Prediction of Gas Emission by BP Neural Network Based On Wavelet Analysis

Xiucai Guo, Zhiqi Ren*, Qinsheng Wang, Chenchen Cui

School of Electrical and Control Engineering, Xi’an University of Science and Technology, Xi’an 710000, China

* Corresponding author e-mail: 1214298329@qq.com

Abstract. This paper proposes a wavelet denoising function and BP neural network self-learning and prediction of combining the mine working face gas emission prediction system, comprehensive utilization of denoising ability of wavelet analysis algorithm combined with BP neural network prediction ability of prediction system, designed. And by using data collected at the scene of the algorithm in MATLAB simulation test, the method is verified by the experiments on the predictions of a working face gas emission quantity has the very good effect.

1. The introduction

At present, most of the energy that our country relies on for economic development is still coal. Gas accident is the most important accident in coal mining. According to the statistics of coal mining gas accidents in China from 2006 to 2016, gas accidents account for one third of mine accidents. There are various causes of mine gas accidents. Based on the investigation and analysis of major and major accidents of mine gas in recent years, it is not difficult to find that the detection and warning of gas emission in coal mining operations and the inaccuracy of its rules before the occurrence of gas accidents are one of the main factors of gas accidents. Moreover, as the mining conditions of coal mine become more complex and more difficult, the gas accident caused by the massive emission of underground gas shows a more serious trend. Therefore, it is of great significance to forecast the amount of gas emission effectively, to grasp the variation law and trend of gas in underground coal mine, to prevent and control gas accidents and to guarantee the life safety of underground workers. So researchers at home and abroad have done a lot of research on the prediction of gas emission. It is found that the amount of gas emission on the working face is affected by many external mining factors and the combined effect of the environment. Different coal mines, different locations of different working points in the same coal seam, and the amount of gas emission on the working face is very different. 2. Grey relational ranking method; 3. Principal component analysis;

When using the above three commonly used methods for prediction, if the geological and environmental factors of the coal mining area change, the mathematical model also needs to be adjusted at the same time [1]. These changes will affect the timely accuracy of the prediction of gas emission. As coal mine monitoring system is increasingly perfect, how to use the monitoring system to save the history data to forecast the gas emission in recent years is a new direction in the field of gas prediction research, due to the above method to deal with the defects of gas emission problems this paper proposes a combination of wavelet analysis and neural network method to forecast the gas emission, wavelet function of powerful denoising ability to to filter the noise, the gas quantity of
collected in the application of neural network powerful ability of fitting in addition to realize the gas emission prediction.

2. Pretreatment of gas data

Mining working face in the environment is more complex, more various interference factors, therefore the sensor data collected in the gas has a different degree of error, if directly with the sensor to build up the forecast model on the collected data will lead to inaccurate prediction model, in order to solve this problem, is proposed in this paper a kind of gas data preprocessing method based on wavelet analysis. will get the data of gas sensor is processed to eliminate the disturbance variable, then the processed data as the training sample of neural network learning for training, Then the factors influencing the amount of gas emission are input into the trained gas prediction model to get the predicted value of the amount of gas emission.

2.1. Wavelet analysis of the filter noise processing

Wavelet analysis has powerful filtering ability, and wavelet function is the most commonly used way to filter and eliminate noise. The signal expression with noise is shown in equation (1):

\[ s(f) = f(i) + s \times e(i) \quad i=0, \ldots, n-1 \]  

Where, \( f(i) \) -- useful signals; \( E(i) \) -- Noise signal;

More than we take the noise model of one of the most simple to explain, \( e(I) \) as the white gaussian noise \( N(0, 1) \), noise level, noise level) to 1. In the real work that can be useful signals are generally characterized by low frequency and regular signal. The interference of noise signal is the high frequency signal, so the process of using wavelet to filter the noise can be used to deal with the following ways: First, the signal was decomposed by threshold threshold. The decomposition process is shown in figure 1, where \( cA1, cA2 \) and \( cA3 \) are useful signals, while noise signals are included in \( cd1, cd2 \) and \( cd3 \). The purpose of noise elimination can be achieved by recombination of decomposed signals processed by threshold threshold. The process of eliminating the noise signal \( s(I) \) is the process of suppressing the noise part of the signal so as to recover the real signal \( f(I) \) from \( s(f) \), as shown in figure 1 below

![Figure 1. Structure diagram of wavelet decomposition](image)
Figure 2. Steps of wavelet filter noise

The specific steps of wavelet denoising are shown in figure 2. In MATLAB, there is a ready-made tool box for wavelet analysis, which contains the commonly used functions for wavelet analysis de-noising, and these functions can be used to decompose and reconstruct the gas data to complete the de-noising. The commonly used wavelets for signal de-noising processing of wavelet analysis include Daubechies (dbN) wavelet, Coiflet (coifN) wavelet and SymletA (symN) wavelet. In this paper, based on wavelet theory analysis, db5 wavelet function and coif5 wavelet function in Daubechies (dbN) wavelet system were selected for filtering and comparison, and the default threshold filtering was adopted. The threshold selection rules are as follows:

1. 'Rigrsure': is an adaptive threshold selection based on stein's principle of unbiased likelihood estimation (quadratic equation)
2. 'Sqtwology': in the form of a fixed threshold, the resulting threshold size is SQRT (2*log (length(x))).
3. 'Heursure': is the synthesis of the first two thresholds, and is the selection of the optimal prediction variable threshold.
4. Minimaxi: it is also a fixed threshold, which produces an extreme value of the minimum mean square error, rather than no error.

With the wavelet function with more than four threshold filtering rules, with the resulting signal-to-noise ratio and the mean square error than to choose the optimal method and threshold rules [2], because of gas sensors in the field of gas data vulnerable to temperature, humidity, dust, noise and other disturbance and to the measured gas emission data of wavelet de-noising processing, based on the field measured average 26 sets of data will be one of the gas emission data processing, wavelet function and the use of MATLAB coif5 db5 wavelet function four rules of threshold filtering, the results are as follows:

Because the value of the parameter is too small to affect the filtering effect of the wavelet function, the parameters are all expanded by 100 times to filter the results, which are then applied after reducing the results by 100 times.
Figure 3. Effect of four threshold methods of db5 wavelet function after noise filtering

Figure 4. Effect of four threshold methods of coif5 wavelet function after noise filtering
The result of wavelet filter noise is judged by the SNR and mean square error. The result of the SNR and mean square error of db5 wavelet function and coif5 wavelet function in four threshold modes is shown in Table 1:

Table 1. Comparison data of filtering effect of two kinds of wavelet functions

| Wavelet function | db5 | db5 | db5 | db5 | Coif5 | Coif5 | Coif5 | Coif5 |
|------------------|-----|-----|-----|-----|-------|-------|-------|-------|
| Missing value method | minimaxi heursure sqtwology rigrsure minimaxi heursure sqtwology rigrsure |
| Signal-To-Noise ratio | 116.4908 | 121.108 | 103.7154 | 121.106 | 131.7125 | 146.7991 | 102.7858 | 146.7982 |
| Mean square error | 1.3374 | 1.0617 | 2.5332 | 1.0629 | 1.5367 | 0.2939 | 2.6538 | 0.2942 |

According to the above table, the best wavelet denoising effect is the coif5 wavelet function and the heursure threshold method. The values after wavelet de-noising are shown in Table 2 below for subsequent neural network training.

Table 2. Original data and filtered data

| sequence number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------|---|---|---|---|---|---|---|---|
| Gas gush (/m³·t⁻¹) | 4.58 | 4.58 | 4.78 | 4.32 | 4.26 | 4.34 | 4.19 | 4.64 |
| Gas gush after treatment (/m³·t⁻¹) | 4.5804 | 4.5814 | 4.7747 | 4.3221 | 4.2636 | 4.3387 | 4.1895 | 4.6385 |

3. Prediction of gas emission by neural network

In the process of coal mining, the gas content of coal mine gas alarm is measured by the percentage of gas, but the data of gas emission is collected by the gas collection system on the working face. In this paper, the gas emission of the working face is studied. According to the national standard of the prediction method of coal mine gas emission, when the coal mining environment is certain, there is a certain mathematical relationship between the gas emission amount and gas content of the mining face\(^{[3]}\), which can be deduced from each other according to the formula.

\[
q_i = D V q_i (2 \sqrt{\frac{V}{W}} - 1) \tag{2}
\]

\[
q_i = 0.026[0.0004(V^2) + 0.16]W_i \tag{3}
\]

\[
q_i = SV \rho(W_i - W) \tag{4}
\]
In equation (2)-(6):

\( Q \) —— gas emission from coal mine, \( \text{m}^3/(\text{m}^2\cdot\text{min}) \);

\( W_o \) —— Coal seam original gas content, \( \% \);

\( q_0 \) —— Gas gush intensity in coal mines, \( \text{m}^3/(\text{m}^2\cdot\text{min}) \);

\( q_1 \) —— Gas gush from the face of extraction, \( \text{m}^3/\text{min} \);

\( q_2 \) —— Gas gush from residual coal blocks on mining face, \( \text{m}^3/\text{min} \);

\( D \) —— Mining face coal wall circumference, \( \text{m} \);

\( V \) —— Average tunneling speed of roadway, \( \text{m/min} \);

\( S \) —— area of face, \( \text{m}^2 \);

\( \rho \) —— Density of coal, \( \text{t/m}^3 \);

\( V_h \) —— volatile component of coal, \( \% \);

\( W_c \) —— residual gas emission from coal transported out of well head, \( \text{m}^3/\text{t} \);

\( W_{cr} \) —— Combustible gas content of wcr-mining face, \( \text{m}^3/\text{t} \);

\( A \) —— coal ash content, \( \% \);

\( W \) —— moisture content of coal, \( \% \);

The coefficients of the above formula are summarized as follows:

\[
M = DV \left(2 \sqrt{\frac{V}{V_h}} - 1 \right)
\]

\[
C = 0.026 \left[0.0004(V')^2 + 0.16\right];
\]

\[
B = SV \rho; \quad G = W_{cr};
\]

Equation 7 can be simplified as follows:

\[
Q = MCW_o + BW_o - BG
\]

Is derived:

\[
W_o = \frac{Q + BG}{MC + B}
\]
internal weight and threshold through the back propagation of error, so as to reduce the nonlinear mapping error.

4. Simulation and analysis
The construction of BP neural network is mainly to determine the network parameters, which can make the data measured by sensor and some experience knowledge [6].

In front of the gas emission of the training set the input nodes and output node, the number of hidden layer nodes, respectively, 5, 6, 1, adopt trainlm learning algorithm, the maximum number of training is 1000, the target error is 0.00001, the training application in table 2 of the top 20 sets of data as the training sample[7], 6 sets of data after training as the test sample using mathematical software MATLAB to process as shown in figure 5, the result is shown in figure 6, test data and its error are shown in table 3 below:

![Simulation process](image1)

![Results curve of BP neural network simulation](image2)

**Table 3.** Forecast and actual gas values

| Gas expected output | 4.6750 | 4.6190 | 4.6194 | 4.6802 | 4.6154 | 4.6481 |
|---------------------|--------|--------|--------|--------|--------|--------|
| Gas actual output   | 4.6749 | 4.6191 | 4.6194 | 4.6806 | 4.6155 | 4.6484 |

The model trained by the neural network can be obtained from the above table, which is proved to be of great use value by its high accuracy in predicting gas content by relevant quantity.

5. summary
Based on wavelet analysis is a powerful denoising function of mining on the acquisition of vulnerable to environmental interference filter, the gas emission data of the gas data and filter the noise and the influencing factors of gas emission, coal seam thickness, burial depth, coal seam gas content, and the production and the degree of day advance data using BP neural network, the ability of self-learning and predicting are simulated, the results it is concluded that this method has the very good usability and model.

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