynomial and the rational type, it can find out the rules. That is $f_L(\cdot)$. Then it can forecast the trend of the track. Of course, it is possible for the lower embedding dimension. However, if it meets the higher embedding dimension system, it is not practical to use the polynomial to do the system simulation. This method is feasible in theory. However, the actual data is limited and the phase space trajectory may be complicated, then it could not get the real mapping relationship $f_L(\cdot)$. In general, according to the given data to structure the mapping:

$$f : R^m \to R^m \tag{4}$$

The function makes f approximates to f in theory. That is,

$$\sum [Y(t+L) - f(Y(t))]^2 \tag{5}$$

The local chaotic prediction method is to make the last point in the phase space trajectories as the center point. And it makes the points which are nearest to the center point as the relevant points. Then is makes the fitting for this points and estimates the trend of these points. Finally, it separates the demanded forecasted values from the coordinates of the forecasted trajectory.

3. The Chaotic Forecasting Method BP-GA Chaos Prediction Algorithm which is based on the BP Neural Network and the Genetic Algorithm

After we analyzed the global chaotic prediction and the local chaotic prediction, we found that the defect of the global prediction was that the computation was complicated, especially when the embedding dimension was high or very complex. When applying the local prediction method to forecast, firstly we found the center point and fit a few points in the neighborhood. We did not consider the influence of the space distance on the prediction among the center points. However, the space distance among the center points in the phase space was a very important parameter. The accuracy of the prediction depended on the several points that the space distance was near to the center point. In order to overcome the above problems, we put forward a new hybrid chaotic prediction algorithm.

In this paper, we established the BP-GA chaos prediction algorithm which was based on the neural network and the genetic algorithm. Firstly, we gave the chaotic time sequence and established the chaotic neural network prediction model. Then we used the genetic algorithm to optimize the weights of the chaotic neural prediction model. Finally, we forecasted the chaotic time sequence. The output value is the prediction value. Among them, the steps of hybrid prediction method between BP neural network and genetic algorithm are as follows.

Firstly, we give chaotic time sequence $x(t)(t=1,2,\cdots)$. According to Takens theorem, we select the proper delay time τ and embedding dimension m. Then, we reconstruct the phase space.

$$Y(t)=(x(t),x(t+\tau),\cdots,x(t+(m-1)\tau))\in R^{M},(t=1,2,\cdots,N)$$

Secondly, we use m sample points in phase space as the m inputs $X[i](i=1,2,\cdots,m)$ for neural network. We can establish neural network model. In order to use genetic algorithm and optimize the connection weights of neural network, we need to adjust the model and structure of neural network. The adjusted neural network structure is as follows.

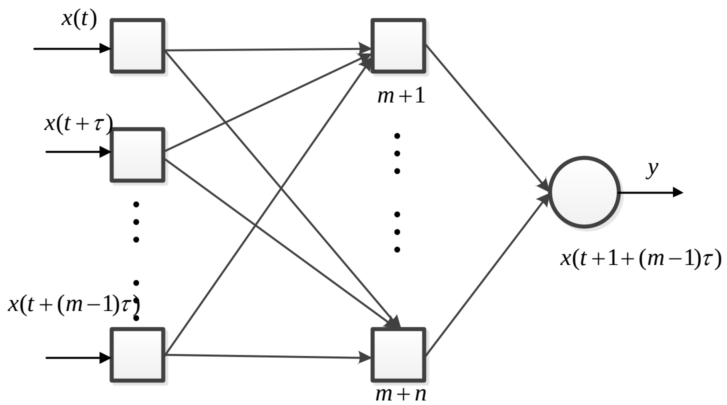

Figure 1. The Structure of the Adjusted Neural Network

In this network, there are m inputs, n middle layer nodes and one output node. There are $m+n+1$ nodes. For the $m+n+1$ nodes, their numbers are $1,2,\cdots,m,m+1,\cdots,m+n,m+n+1$. We use $w_{ij}(1\le i,j\le m+n+1)$ to express the connected weight from i node to j node. Then, the chaotic time series neural network model is as follows.

$$X[i]=x(t+(i-1)\tau),i=1,2,\cdots,m \tag{6}$$

$$y[m+i]=f(\sum_{i=1}^{m}w_{ij}x[i]),\ j=1,2,\cdots,n \tag{7}$$

$$z=f(\sum_{i=1}^{m}w_{m+j,m+n+1}y[m+j]) \tag{8}$$

z is the output of neural network node. $f(\cdot)$ f is non-linear Sigmoid function.

The third step is to determine the initial population. In improved neural network construction, we assume $w_{ij} = 0$ if there is no connection between i node and j node. Then we can give the matrix that is formatted by the connection weights for each node.

$$W = (w_{ij})_{(m+n+1)\cdot(m+n+1)} = \begin{bmatrix} 0_{m\cdot m} & w_{m\cdot m} & 0_{m\cdot 1} \\ 0_{n\cdot m} & 0_{nn} & w_{n\cdot 1} \\ 0_{1\cdot m} & 0_{1\cdot n} & 0 \end{bmatrix} \tag{9}$$

Among them,

$$w_{m\cdot n} = \begin{bmatrix} w_{1,m+1} & w_{1,m+1} & \cdots & w_{1,m+n} \\ w_{2,m+1} & w_{2,m+2} & \cdots & w_{2,m+n} \\ \vdots & \vdots & \vdots & \vdots \\ w_{m,m+1} & w_{m,m+1} & \cdots & w_{m,m+1} \end{bmatrix} \tag{10}$$

$$w_{m\cdot n} = (w_{m+1,m+n+1}, w_{m+2.m+n+1}, \cdots, w_{m+n,m+n+1})^T$$

And other modules are all zero matrixes.

Then we assume threshold value for each node is

$$\theta_i (i = 1, 2, \cdots, m+n+1) .$$

They also formulate a matrix

$$\theta = (\theta_i)_{1\cdot(m+n+1)} = (\theta_1, \theta_2, \cdots, \theta_{m+n+1}) .$$

The connection weight matrix is a matrix that the lower triangular matrix is zero. This is because the neural network is a non-feedback network. In network, there are $(m+1)\cdot n$ non-zero elements. They express all connection weights in network. Threshold matrix is a $m+n+1$ elements matrix. Generally, there is on threshold value in input layer. That is, $\theta_i = 0$. The matrix which is constructed by non-zero threshold can be expressed as

$$\theta = (\theta_i)_{1\cdot(n+1)} = (\theta_{m+1}, \theta_{m+2}, \cdots, \theta_{m+n+1})$$

Therefore, we need to determine $n+1$ non-zero thresholds. The connection weight and threshold have $(m+1)\cdot n + (n+1)$ non-zero values. We use the digital strings which are composed by the binary codes to express the individual chromosome in a population. $(m+1)\cdot n$ non-zero connection weight and $n+1$ non-zero threshold compose a group of data.

That is

$$(w_{1,m+1}, \cdots, w_{1,m+n}, \cdots, w_{m,m+1}, \cdots, w_{m,m+n}, \cdots, w_{m+1,m+n+1}, \cdots, w_{m+n,m+n+1}, \theta_{m+1}, \cdots, \theta_{m+n+1}) \tag{11}$$

In above function, the data represents an individual. A plurality of such data sets can compose the initial population. Such data in the group are real number. We need to convert them into the binary code digit string.

$$A = \min_{i,j,k}(w_{ij}, \theta_k) ,$$

$$B = \max_{i,j,k}(w_{ij}, \theta_k)$$

$$i, j, k = 1, 2, \cdots, m+n+1 \tag{12}$$

For all the weights and threshold values, there are

$$A \le w_{ij}, \theta_k \le B$$

And

$$i, j, k = 1, 2, \cdots, m+n+1$$

We use l binary number to represent the weights and thresholds in above range. Therefore, the values which are expressed by the actual weights or thresholds and the binary digital string have the following relationship.

$$(w_{ij})_b = \frac{(w_{ij}) - A}{B - A}(2^l - 1)$$

or

$$(\theta_k)_b = \frac{(\theta_k) - A}{B - A}(2^l - 1)$$

$$i = 1, 2, \cdots, m + n. j, k = m + 1, m + 2, \cdots, m + n + 1$$

w_{ij} or θ_k is the actual weight value. $(w_{ij})_b$ or $(\theta_k)_b$ is the binary integer which is expressed by l digital strings. $[A, B]$ is the range of the weights and thresholds. According to the multi parameter coding method, we cascade all weights and threshold which are corresponding to $0/1$ codes. Then we can get an individual of an initial population.

We express A, B as binary integers and remember them to $(A)_b$ and $(B)_b$. That is, we substitute the weights in formula [11] and thresholds for $(A)_b$.

$$\min = ((A)_b, (A)_b, \cdots, (A)_b)$$

is the minimum value in the group. Similarly, we substitute the weights in formula [11]and thresholds for $(B)_b$.

That is,

$$\max = ((B)_b, (B)_b, \cdots, (B)_b)$$

is the maximum value in the group.

Then,

$$H = \max - \min$$

is the population size. That is, the group has H individuals. After determining the population size, we begin to select the initial population. We convert all weights in formula [11] and thresholds to binary numbers and there are L number.

$$L = l \cdot (m \cdot n + 2 \cdot n + l)$$

We divide L into H equal division. And we use the following function to calculate the interval number $I = \frac{2^L - 1}{H}$. Then we use binary number $I, 2I, \cdots, hI$ to code and get the initial populations which are composed by h individuals equally.

The fourth step is the fitness function. The sum of square error for output codes of neural network is

$$e = \sum_{k=m+1}^{m+n+1} (d_k - y_k)^2 .$$

d_k and y_k are the desired output and actual output of k output node. The fitness function is $f = \frac{1}{e}$. Then we adjust the fitness function $f' = af + b$. f' is the adjusted self-fitness function. f is the original fitness function. And a and b are coefficients.

Among them,

$$a = \frac{(c-1) f_{avg}}{f_{\max} - f_{avg}}, b = \frac{(f_{\max} - cf_{avg}) f_{avg}}{f_{\max} - f_{avg}}. \tag{13}$$

f must be non-negative. f_{avg} is the average value of current group. $f_{\max}$ is the maximum value in current group. The adjusted fitness degree maximum value should be the average of specified multiple for original fitness degree. The rage of specified multiple c is in [1,2]. Whether the fitness degree function is suitable is related to the constant value. According to the paper [20], we select $c = 2$.

The fifth is the replication operation. Firstly, we order all individuals in the group. According to the level of the fitness degree for each individual, we order them for descending list. Secondly, we divide all individual into four equal parts from the top to the bottom. Finally, we throw away 1/4 proportion individuals which is ordered in the last. That is, they are eliminated and could not into the next generation. We copy all individuals that the fitness degree are ordered in the middle of 1/2 proportion. That is, they can be into the next generation. The rest individuals are copied two duplicates. That is, the two duplicates are selected into the next generation.

The sixth is the crossover operation. In the initial stage of the evolution, in order to enhance the diversification degree of the population and increase the competition among individuals, it needs to expand the crossover operation among parents. Then it can produce many new individuals. However, in the later stage of evolution, with the increase of the evolution times, the solution set group closes gradually to the optimal solution. At this time, if we adopt the larger cross ratio, it will produce many new individuals which distribute in the whole space. And it reduces the proportion that the food fitness individuals in groups. Therefore, larger cross ratio will lead to destruct the excellent individual proportion and delay the convergence process. In this paper, the formula for the cross rate is as follows.

$$p_c = p_{c0} - (p_{c\min}) * d / D \tag{14}$$

p_{c0} is the initial crass ratio. d is the evolution times currently. And D is the total number of the evolution.

The seventh is the mutation operation. In the basic genetic algorithm, the mutation probability is fixed and it is usually a very small constant. In the later genetic evolution, if the mutation probability does not change, the average fitness of the population is close to the most optimal individual. In addition, the individual gene in the group is very similar. Therefore, it makes the genetic evolution process have no competition. It becomes like a random selection. It reduces the speed of the evolution, even makes the evolution stagnation, reduces the diversity of the population and is easy to cause the local convergence. Then it produces the greatly influence on the efficiency of the algorithm. Therefore, we use the following variant probability formula.

$$p_m = \begin{cases} p_{m\_\max} - (p_{m\_\max} - p_{m\_\min})(f' - f'_{avg}) / (f'_{\max} - f'_{avg}) \geq f_{avg} \\ p_{m\_\max},\ f' < f_{avg} \end{cases} \tag{15}$$

Among them, p_m is the mutation probability of the variation individual. $p_{m\_\max}$ is the maximum mutation probability. Here, we take $p_{m\_\max} = 0.2$. $p_{m\_\min}$ is the minimum mutation probability. Here, we take $p_{m\_\min} = 0.01$. f' is the fitness degree of the variation individuals. $f_{\max}$ is the maximum fitness degree in the population. And f_{avg} is the average value of the group fitness degree in each generation.

The eighth step is the population optimization. At the time, drone-rearing colony and subgroup have h individuals respectively. We put the drone-rearing colony and subgroup become one group. They compose $2h$ individuals. And we number them according to their sizes of the fitness degree.

Therefore, the copy probability of k in $2h$ population is as follows.

$$p(k) = \begin{cases} \dfrac{(h-1)-k}{h-1}, k = 0,1,2,\cdots,h-1 \\ \dfrac{k-h}{h}, k = h, h+1,\cdots,2h-1 \end{cases} \tag{16}$$

We select h individuals which have the maximum copy probability to compose the new progeny population.

The ninth is the iterative. For the new progeny population, we calculate, copy, exchange and operate the fitness degree for the iteration. The evaluation rule of the iterative is to test the relative error of the two adjacent iterations. We test whether they satisfy the accuracy.

$$E(f'^{(k+1)}, f'^{(k)}) = \frac{\max_i(f_i'^{(k+1)}) - \max_i(f_i'^{(k)})}{\max_i(f_i'^{(k)})} < \varepsilon \quad k = 0,1,\cdots, i = 1,2,\cdots, h \tag{17}$$

In the formula, $E(f'^{(k+1)}, f'^{(k)})$ is the relative error of two iterations. $\max_i(f_i'^{(k)})$ is the maximum fitness degree of the chromosome in the k iteration. $\max_i(f_i'^{(k+1)})$ is the maximum fitness degree of the chromosome in the $k+1$ iteration. ε is the given evaluation standard. We take $\varepsilon = 0.001$. If the relative error is less than the given standard, the genetic algorithm ends and puts the optimal solution. Is the relative error is more than the given standard, we continue to copy, change and mutate until the optimal solution is obtained.

4. The Numerical Analysis

We use the BP-GA chaos prediction algorithm method to forecast the product inventory for one company. We collect 100 sets of data. Among them, the first 90 sets are the training data. And the last 10 sets are the sample data. Firstly, we compute the maximum Lyapunov index of the inventory time series. The index is 0.0061. And it is greater than zero. This illustrates that the inventory time series has the chaos. And we can use the chaotic method to forecast. The flow chart of BP-GA chaos prediction method is as follows.

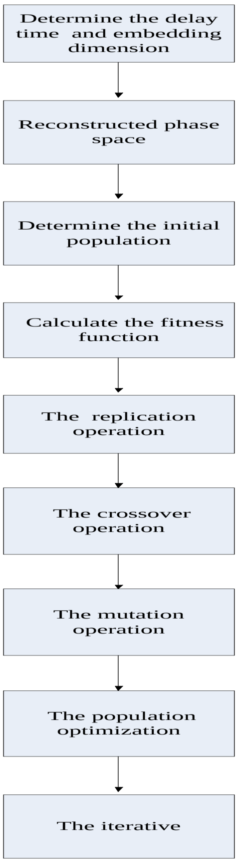

Figure 2. The Flow Chart of BP-GA Chaos Prediction Method

Then, we use the BP-GA chaos prediction to predict the inventory. The results are as follows.

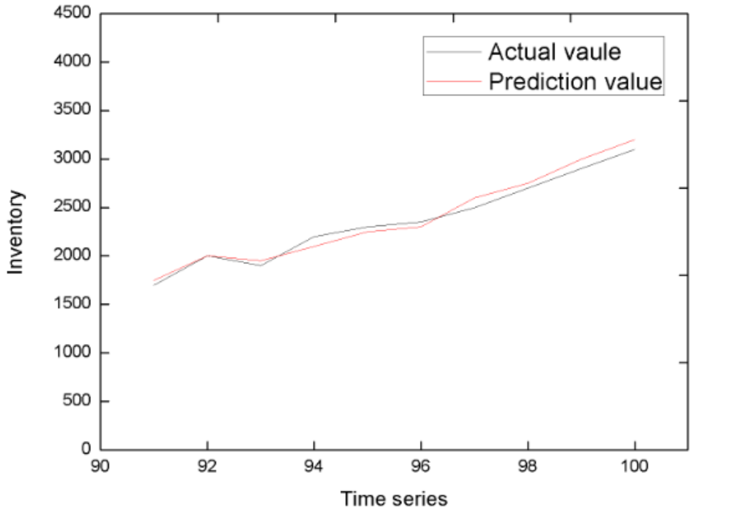

Figure 3. The Actual Value and the Prediction Value

From the above figure, we can see that the results of the chaotic prediction method are more accurate and achieve good results. This method has more accuracy for forecasting the inventory of supply chain. The error is smaller. And the prediction result is more ideal.

Then, we use the different methods to predict the inventory and compare with BP-GA method. The results are as follows.

Table 1. The Comparing of the Different Methods

Method	Linear regression analysis	logarithmic function	exponential smoothing	genetic algorithm	Chaos prediction method	BP-GA
The sum of error	17.82%	15.21%	15.63%	9.58%	10.31%	4.57%

From this table, we can see that the sum of the error of BP-GA is less than the other methods. It follows that the prediction accuracy of BP-GA method is higher. The fact proves that the method has good feasibility and applicability.

5. Conclusion

For the daily business, the inventory cost occupies a large proportion in the total cost of the enterprise. If the inventory of the enterprise is too low, the enterprise will cause a lot of loss due to the out of stock. If the inventory of the enterprise is too high, the enterprise will take a lot of inventory cost. Therefore, the enterprise is strict to the inventory level. According to forecasting the inventory amount of the enterprise in supply chain, the enterprise can control better the inventory cost and increases the money amount in circulation. In this paper, we did the following work. Firstly, we summarized the chaotic prediction methods. Secondly, according to the summary of the results, we put forward a new chaotic prediction algorithm which was based on the BP neural network and the genetic algorithm. Thirdly, we used the algorithm to forecast the inventory amount of the product. The results showed that the prediction results were more accurate. And it had good feasibility and applicability.

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