Prediction of Gas Content Based on Analysis of Grey Association and PB Neural Network

Genyin Cheng[1], Liming Qi[2], Xuexi Chen[2], Yujiao Ma[2]

[1]*Division of Science & Technology North China Institute of Science and Technology Beijing, China.*

[2]*chool of Safety Engineering North China Institute of Science and Technology Beijing, China*

Email: gycheng@ncist.edu.cn

Abstract: Analyze gas content factors applied by gray association. The data was normalized, the grey association sequence of the factors were obtained and they are all above 0.6. List them form large to small: the thickness of mudstone(SSM) on roadway floor> the thickness of mudstone(SSM) on roadway roof> the thickness of coal roof> fault throw> the distance to the latest fault> buried depth. The six factors were inputted in artificial neural network, the value of gas emission is outputted after network forecasting. The result display that the average error between actual and forecasting data is 2.25%, the forecasting precision is so high that it can be used in coal mine production.

Keywords: gas content; forecasting; analysis of gray association; artificial neural network(ANN)

1. Introduction

The three kinds of factor of gas content in coal bed consist of gas storage condition, areal geological structure and mining work, it's easy or hard to deal with these factors quantificationally. The complication of geological condition and mining technique are caused by deeper exploitation of coal seam, so as the factors of gas content increased and have non-linear correlativity. The orthodox statistical analysis is unappeasable. The artificial neural network can represent the perplexing non-linear correlativity, and it have Fault-Tolerant, well. After network training using stated data, we can forecast objective data by inputting known number, so it can be good used in disasters prediction. The prediction process is actualized by Matlab artificial neural network toolbox. Mine is a typical grey system, so it's feasible to analyze it with gray association. The grey relational order is computed, and then we can establish the input unit of ANN. We can also eliminate the factors which has low linkage with gas content, it can help the network to increase operation speed, especially in complex data system[1-3].

2. Analysis of Gray Association

The three kinds of factor of gas content in coal bed consist of gas storage condition，areal geological structure and mining work, it's easy or hard to deal with these factors quantificationally. To improve the efficiency of ANN, use analysis of gray association to select the more important factors to train the network[4,5].

We regard 12 gas content data of 7# coal seam as reference sequence, and the corresponding six factors as comparative sequence: the thickness of mudstone(SSM) on roadway floor, the thickness of mudstone(SSM) on roadway roof, buried depth, the distance to the latest fault, fault throw, the thickness of coal roof, denoted as X_1、X_2、X_3、X_4、X_5、X_6.

Table 1. The quantified factors of gas content of 7# coal seam

ordinal number /k	measure location	X_0/gas content	X_1/ thickness of mudstone on roadway floor	X_2/ thickness of mudstone on roadway roof	X_3/ buried depth	X_4/ the distance to the latest fault	X_5/fault throw	X_6/ the thickness of coal roof
1	7708LZ	2.02	1.10	4.20	343.00	4.70	8.50	5.40
2	7708CL	2.09	1.20	4.30	293.00	1.30	5.00	5.50
3	7708CL	2.16	1.30	4.50	313.00	0.60	6.00	5.50
4	7503 LZ	0.4	0.25	0.90	328.00	5.40	3.30	5.20
5	7503C L	1.91	0.95	4.10	298.00	7.40	6.00	5.40
6	7503CL	1.8	0.90	3.90	323.00	5.80	8.50	5.30
7	7519CL	3.53	1.80	7.60	566.00	0.90	7.00	5.60
8	7519CL	3.46	1.70	7.40	523.00	0.50	9.50	5.60
9	7519 LZ	0.65	0.40	1.70	596.00	3.20	7.00	5.60

10	7519 LZ	0.72	0.40	1.80	568.00	0.60	5.20	5.60
11	7539 LZ	0.5	0.30	1.10	663.00	2.50	5.00	5.40
12	7539CL	0.54	0.30	1.20	650.00	1.00	5.00	5.10

Note: CL denote Cai Liao road, LZ denote Liu Zi road.

Because the difference of the units of the factors in gray system, we must Normalize the data firstly. For the forecasting system is atemporal sequence, interval-valued method is adopted to quantify the data to remove the dimension. The equation (1) are as follows.

$$X'_i(k) = \frac{X_i(k) - MinMinX}{MaxMaxX - MinMinX} \quad (1)$$

if $\Delta_i(k) = |X_0(k) - X_i(k)|$, the coefficient gray association between X_i and X_0 computed as (2).

$$\varepsilon_i(k) = \frac{MinMin\Delta_i(k) + \rho MaxMax\Delta_i(k)}{\Delta_i(k) + \rho MaxMax\Delta_i(k)} \quad (2)$$

ρ is regard as distinguishing coefficient, and ρ =0.5.

The (3) for association degree as follow.

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k) \quad (3)$$

In (1)-(3):

X_0 ——reference sequence;

X_i ——comparative sequence;

k ——sequence index;

γ_i ——the association degree between comparative sequence X_i and reference sequence X_0;

n ——the factor number.

Gray correlation coefficient of each factors calculated use the Matlab Numerical Computation Function,

and formula (1)-(3): $\gamma_1 = 0.9464$, $\gamma_2 = 0.9728$, $\gamma_3 = 0.6158$, $\gamma_4 = 0.6601$, $\gamma_5 = 0.6964$, $\gamma_6 = 0.7203$.

the sequence: $\gamma_2 > \gamma_1 > \gamma_6 > \gamma_5 > \gamma_4 > \gamma_3$, i.e: the thickness of mudstone(SSM) on roadway floor> the thickness of mudstone(SSM) on roadway roof> the thickness of coal roof> fault throw> the distance to the latest fault> buried depth. Because the coefficients are all above 0.6,so it's feasible to be inputting units.

3. ANN Forecasting

3.1 Sample Training

BP ANN is used to train the network, the training sample show in table 1. We define 6 inputting units, according to theorem Kolmogorov, the middle-layer nerve units defined 13, and outputting unit 1. The middle transfer function defined as tansig, output-layer function as logsig. For the inputting data had Normalized in gray association analyse, the data output between 0 and 1, it's feasible to the network[6-8].

The result of Web-based Learning show in figure 1.Error accuracy of net is small enough after 4 training.

Figure1　Training error curve of 7# coal seam

3.2 Sample Test

Select 4 groups of data form 12 groups of training sample stochastically, to evaluate the testing precision, the testing sample show in table 2, and the result show in figure 2.

Table.2　Testing sample of 7# coal seam

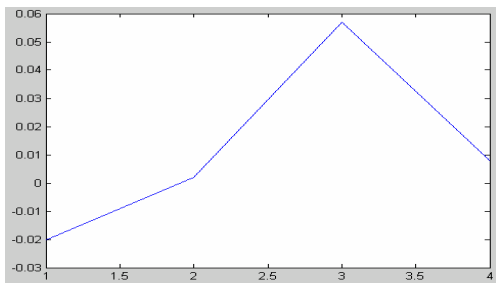| ordinal number	location	mudstone roadway floor thickness	mudstone roadway roof thickness	buried depth	latest fault distance	fault throw	coal roof thickness	Gas content
1	7708 CL	1.30	4.50	313.00	0.60	6.00	5.50	2.16
2	7503LZ	0.25	0.90	328.00	5.40	3.30	5.20	0.40
3	7503 CL	0.95	4.10	298.00	7.40	6.00	5.40	1.91
4	7539 L	0.30	1.10	663.00	2.50	5.00	5.40	0.50

Figure.2　predicting error curve of 7# coal seam

The errors tested by the 4 groups data are : 2%、0.2%、5.8%、0.7%, the average data is only 2.25%. so the ANN model of 7# coal seam is feasible to forecast the gas content data, if the influenced factors data are known.

3.3 Unknown Area Gas Content Forecasting of 7# Coal Seam

Geologic datum of eastern mine which show in table 3 is

collected firstly, input it into net, then, the program op-erate the gas content data which show in table 3.

Table .3 Forecasted gas content of 7$^{\#}$ coal seam

ordinal number	mudstone roadway floor **thickness**	mudstone roadway roof **thickness**	buried depth	latest fault distance	fault throw	coal roof thickness	Gas content
1	1.2	4.3	220	3.3	8.5	5.5	3.4173
2	1.1	4.1	200	2.8	12	4.7	2.0386
3	0.8	4.0	310	1.3	6.5	5.2	3.3519
4	0.5	1.4	330	2.6	3.3	4.9	0.4210
5	0.6	1.8	340	5.2	10	5.0	0.4360
6	0.9	2.3	340	1.3	10	6.1	0.8651
7	1.2	2.4	420	0.8	2.5	5.7	0.8889
8	1.1	2.2	440	1.2	3	5.8	0.8610
9	1.4	2.8	430	0.4	6.5	5.8	1.5265
10	0.6	2.4	510	0.5	14	5.6	1.0132
11	0.4	2.0	568	0.8	8	5.2	0.7299
12	0.6	1.8	320	6.5	5.2	5.5	0.4138
13	0.7	3.2	290	5.8	5.2	5.7	2.1963
14	1.1	4.2	270	9.8	2.8	6.0	3.5046
15	0.8	2.0	400	6.0	5.0	5.2	0.4247

4. Conclusions

(1)Apply analysis of gray association to normalize the geologic factors of coal seam: the thickness of mudstone(SSM) on roadway floor, the thickness of mudstone(SSM) on roadway roof, buried depth, the distance to the latest fault, fault throw, the thickness of coal roof, compute the gray association coefficient , so as to define the inputting units of ANN.

(2)the sequence of gray association coefficient show that, the most important gas content factors of Yao Qiao Mine are fault throw，and the thickness of mudstone(SSM) on roadway floor or roof, the more important factor are the thickness of coal roof, and buried depth.

(3) after 4 iterative algorithms, the ANN training error below 0.001, show that ANN model which established on the base of analysis gray association has High-precision, and it can be used to forecast gas content primely.

(4) The max and min data in ANN model array is not in the known data range, but the distensible data range which accord with real situation.

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