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Predicting natural gas consumption by using the back propagation neural network and the gray model

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ABSTRACT

The back propagation neural network and the gray model for predicting natural gas consumptionhave been introduced in the present article. Two new methods for predicting natural gas consumptionin China have also been pointed out based on the back propagation neural network and the gray model. The experimental results show that both models can predict natural gasconsumption in China and the experimental data are in agreement with the quantitative analytical conclusions drawn from the calculated data. This proves that two types of new models can be used to predictnatural gas consumption. It results in good economic and social benefits in China.

KEYWORDS

Predict;
Natural gas;
China;
Back propagation neural network;
Gray model

INTRODUCTION

Natural gas has a lot of advantages such as being clean,highly efficient, abundant and easily storable. The global natural gas yield and consumption in 2005 reached 2.763×10^{12} m^3 and 2.749×10^{12} m^3, respectively. The demands for natural gas had gradually increased to 3.3% of the global natural gas production every year and were 25% of total energy. Chinese natural gas consumption was only 1.7% of total world natural gas consumption; however Chinese increment in natural gas consumption got 20.8%. Natural gas as a clean energy is widely used in different areas such as electricity power, car market and residential fuel, etc[2].

In the present paper, the back propagation neural network and the gray modelhave been discussed. Two new methods for predicting natural gas consumption in China have also explained based on the back propagation neural network and the gray model.

DISCUSSION

The back propagation neural network[3]

A back propagation neural network was one type of an artificial network. RumelhartMcclellan pointed out the back propagation neural network[1]. It was supposed that N types of samples were.

$(x_j, y_j)(j = 1, 2, \cdots, N)$

Where x_j- output; y_j- hope output

The back propagation neural network solved was listed as follows.

(1) Each beginning value ($w = (\omega_1, \theta_1, \omega_2, \theta_2)$) did not equal 0 and a speed range was $0<U\leq 1$.

Where $\omega_1, \theta_1, \omega_2, \theta_2 \in R$- unknown parameters.

(2) Forward scatter propagation was calculated as fol-

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lows.

$h_j = g(\omega_1 x_j + \theta_1), (j = 1, 2, \cdots, n)$

$\hat{y}_j = f(\omega_2 x_j + \theta_2), (j = 1, 2, \cdots, n)$

Where $f, g - R \to R$'s differentiablefunction.

(3) Backward scatter propagation was described as follows.

$net_1 = \omega_1 x_j + \theta_1$

$net_2 = \omega_2 h_j + \theta_2$

$\delta_1 = (\omega_2 \delta_2) h^{'}(net_1)$

$\delta_2 = (y_i - \hat{y}) f^{'}(net_2)$

$e_1^j = \delta_1 \times x_j$

$e_2^j = \delta_1$

$e_3^j = \delta_2 \times h(net_1)$

$e_4^j = \delta_2$

(4) Weight average values were written as follows.

$$\omega_1^{'} = \omega_1 + u\sum_{j=1}^{N} e_1^j$$

$$\theta_1^{'} = \theta_1 + u\sum_{j=1}^{N} e_2^j$$

$$\omega_2^{'} = \omega_2 + u\sum_{j=1}^{N} e_3^j$$

$$\theta_2^{'} = \theta_2 + u\sum_{j=1}^{N} e_4^j$$

(5) Calculation would be stopped if error square ($SSE = \sum_{j=1}^{N}(y_j - \hat{y}_j)$) satisfied a given condition, otherwise go back step 2.

Predicting a model for natural gas consumption based on sample of a scatter diagram was written as follows.

$$y = \frac{k}{1 + be^{-ax}}$$

It was supposed that the beginning value (W), the speed (u) and the iteration number were (0.1,--0.1,0.1,0.1), 5×10^{-3} and 5216, respectively. The final results were listed as follows.

SSE = 1.999976

W = (0.227855, -0.103626,0.225404, 0.072450)

$$\hat{y} = \frac{13.798844}{1 + 3.449909e^{-0.227855x}}$$

TABLE 1 presented the results for predicting natural gas consumption. The experimental results showed that actual natural gas consumption was very close to predicting natural gas consumption, so the back propagation neural network was a good model for predicting natural gas consumption.

TABLE 1: The results for predicting natural gas consumption

Actual natural gas consumption (10^7 m^3)	Predicting natural gas consumption (10^7 m^3)	Relative error (%)
3.78	3.68	2.65
4.19	4.33	-3.34
4.83	5.03	-4.14
5.56	5.78	-3.96
6.71	6.56	2.24
7.99	7.34	8.14
8.60	8.12	5.58
9.24	8.86	4.11
9.67	9.56	1.14
9.87	10.20	-3.34
10.49	10.77	-2.67
10.92	11.27	-3.21
10.93	11.71	7.14
12.39	12.08	2.50
12.59	12.40	1.51

The gray model[3]

GM (1, 1) was one of the main and basic gray models. GM (1, 1) was described in details. The original samplein the sequence was listed as follows.

$$X^{(0)} = \left\{x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\right\}$$

New sequence based on the above equation was written as follows.

$$X^{(1)} = \left\{x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n)\right\}$$

$X^{(1)}$ wasdescribed as follows.

$x^{(1)}(t) = \sum_{i=1}^{t} x^{(0)}(i), (i = 1, 2, \cdots, n)$ or

$x^{(1)}(t) = \theta x^{(1)}(t) + (1-\theta) x^{(1)}(t+1), (t = 1, 2, \cdots, n \quad and\ 0 < \theta < 1)$.

It was supposed that $x^{(0)}(t) + ax^{(1)}(t) = b$. It was simply described as follows.

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b$$

Two parameters (a and b) were calculated with the least square method.

$X^{(0)}(t)$ and $X^{(1)}(t+1)$ were obtained as follows.

$$X^{(0)}(t) = X^{(1)}(t) - X^{(1)}(t-1) = (1-e^{a})(x^{(0)}(1) - \frac{b}{a})e^{(-at)},$$

$$(t = 1, 2, \cdots, n-1)$$

$$X^{(1)}(t+1) = (x^{(0)}(1) - \frac{b}{a})e^{(-at)} + \frac{b}{a}, (t = 1, 2, \cdots, n-1)$$

TABLE 2 showed the actual natural gas consumption in a given area. Based on the datum from TABLE 2, the results of predicting natural gas consumption were obtained and shown in TABLE 3. The experimental results presented that actual natural gas consumption was very close to predicting natural gas consumption, so the gray model was a good model for predicting natural gas consumption.

TABLE 2 : The actual natural gas consumption in a given area

Natural gas consumption (10^6 m^3)
1127.91
1244.25
1277.74
1298.25
1501.22
1616.12
1816.25
2012.78
2007.74
2051.07

TABLE 3 : The results of predicting natural gas consumption and relative errors

Actual natural gas consumption (10^6 m^3)	Predicting natural gas consumption (10^6 m^3)	Relative errors(%)
1616.12	1541.41	4.62
1816.25	1670.53	8.02
2012.78	1810.67	10.04
2007.74	1915.43	4.60
2051.07	2072.45	1.04

CONCLUSION

In this paper, the author has introduced that the back propagation neural network and the gray model lead to and are closely in accordance with predicting the practical experimental values. Natural gas consumption in China can be accurately estimated. Theback propagation neural network and the gray model point out that predicting natural gas consumption not only has a very important significance, but also provides a theoretical reference for chemical plants or oil companies. It is important for Chinese government to design and utilize rightly and optimize natural resources and may increase Chinese government's benefits. This mathematical method is effective, economic, simple and convenient, and thus it is suitable for chemical plants or oil companies in China.

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