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The prediction of the gas emission with artificial neural network

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Abstract. This paper predicted the gas emission in mining face with the back propagation neural network, the radial basis function neural network and the general regression neural network. By comparing the measured values and the prediction values, it indicated that all of three artificial neural networks were capable of predicting the gas emission. And the radial basis function neural network showed the best performance in the prediction of the gas emission.

1. Introduction

Gas emission in mining face is a key factor which affects the safe production in the coal mining. According to the statistical data, the ratio between the deaths due to gas emission and the total deaths in the coal mining in China is 57.4% [1]. It demonstrated that the death caused by the gas emission is the primary death cause in the coal mining in China. Therefore, it will be useful to predict the gas emission in the coal mining, which could keep the production in safe and avoid the deaths. Since the last century, various methods were developed to predict the gas emission in coal mining, which included the statistical method, gas content method, calculation with sources method, and analogy method [2]. Although these traditional methods can be used to predict the gas emission, there were some limitations for those methods because those methods were built based on the linear relationship which were used to map the gas emission and the various factors. Since the factors affecting the gas emission are complicated, it is hard to describe those factors in linear relationship. Hence, the prediction of gas emission needs to find another method that can describe the non-linear relationship.

With the rapid development of computer technology and the artificial intelligence, artificial neural network (ANN) is applied to predict the gas emission. ANN has the characteristics of high parallel processing, highly nonlinear mapping and self-organizing structure. ANN does not need to know the exact relationship between input and output, and does not require a large number of parameters. It only needs to know the unsteady factor that causes the output change. Compared with traditional data



processing methods, ANN has advantages in predicting the gas emission with fuzzy data, random data and non-linear data.

The more common ANN that is used to predict the gas emitted is the back propagating neural network (BPNN) [3]. However, BPNN requires a large number of training samples to predict the gas emission, which the parameters of BPNN cannot be determined easily for the limited number of the training samples. Hence, the accuracy of the prediction by using BPNN is limited. Recently, the radial basis function neural network (RBFNN) and generalized recurrent neural network (GRNN) were developed to predict the gas emission. RBFNN and GRNN have a stable structure, faster convergence rate, higher accuracy in prediction. Therefore, RBFNN and GRNN were suitable for dealing with the non-linear problem such as gas emission prediction. In this paper, three ANNs including BPNN, RBFNN and GRNN are compared to predict the gas emission.

2. Method

2.1 Artificial Neural Network

The concept of ANN appeared in 1943 year [4]. BPNN is one of the most widely used ANN. BPNN contains a three-layer structure, which includes an input layer, a hidden layer and an output layer (see Figure 1). The hidden layer utilized the S type activation function, and the output layer had the form of a linear activation function.

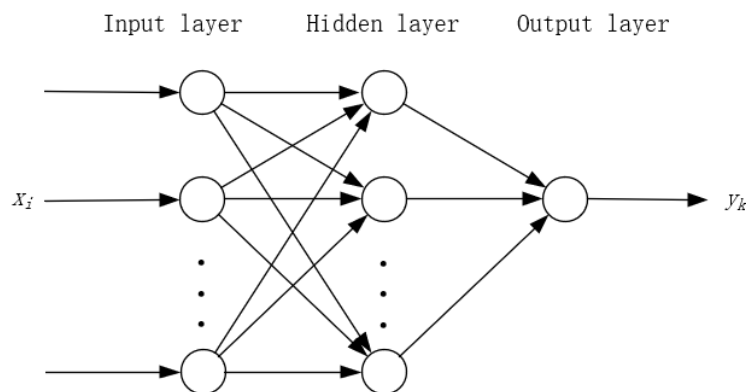


Figure 1. Back-propagation neural network structure map

RBFNN was proposed by Powell in 1985 [5]. RBFNN is also a three-layer network. Compared with BPNN, the activation function in the hidden layer in RBFNN is the radial basis function. The typical radial basis function is the Gaussian function, and the equation is below:

$$k(\|x - x_c\|) = e^{-\frac{\|x - x_c\|^2}{2\sigma^2}}$$

GRNN is developed based on RBFNN. The difference between the GRNN and RBFNN is that GRNN used the probability density function as the weight in the output layer.

The output mathematical expression of GRNN is:

$$\hat{Y} = E(y|X) = \frac{\int_{-\infty}^{\infty} y f(X, y) dy}{\int_{-\infty}^{\infty} f(X, y) dy}$$

where the $\hat{Y}$ is the output, and $f(X, y)$ is the joint probability density function.

$$\hat{Y} = \frac{\sum_{i=1}^n y_i e^{-\frac{\|x - x_{ci}\|^2}{2\sigma^2}}}{\sum_{i=1}^n e^{-\frac{\|x - x_{ci}\|^2}{2\sigma^2}}}$$

2.2 Evaluation Index

For the predictions of three ANNs the results are evaluated by the following indexes: Mean absolute error (MAE, Mean Absolute Error), mean absolute percent error (MAPE, Mean Absolute Percentage Error), RMS error (RMSE, Root Mean Square Error) and relative mean square error (RRMSE, Relative Root Mean Square Error). And their indicator expressions are as follows:

$$\begin{aligned} \text{MAE} &= \frac{1}{n} \sum_{i=1}^n |\hat{y}(i) - y(i)| \\ \text{MAPE} &= \frac{1}{n} \sum_{i=1}^n \left| \frac{\hat{y}(i) - y(i)}{y(i)} \right| \\ \text{RMSE} &= \sqrt{\frac{1}{n} \sum_{i=1}^n (\hat{y}(i) - y(i))^2} \\ \text{RRMSE} &= \sqrt{\frac{1}{n} \sum_{i=1}^n \left(\frac{\hat{y}(i) - y(i)}{y(i)} \right)^2} \end{aligned}$$

where $\hat{y}(i)$ represents the i prediction, and the $y(i)$ represents the i measured value; the n represents the number of predictions.

2.3 Data

The factors and the measured data of gas emission can be found in this paper [6].

3. Result

The predicted values of gas emission with the three ANNs were listed in the Table 1. And the measured gas emission and the three prediction values were showed in Figure 1. The evaluation indexes are showed in Table 2

Table 1. Predictions of gas emission with ANNs

No.	Measured Value	BPNN		GRNN		RFNN	
		Prediction	Relative Error	Prediction	Relative Error	Prediction	Relative Error
1	3.34	4.37	30.84%	4.09	22.38%	3.56	6.59%
2	2.97	4.04	35.89%	3.96	33.24%	3.56	19.87%
3	3.56	4.38	23.02%	3.10	-12.84%	3.34	-6.18%
4	3.62	3.82	5.55%	3.65	0.96%	4.17	15.19%
5	4.17	4.90	17.39%	3.72	-10.81%	3.62	-13.19%
6	4.60	4.69	2.05%	4.61	0.21%	4.92	6.96%
7	4.92	3.24	-34.23%	4.70	-4.51%	4.06	-17.48%
8	4.78	3.37	-29.59%	4.96	3.71%	5.23	9.41%
9	5.23	4.41	-15.71%	4.81	-8.13%	4.78	-8.60%
10	5.56	5.94	6.88%	3.21	-42.29%	5.23	-5.94%

11	7.24	8.08	11.62%	7.17	-1.00%	7.68	6.08%
12	7.80	7.45	-4.52%	7.97	2.22%	7.95	1.92%
13	7.68	5.38	-29.92%	7.49	-2.47%	7.24	-5.73%
14	8.51	8.02	-5.78%	6.99	-17.83%	8.04	-5.52%
15	7.95	7.15	-10.05%	6.64	-16.54%	8.04	1.13%
16	4.06	3.38	-16.80%	5.71	40.52%	4.92	21.18%
17	4.92	5.22	6.06%	5.15	4.68%	4.60	-6.50%
18	8.04	7.66	-4.78%	6.72	-16.46%	7.95	-1.12%

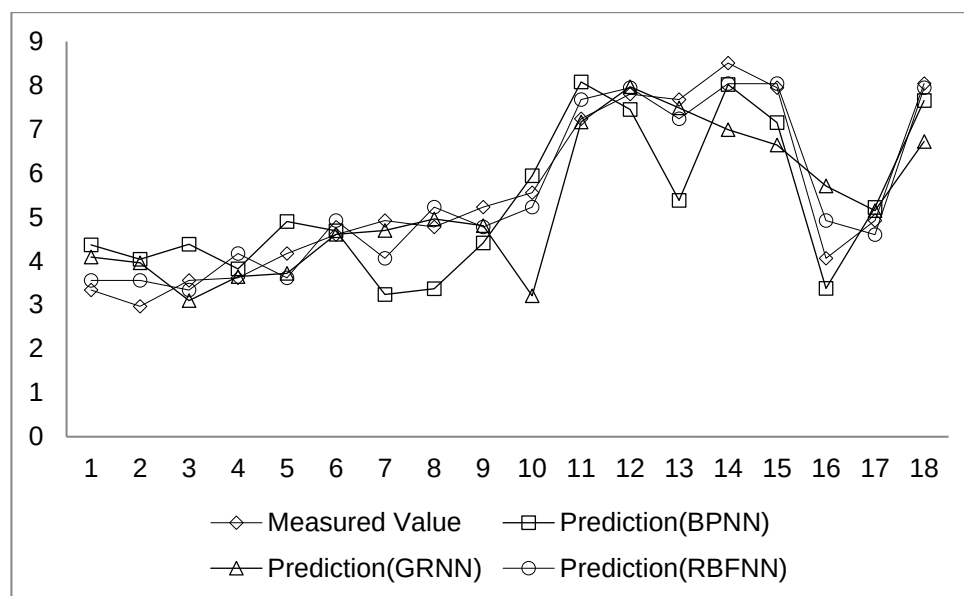


Figure 2. Prediction of gas emission with three ANNs

Table2. Evaluation index of three ANNs

Evaluation indicators	MAE	MAPE	RMSE	RRMSE
BPNN	0.7983	0.1614	0.9565	0.1969
GRNN	0.6844	0.1338	0.9631	0.1875
RBFNN	0.4111	0.0881	0.4652	0.1062

From **Table1**, it showed that the relative error between the measured data and the prediction by using the BPNN, GRNN and RBFNN is 16.14%, 13.38% and 8.81%, respectively. It demonstrated that the RBFNN can achieve the minimum error for predicting the gas emission. **Figure 2** also verifies the above results that the RBFNN was the best for predicting the gas emission of the three ANNs.

The evaluation index results showed that the MAE, MAPE, RMSE and RRMSE in the prediction by using RBFNN were 0.4111, 0.881, 0.4652 and 0.1062, respectively. All of the four indicators by using RBFNN were less than the other two ANNs.

4. Conclusion

The ANNs including BPNN, GRNN and RBFNN can be used to predict the gas emission in the coal mining. Moreover, the performance of RBFNN of the three ANNs is the best. The averaged relative error by using RBFNN is 8.81%, which was close to the measured data.

References

- [1] Jiang W, Huo Z and Qin Y 2008 Predicted technology of mine gas emission *Coal Science and Technology* **36** 1-4.
- [2] Li S and Jing X 2007 Study on the present situation and advancement of predicting gas emission amount *Shaanxi Coal* 20-22.
- [3] Zhu H, Chang W and Zhang B 2007 Different -source gas emission prediction model of working face based on BP artificial neural network and its application *Journal of China Coal Society* **32** 504-508.
- [4] Sun Z, Zhang J, Zhu L and Guo L 2007 Application of Artificial Neural Model for Predicting Gas in the Coal Mine *Journal of Hebei Institute of Technology* **29** 4-7.
- [5] Qiao J and Han H 2010 Optimal Structure Design for RBFNN Structure *Acta Automatica Sinica* **36** 865-872
- [6] Liu Y and Xiao G 2003 Estimation procedure of methane released from coal face using artificial neural networks *Safety in Coal Mines* **34** 11-13