ISSN : 0974 - 7435 Volume 10 Issue 18

2014

BioTechnology
An Indian Journal

FULL PAPER

BTAIJ, 10(18), 2014 [10444-10450]

Prediction research on food cold-chain logistics demand based on grey and AW-BP

Bi Ya*, Chu Ye-Ping, Tao Jun-Cheng
School of logistics and engineering management, Hubei University of Economics, China Hubei Wuhan, 430205, (CHINA)
E-mail : idabiya@126.com

ABSTRACT

The food cold-chain logistics is a typical nonlinear complex system, for which the traditional prediction method has been stretched thin. In view of the characteristics of Chinese economic development and the availability of the statistical data, the paper took the food cold-chain logistics system of Hubei province as the research object and designed the prediction method based on grey and AW-BP. The prediction method combined the advantages of low requirement of grey prediction method for statistical data and strong nonlinear capacity of BP neural network and overcome the disadvantages of too slow convergence and being easily caught in local optimum of general BP neural network by methods of correction of error function, introduction of dynamic adaptive weight etc. Through a large number of experiments, it is proved that the new prediction method is greatly improved in rate and precision of convergence and the capability of getting rid of local extremum and is a practical and efficient prediction method; simultaneously, the prediction data about future demands of the food cold-chain logistics of Hubei province were obtained and the analysis on the development trend and the scale of the food cold-chain logistics system of Hubei province was made according to the prediction data.

KEYWORDS

Food cold-chain logistics; Grey prediction method; Neural network; Dynamic adaptive; Optimization algorithm.

INTRODUCTION

The food cold-chain logistics is a specific supply chain system which means advanced technical means and methods are adopted to ensure that the whole logistics process is always in proper conditions so that the quality and safety of food can be maintained at the greatest extent, the quality decreasing rate of food can be delayed and the loss and pollution of food can be reduced. With the rapid development of Chinese economy, the production and the consumption of food also increase rapidly, resulting in the huge demands for the food cold-chain logistics. The infrastructure of cold-chain logistics is carried out in various regions. However, since the theoretical research of the food cold-chain logistics in China falls far more behind the development of practice, the food cold-chain logistics industry developed basing on this has many problems to be solved. Under the current situation, relevant functional departments have to realize the reasonable planning and guidance for it by mastering the quantized data of the trend and the scale of future development of the food cold-chain logistics industry to promote its smooth and healthy development. However, it is a pity that the relatively mature prediction method cannot well adapt to the complex large-scale nonlinear system of the food cold-chain logistics which is lack of historical statistics data and the demand prediction work of the food cold-chain logistics system comes to a deadlock.

Based on this, in this paper, the food cold-chain logistics system of Hubei province was taken as the research object, the grey prediction method was organically combined with the neural network on the basis of the full consideration for the characteristics of the food cold-chain logistics system and a totally new prediction method based on grey and AW-BP was worked out. The totally new prediction method can give play to the advantages of low requirement of the grey prediction method for statistical data and powerful nonlinear function of the neural network and can overcome the disadvantages of BP neural network of slow convergence rate and being easily caught in local optimum etc.

DATA SOURCE AND INTRODUCTION

Determination of statistical indicators

“Logistics Demand” represents the logistics development condition of a country or region. Since the economic background, the geographic position and the policy direction of different countries and regions are all different, resulting in great deviation in cognition and statistics of “Logistics Demand”. At present, there is still no unified statistical indicator that can be used for representing “Logistics Demand”. In the theoretical circle, it is widely believed that the three statistical indicators of “Freight Volume”[1], “Logistics Cost”[2,3] and “Proportion in GDP”[4,5] can reflex the total demands of logistics to a certain extent and can be taken as the statistical indicators representing “Logistics Demand”. But due to the limited knowledge of modern logistics industry of our country and inconsistent statistical caliber, the accuracy and the availability of the statistical data relevant to the three indicators are all poor. Therefore, we cannot use the internationally commonly used statistical indicators to carry out relevant researches.

We think that: the food cold-chain logistics system of Hubei province follows the rule of general logistics system and the total consumption of the clod-chain food reflects the demand of the region for the cold-chain food within a period of time; simultaneously, in consideration of the availability and the truth of the statistical data, we adopt the “Total Consumption of Cold-chain Food” as the statistical indicator representing the demand of the food cold-chain logistics system.

Data source and treatment

We carry out an accumulative counting and conclude the consumption gross of cold-chain food from the annual consumption of ordinary cold-chain food in Hubei during 2000-2009 extracted from statistic yearbook by Hubei Statistical Bureau. The specific data are seen in TABLE 1.

TABLE 1 : Consumption gross of cold-chain food in Hubei during 2000-2009 (ten thousand tons)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pork	4.49	4.70	5.01	6.40	6.51	7.92	8.05	7.40	8.08	8.88
red meat	0.56	0.55	0.58	0.62	0.63	0.88	0.91	0.95	0.89	0.99
other poultry	0.74	0.89	1.09	1.23	1.2	1.84	1.91	1.97	2.04	2.09
egg and egg products	1.89	1.86	2.00	2.12	2.15	2.29	2.35	2.49	2.60	2.76
Fish	1.60	1.36	2.47	2.68	2.73	3.23	3.35	4.13	5.19	5.95
fresh vegetables	27.3	26.5	26.7	28.0	28.4	37.9	43.7	49.5	52.3	54.2
Fruits	10.4	10.5	11.0	11.4	11.6	12.4	13.0	13.5	14.8	15.2
dairy products	1.12	1.46	2.47	2.82	2.87	2.96	3.38	3.96	4.44	5.07
Pastry	0.69	0.74	0.79	0.92	0.94	1.18	1.22	1.53	1.62	1.73
Total	48.79	48.56	52.11	56.19	57.03	70.6	77.87	85.43	91.96	96.87

PREDICTION METHOD BASED ON GREY AND AW-BP

With fewer requirements for data, the grey prediction model can eliminate the impact of distortion data on system and is especially adapted to the prediction of the system lack of statistical data. But it has difficulty in approaching nonlinear function[6,7]. BP neural network has both very strong nonlinear mapping capacity and robustness and inherent disadvantages. Obviously, there is good complementation between grey prediction model and BP neural network. Therefore, we firstly optimized BP neural network and then organically combined the grey prediction model with the optimized BP neural network to form a totally new BP neural network model based on grey and adaptive weight (hereinafter referred to as prediction model based on grey and AW-BP). The specific realization process is shown in Figure 1.

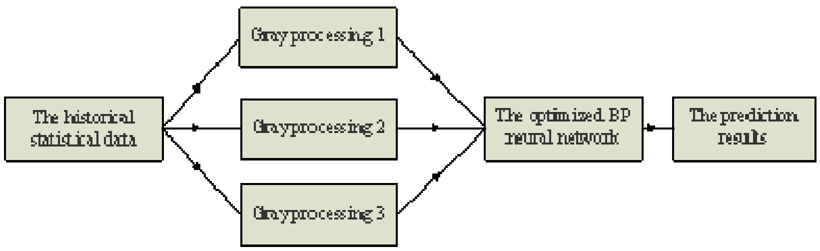

Figure 1 : The realization of the AW-BP algorithm

BP neural network is an artificial neural network of feedforward type which has typical characteristics of artificial neural network and is very adaptive to the prediction of complex nonlinear system of food cold-chain logistics. However, the linear gradient descent is adopted by the error correcting algorithm of BP neural network. The error is corrected by the fixed weight value and the threshold value of the algorithm, the relationship between the current search location and the optimal value cannot be reflected according to the real-time condition of the error. Therefore, the phenomena of slow convergence which happens when the optimal point is missed and even non-convergence may easily appear[8]. And if the solution found by the algorithm cannot meet the requirement of the error, the initial point has to be reselected and the computational process has to be executed again. Under the worst situation, the solution has to be found out throughout the whole searching space. Thus it can be seen that BP neural network has two most apparent defects: a) easily being caught in local optimum; b) flow convergence and even non-convergence. Directing at these two major problems, we put forward the following improvement methods:

Correct its error function aiming at the problem of easily being caught in local optimum

The error formula of general BP neural network is:

$$E = \frac{1}{2}\sum_{K=1}^{P}(O_K - D_K)^2 \tag{1}$$

Formula (1) is a typical deformation form of square-error. Since its function expression is not of convex form and has many local minimums, the optimizing difficulty is increased greatly. We optimize it and correct its functional form to make it a monopole point function, thereby fundamentally solving the problem that the neural network can be easily caught in local optimum.

We define a new error function in broad sense:

$$E = \frac{1}{2}\sum_{K=1}^{P}[O_K(O_K - D_K) + \frac{1}{2}\lambda(D_K^2 - O_K^2) + \frac{1}{2}(1 - \frac{D_K}{O_K})^2] \tag{2}$$

Where, $O_k = (o_1, o_2, \ldots, o_p)$ is target vector quantity; D_k is the output in output level; λ is the adjustment factor.

Correct its fixed weight value aiming at the problem of too slow convergence

The reason why the convergence of BP neural network is too slow is that the fixed weight in the linear gradient descent may easily cause the search process to miss the optimal solution, thereby causing repeated search in the searching space. Therefore, the dynamic adaptive weight is introduced to cause the optimizing process to be able to make adaptive adjustment according to the error[9].

During the search process, too small value of the weight may result in too slow correction rate of BP neural network, thereby enlarging the computation overhead and increasing the convergence time; on the contrary, too large value of it may cause the search to rapidly go near the local extreme point and generate shock during the convergence process, thereby resulting in non-convergence. Given this, we set the weight value to be variables which can be real-timely adaptive to changes according to error information. That is to say, according to the error fed back, the value of the weight is increased if the current search is far away from the optimal value and the optimizing rate of the algorithm in the region is also accelerated to approach the optimal solution as soon as possible; if the current search is near to the optimal value, the value of the weight is reduced and the optimizing rate of the algorithm in the region is lowered to avoid missing the optimal solution or reduce the sharp fluctuation near the local optimum. In this way, it is conductive to the faster searching of globally optimal solution and the acceleration of the convergence rate.

The calculation formula of self-adaption weight:

$$v(N+1) = \frac{E(N)}{E(N-1)} v(N) \quad \textbf{(3)}$$

Where, v is the adaptive weight; N is the iteration.

ESTABLISHMENT OF PREDICTION MODEL ON GREY AND AW-BP

Model structure

(1) Hierarchical structure: the prediction model is of three-layer structure, input layer-hidden layer-output layer. According to the empirical formula, the nerve cells of the hidden layer in the training model are set to be 9, 12 and 15 respectively and the final prediction model structure is determined according to the training results.

(2) Interlayer process mode: the sample dimension and structure are shown in TABLE 2.

TABLE 2 : Model structure and sample dimension of training model

	training model 1	training model 2	training model 3
input layer	4	5	6
hidden layer	9	12	15
output layer	1	1	1

Sample data processing

Consider the gross consumption of cold-chain food for Hubei food cold-chain logistics system during 2000-2009 as sample data. Given that the input sample data possess different dimensions, in order to objectively reflect the real effect of training sample data on output result, input and output data will be made normalization processing. Meanwhile, in order to speed up the backward transmission of error and avoid the extremum space at two top ends of Sigmoid function, data after normalization processing need to be made correction processing. Data after processing are seen in TABLE 3.

Normalization processing on data:

$$x^1 = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \quad \textbf{(4)}$$

Correction processing of data:

$$x^2 = 1 - \frac{1}{e^{[0.1625 + \frac{(1.8971 - 0.1625)(x^1 - x_{\min})}{x_{\max} - x_{\min}}]}} \quad \textbf{(5)}$$

TABLE 3 : Data after processing

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
y_1	0.1570	0.1500	0.2517	0.3537	0.3729	0.6147	0.7033	0.7738	0.8211	0.8500

After the training is completed, data after normalization processing will be recovered and made post-processing, namely anti-normalization processing

$$\bar{y} = \frac{(\bar{y}_{\max} - \bar{y}_{\min})}{1.8971 - 0.1625}[\ln(\frac{1}{1 - y^{'}}) - 0.1625] + \bar{y}_{\min} \quad \textbf{(6)}$$

Setting of parameter

Transfer function: Sigmoid function; Weight value: initial weight value is generated in the section [-1, 1] by random function; Expectation error: Formula 2.

PRACTICAL EXAMPLE

Training process

Basing on the dimension of training samples in TABLE 2 and the data in TABLE 6, the training is carried out for the training model. When the number of nerve cells of the hidden layer is respectively 9, 12 and 15, the corresponding training convergence and error conditions are shown in Figures 2, 3 and 4 annd the eror values are shown in TABLE 4.

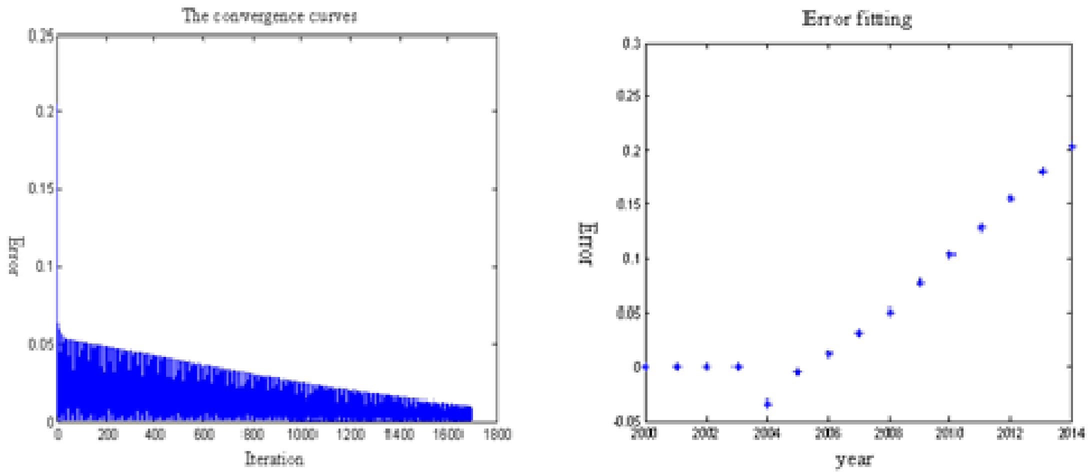

Figure 2 : Convergence and error condition of prediction model with number of neuron in hidden layer as 9

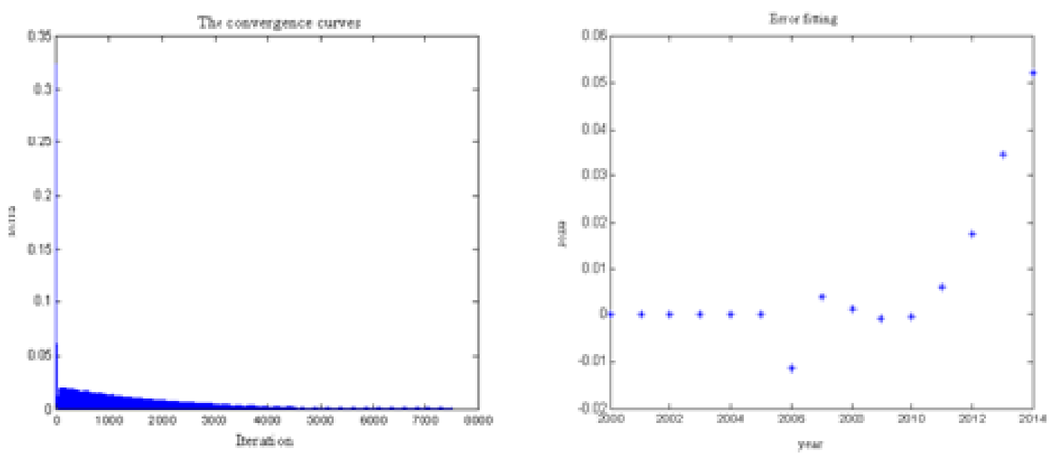

Figure 3 : Convergence and error condition of prediction model with number of neuron in hidden layer as 12

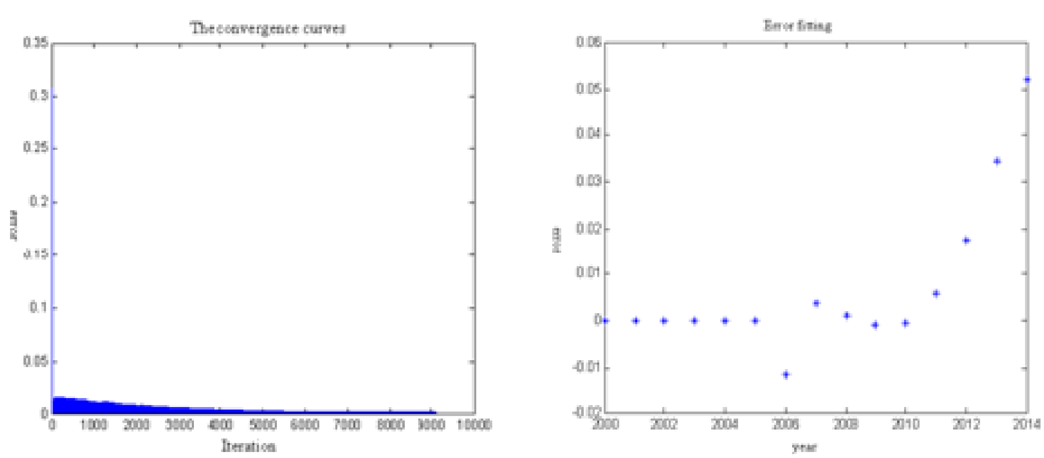

Figure 4 : Convergence and error condition of prediction model with number of neuron in hidden layer as 15

TABLE 4 : Convergence iteration and error value in the training process of prediction model

The number of neurons in input layer	The number of neurons in hidden layer	The number of neurons in output layer	Iteration	The error value
4	9	1	1694	0.9986
5	12	1	1121	1.1459
6	15	1	7520	0.0685

It can be seen from the above data that although the training modes 1 and 2 have fast convergence rate in training, the convergence precision is not high; although model 3 has slower convergence rate, the convergence precision is high. After trade-off, we selects the training model with 15 nerve cells in the hidden layer as the prediction model of demand of the food cold-chain logistics system of Hubei province.

Prediction results

The trained prediction model based on grey and AW-BP is used to predict the demand of the food cold-chain logistics system of Hubei province and the grey prediction value of total consumption of the cold-chain food of Hubei province from 2000 to 2013 is input to output the prediction value of the total cold-chain food consumption of the food cold-chain logistics system of Hubei province from 2000 to 2014. And the fitting and error of the prediction results are shown in Figure 5 and the prediction data are shown in TABLE 5.

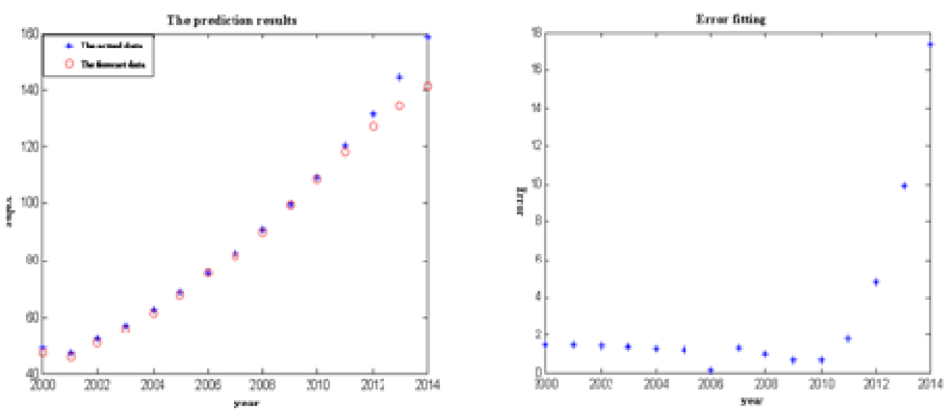

Figure 5 : Fitting figure and error figure for the prediction result of combination-type prediction model based on grey series and AW-BP

TABLE 5 : Prediction data of combination-type prediction model based on grey series and AW-BP

Year	2010	2011	2012	2013	2014
Prediction data	0.6716	0.7132	0.7454	0.7691	0.7866
The value of anti-normalization	108.3569	117.0470	124.6745	130.9339	136.0156

RESULT AND DISSCUSS

(1) The grey model and the prediction model based on grey and AW-BP are respectively used to predict the demand of the food cold-chain logistics system of Hubei province and all statistical performances are compared as shown in TABLE 6. It can be seen that: the two prediction models all can finish the prediction work. But compared with the prediction model based on grey and AW-BP, the statistical performances of the grey model are worse; based on the strong nonlinear processing capacity of BP neural network and the comprehensive optimizing of BP neural network, all statistical performances are improved by 2-3 orders of magnitude and the effect is remarkable.

TABLE 6 : Performance comparison between two prediction models

	MSE	*CD*	*MD*	*MAPE*
The grey prediction method	6.5841	0.9994	-0.0414	0.02717
The prediction model based on grey series and AW-BP	0.0157	0.9934	-0.0313	0.050600

(2) Aiming at some inherent defects of BP neural network, two important optimizing measures are provided in the paper: the first is to optimize the error function aiming at the problem of being easily caught in local optimum of BP neural network; the second is to adopt the method of dynamic adaptive weight value to optimize the search algorithm of BP neural network aiming at the slow rate of convergence of BP neural network at the late period of iteration. Experimental data show that the optimizing measures can obviously improve the precision and the robustness of prediction model and the optimizing ideas and measures are proper.

(3) The food cold-chain logistics system is a typical complex nonlinear system. In view of various reasons, the system is extremely lack of historical statistical data and the accuracy and the availability of the only statistical data are poor. The monomial prediction method is adopted for the prediction and the prediction results are not ideal. The grey prediction method is organically combined with BP neural network, all advantages of monomial prediction method are fully utilized and disadvantages are avoided. Therefore, terrific prediction results are achieved.

(4) It can be seen from the prediction data that the demand of the food cold-chain logistics system of Hubei province increases slightly year by year and the rate of increase is decreasing which is far lower than GDP. Thus it can be seen that the upsurge of the current infrastructure construction of cold-chain logistics is lack of rationality. If it is not stopped in time, serious result of resources and capital waste will be caused.

ACKNOWLEDGEMENT

This work was financially supported by The National Social Science Fund (Project Number: 14BJY139) ; Hubei Education Department Scientific Research Project (Project Number:Q20132206) ; Hubei Logistic Development Research Center Sponsored Project.

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