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# Coal mine production logistics system security prediction based on RS-WNN

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## ABSTRACT

Coal mine production logistics system security state prediction is an important content of coal mine accident prevention and control. The paper proposed a prediction model of the coal mine production safety state based on rough set and wavelet neural network, The model using RS to determine the impact of the main influencing factors and then predict the safety status based on WNN. The empirical results show that the model in coal mine production logistics system security state prediction has high accuracy,which can help strengthen the prediction of coal mine safety state, enhancing the level of security. 

## KEYWORDS

Coal mine production logistics system;
RS;
WNN.

## INTRODUCTION

Mine production is a multi-link, multi-step production process complex system consisting of people, machines and environment, which existing various forms of disasters. In recent years, gas explosion, coal dust explosion, roof accident, flood, transportation, ascension and many other disasters occurred frequently in coal mining enterprises. They had seriously affected the people lives and caused great economic losses. Coal production compared with other industry has its obvious features, safety state of coal mine production logistics system is affected by many factors. The existing prediction work does not reach the designated position, making the safety state volatile. Therefore, to strengthen the prediction of coal mine production system safety state is conducive to timely eliminate the hazard which may cause disasters of coal mining enterprises and enhance the level of security.

Currently, many scholars studied evaluation and prediction of mine production logistics system security state. Hu Shanting[1] evaluate coal mine safety level control ability from the perspective of safety state; Gao Deli[2] points out that the use of combination evaluation method can improve the accuracy of coal mine safety risk assessment, which is a kind of effective method of coal mine safety risk assessment; Bai Nan[3] establish the grey prediction model by using B/S model and grey forecasting theory in view of the coal mine accident statistics, realizing the function of online management and prediction visualization. Visible, many scholars have proposed by using multiple linear regression[4,5], gray theory model[6] and many other nonlinear methods[7] to forecast coal mine safety state. But the existing prediction methods is lack of autonomous learning ability and uncertainty is bigger subjectively, in practice, there are many influence factors of coal mine safety state and they are volatile, which reduces the accuracy of these methods.

In recent years, neural networks have been widely used in the assessment and prediction of the safety state. Ma Liyi[8] used fuzzy neural network to analyse the information system security risk assessment; combining space vector theory, Fang Yong[9] used neural networks and fuzzy evaluation method to predict two-lane highway motor vehicle traffic safety; Chen Fan[10] used RBF neural network to analyse the subway construction risk assessment; Zhang Jianhua and li song use the BP neural network respectively evaluate security capacity about cotton diseases[11] and short-term traffic flow[12]. Visible, neural network is widely applied in all kinds of system security evaluation, but the existing neural network methods in practical application exist many problems such as the hidden layer nodes center value is difficult to determine[13], and it is easy to fall into local minimum and convergence speed is slow[14], affecting the accuracy of use. WNN's good time-frequency local features can make up for the shortcomings of these methods, but so far few people applied it to predict the coal mine production logistics system security state. In addition, In addition, in the coal production logistics system, a number of factors affect the safety state, If WNN is used directly in coal mine production logistics system, the network structure is quite complicated and learning speed is slow, besides the accuracy of prediction error is relatively large, leading to the result is not ideal.

Therefore, combining with the characteristics of coal mine production logistics system, this paper established a secure state prediction model based on RS-WNN. Dig out the main factors from a number of mine safety factors affecting the state, and predict the safety state of coal mine production logistics system through analyzing the main influence factors[15].

## THE ESTABLISHMENT OF THE PREDICTION MODEL

### The theory of RS

The theory of RS is a kind of data analysis theory that can process uncertain and fuzzy knowledge, classify the observation and analyzing data, find implicit knowledge in the process of classification and reveal the potential regularity. RS method can use set theory as the mathematical tool, simplify incomplete, inconsistent and imprecise data efficiently, calculate the minimum expression of knowledge and get reasonable decision scheme. Based on the principle of RS, its simple steps can be summarized as: (1) Based on observational data as row, based on data attribute as column, establish a decision table; (2) Delete redundant and wrong object, then sort decision table; (3) Under the condition of the compatibility of the decision table, reduce the attribute and cut the redundant attribute value; (4) Integrate of the decision table and merge the row.

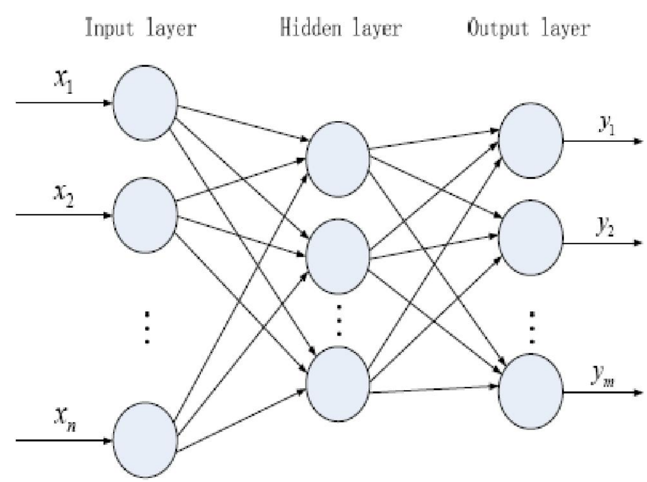
### The model of WNN

WNN can combine the wavelet transform with neural network organically, use wavelet basis function which is determined by the parallel and contraction factor instead of Sigmoid function in neural network[16], constitute WNN with less series items and implement the optimal approximation with a given time series. It has good prediction ability and faster convergence speed[17,18].

WNN is composed of input layer, hidden layer and output layer, as is shown in graph 1. In the application of the network, adjust the coefficient between each layer to realize the prediction of the network.

Specific steps are as follows:

Suppose $\mu_{ij}$, $\omega_{j}$ respectively as the connective weights between input layer and hidden layer, hidden layer and




**Graph 1 : The structure of WNN**

output layer, generate randomly in the interval (0, 1), and initialize the scale factor $a_j$ and shift factor $b_j$.

Calculate the output value $v'$

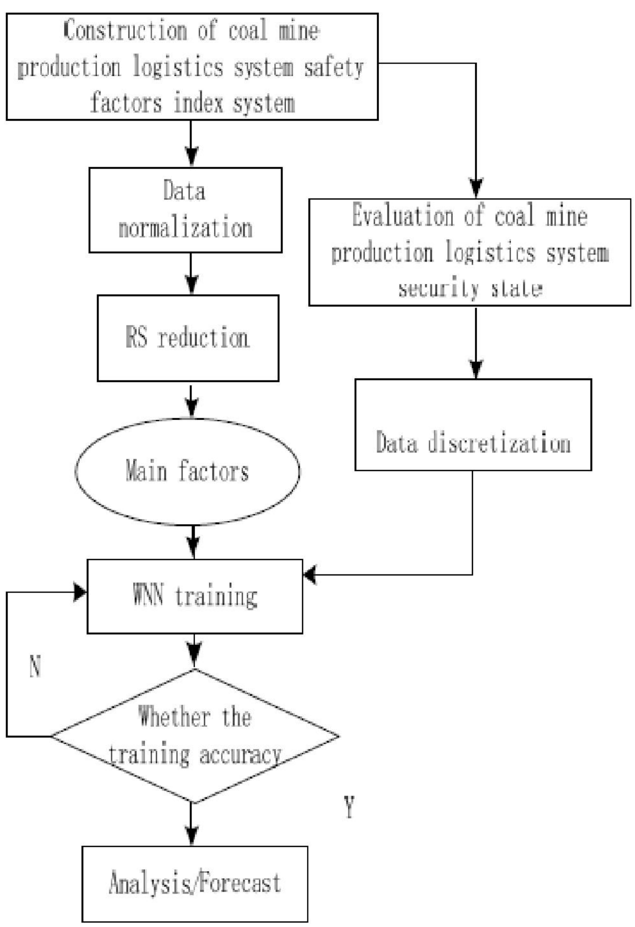
$$v'_n = \sum_{j=1}^{T} w_l h \left[ \left( \sum_{i=1}^{s} u_{ij} x_n(i) - b_j \right) / a_j \right] \quad \textbf{(1)}$$

For it, h is Morlet wavelet function, xn is input value. Adjust the parameters until the network output is within the range of standard error.

### The establishment of the prediction model based on RS -WNN

From the foregoing, RS method can selecte principle factors from a large number of factors; WNN algorithm not only can combine with the good self-study ability of neural network, but also can use the localization properties of wavelet transform, with strong fault tolerant approximation ability and good prediction ability. The security state prediction on coal mine production logistics system is a typical multi-factor forecasting, thus, this paper establishes a security state

prediction model on coal mine production logistics system based on RS and WNN, as is shown in graph 2.




**Graph 2 : Coal mine production logistics system security state prediction model**

First, the hybrid model proposed in this paper, finds out the major influence factors of the security state of coal mine production logistics system by using RS method; Second, the training set consist of the main influence factors is trained by using WNN; Finally, predict the security state of coal mine production logistics system by using WNN model after the training.

## EMPIRICAL STUDY

### A To select coal mine production logistics system security state factors

Refering to the "Coal Mine Safety Regulations", determine the original factors of coal mine production logistics system security state from 30 coal enterprises of Henan Pingdingshan Coal Group, Jiaozuo Coal Group, Zhengzhou Coal Industry Group and other eight coal enterprises. From the economic and social factors, regulatory factors, production technology, accident treatment and logistics capability factors, build factors index system of coal mine production logistics system security state, See TABLE 1.

### B Data collection and processing

Standardize qualitative and quantitative indicators included evaluation system, to make the indicators comparable across the entire system.

### (1) Quantitative indexes

In quantitative indicators, Poor is big and small and tend is not necessarily in the same, For the measurement unit is inconsistent differential have greatly small, incline to is not necessarily the same, so we must be performed with chemotaxis and standardized treatment, method is as follows:

The bigger the better about assessing trends:

$$F_i = (x_i - x_{i\min}) / (x_{i\max} - x_{i\min}) \quad \textbf{(2)}$$

The smaller the better about assessing trends:

$$F_i = (x_i - x_{i\max}) / (x_{i\max} - x_{i\min}) \quad \textbf{(3)}$$

Among them, $x_{j\min}$ is the minimum value of the j-th

TABLE 1 : Security state factors index system

| Level indicators | secondary indicators |
|---|---|
| economic and social | Coal consumption $c_1$,<br>security funds utilization rate $c_2$,<br>security funds utilization rate $c_3$ |
| regulatory | Security qualified team percentage $c_4$,<br>safety review success rate $c_5$,<br>testing and inspection facilities $c_6$ |
| production technology | Machinery and equipment operating conditions $c_7$,<br>special types certified rate $c_8$, gas drainage rate $c_9$ |
| accident treatment | Scene purification and recovery compliance rate $c_{10}$,<br>medical rescue efficiency $c_{11}$,<br>accident warning technology $c_{12}$ |
| logistics capability | Tunnel ventilation evaluate situation $c_{13}$,<br>transportation distribution capability $c_{14}$, emergency logistics scheduling command ability $c_{15}$ |

index has been determined, $x_{j\max}$ is the maximum of the j-th index identified; $F_j$ is the standardization of target value.

**(2)Qualitative indexes**

In view of the qualitative indexes, this paper organized expert panel to conduct research from 30 mines selected above. Obtain quantitative results by the use of expert scoring method, then make standardized treatment. The approach is similar to quantitative indicators approach.

Organize the assessment results of 30 mines based on the data processing method above. Assess the security levels by the 2013 coal mine safety quality standardization evaluation rating method, and the safety state of coal mine production logistics system is divided into relatively safe, safe and less safe 3 levels. The results are shown in TABLE 2.

The Data reduced by RS targets must be discrete. Firstly discrete data preprocessing before attribute reduction. The value range is represented by [90,100), [80,90), [70,80), [60,70), (0,60). Using discrete data 4, 3, 2, 1, 0 to respective each score range, Meanwhile express coal mine safety state at three levels in discrete data 3, 2, 1. Discrete data obtained are shown in TABLE 3.

According to the basic steps of RS reduction, establish the discernable matrix, a=5%, attribute reduced, results are shown in TABLE 4.

The reduction simplifies the original subjective evaluation system, the index system reduced are as follows:security funds utilization rate$C_2$, safety review success rate $C_5$, Machinery and equipment operating conditions $C_7$, accident warning technology $C_{12}$, tunnel ventilation evaluate situation $C_{13}$, transportation distribution capability $C_{14}$, As the input vector of the WNN.

## C The train of evaluation model and the result analysis

(1) The determination of input layer and output layer then to qualitative, converts qualitative to quantitative output through output through RS-WNN model and then makes qualitative predictions on the security state of coal mine production logistics system by synthesizing the evaluation set and the output result. This paper uses the factor index number after the reduction as the number of input layer neurons, security assessment level of coal mine production logistics system as the output layer. In conclusion, we can set up six input-output network.

(2) The determination of the hidden layer and hidden layer wavelet function

This paper uses three layers of WNN with single hidden layer to madel. During the modeling, set the initial vector as 0.002 and momentum coefficient as 0.002,

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TABLE 2 : Coal mine production logistics system security state factors quantization table

| Coal mine | The evaluation index | | | | | | | | | | | | | | | Coal mine safety level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $c_6$ | $c_7$ | $c_8$ | $c_9$ | $c_{10}$ | $c_{11}$ | $c_{12}$ | $c_{13}$ | $c_{14}$ | $c_{15}$ | |
| 1 | 84 | 66 | 64 | 58 | 58 | 92 | 76 | 95 | 83 | 69 | 72 | 69 | 78 | 68 | 85 | relatively safe |
| 2 | 59 | 68 | 59 | 76 | 74 | 58 | 49 | 72 | 61 | 76 | 86 | 58 | 91 | 76 | 59 | less safe |
| 3 | 55 | 94 | 86 | 53 | 59 | 79 | 81 | 82 | 78 | 91 | 69 | 59 | 75 | 68 | 57 | relatively safe |
| 4 | 59 | 78 | 63 | 69 | 68 | 63 | 59 | 78 | 67 | 57 | 75 | 49 | 81 | 66 | 56 | less safe |
| 5 | 91 | 75 | 76 | 84 | 91 | 90 | 86 | 89 | 77 | 68 | 84 | 84 | 86 | 94 | 91 | safe |
| 6 | 81 | 76 | 86 | 76 | 86 | 84 | 35 | 85 | 84 | 65 | 75 | 39 | 79 | 84 | 80 | safe |
| 7 | 88 | 72 | 77 | 64 | 38 | 86 | 76 | 76 | 66 | 67 | 58 | 58 | 48 | 49 | 83 | relatively safe |
| 8 | 57 | 72 | 64 | 76 | 76 | 65 | 84 | 68 | 58 | 76 | 69 | 71 | 65 | 67 | 57 | less safe |
| 9 | 61 | 58 | 68 | 87 | 58 | 87 | 81 | 71 | 82 | 81 | 76 | 76 | 69 | 58 | 84 | safe |
| 10 | 68 | 69 | 89 | 91 | 51 | 85 | 67 | 81 | 71 | 75 | 75 | 48 | 48 | 57 | 84 | relatively safe |
| 11 | 68 | 79 | 76 | 86 | 87 | 91 | 59 | 95 | 82 | 81 | 81 | 68 | 58 | 77 | 75 | relatively safe |
| 12 | 89 | 58 | 61 | 72 | 84 | 76 | 79 | 82 | 94 | 92 | 75 | 65 | 75 | 94 | 76 | safe |
| 13 | 85 | 84 | 82 | 64 | 76 | 71 | 85 | 76 | 82 | 86 | 74 | 83 | 76 | 86 | 69 | relatively safe |
| 14 | 57 | 67 | 49 | 59 | 76 | 59 | 76 | 68 | 75 | 76 | 76 | 86 | 76 | 76 | 90 | less safe |
| 15 | 72 | 82 | 72 | 81 | 68 | 82 | 76 | 62 | 71 | 82 | 82 | 58 | 48 | 72 | 82 | relatively safe |
| 16 | 91 | 78 | 58 | 70 | 82 | 91 | 59 | 59 | 48 | 81 | 84 | 56 | 72 | 58 | 70 | less safe |
| 17 | 83 | 46 | 67 | 76 | 56 | 72 | 39 | 58 | 75 | 49 | 91 | 59 | 68 | 82 | 59 | less safe |
| 18 | 76 | 35 | 60 | 67 | 58 | 82 | 47 | 81 | 85 | 82 | 72 | 39 | 58 | 78 | 85 | relatively safe |
| 19 | 71 | 90 | 72 | 78 | 62 | 64 | 94 | 82 | 76 | 86 | 81 | 78 | 77 | 86 | 76 | safe |
| 20 | 59 | 94 | 90 | 58 | 94 | 58 | 89 | 76 | 89 | 78 | 76 | 79 | 85 | 78 | 68 | safe |
| 21 | 82 | 84 | 84 | 60 | 55 | 82 | 76 | 91 | 85 | 68 | 92 | 59 | 78 | 87 | 92 | relatively safe |
| 22 | 69 | 85 | 73 | 93 | 75 | 81 | 49 | 67 | 92 | 59 | 71 | 58 | 68 | 58 | 82 | relatively safe |
| 23 | 61 | 76 | 81 | 81 | 77 | 87 | 81 | 85 | 58 | 81 | 68 | 59 | 64 | 49 | 73 | relatively safe |
| 24 | 87 | 78 | 84 | 91 | 83 | 84 | 59 | 91 | 75 | 57 | 92 | 49 | 75 | 86 | 82 | relatively safe |
| 25 | 86 | 59 | 92 | 72 | 74 | 59 | 86 | 82 | 85 | 71 | 84 | 84 | 79 | 85 | 71 | safe |
| 26 | 59 | 67 | 76 | 76 | 45 | 82 | 35 | 87 | 76 | 76 | 75 | 39 | 68 | 39 | 81 | safe |
| 27 | 68 | 89 | 58 | 81 | 45 | 84 | 76 | 85 | 84 | 68 | 72 | 58 | 39 | 58 | 84 | relatively safe |
| 28 | 72 | 87 | 48 | 67 | 68 | 92 | 84 | 71 | 91 | 82 | 82 | 71 | 81 | 68 | 85 | relatively safe |
| 29 | 81 | 60 | 71 | 69 | 54 | 81 | 81 | 82 | 70 | 89 | 67 | 76 | 71 | 48 | 59 | less safe |
| 30 | 90 | 51 | 89 | 59 | 58 | 87 | 67 | 59 | 58 | 81 | 69 | 48 | 58 | 73 | 82 | less safe |

select the maximum error learning method and determine the total iterative error of the network model as 0.001 and the biggest learning count as 2000. As there is not yet a certain method to select the hidden layer of the wavelet function of WNN, this paper adopts the trial and error method, that is the other parameters are constant, using different wavelet functions for training, testing model, comparing each target error and finding out the optimal wavelet function. The wavelet function determined by this method is Morlet wavelet function[22], the expression is:

$$\psi(t) = \cos(1.75t)\exp\left(\frac{-t^2}{2}\right) \quad (4)$$

(3) The evaluation of the model of training

Based on the WNN model, this prediction model is trained in the experimental platform of MATLABR2012b, uses 20 groups'data from the 30 groups'data surveyed as the training sample, 10 groups as the test sample. The training sample can be input into the WNN for self-learning training and get the final weight, as is shown in TABLE 5. Then use the trained network to test samples.

For convenient for comparison, WNN and RS-WNNwere tested respectively in the simulation. All the data had been trained and tested. The MSE curves of

**TABLE 3 : Discrete data Table**

| Coal mine | Condition attributes | | | | | | | | | | | | | | | Decision attribute |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $c_6$ | $c_7$ | $c_8$ | $c_9$ | $c_{10}$ | $c_{11}$ | $c_{12}$ | $c_{13}$ | $c_{14}$ | $c_{15}$ | |
| 1 | 3 | 1 | 1 | 0 | 0 | 4 | 1 | 4 | 3 | 1 | 2 | 0 | 2 | 1 | 3 | 2 |
| 2 | 0 | 1 | 0 | 2 | 2 | 0 | 3 | 2 | 1 | 2 | 3 | 1 | 4 | 2 | 0 | 1 |
| 3 | 0 | 4 | 3 | 0 | 0 | 2 | 1 | 3 | 2 | 4 | 1 | 3 | 2 | 1 | 0 | 2 |
| 4 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 2 | 1 | 0 | 2 | 2 | 3 | 1 | 0 | 1 |
| 5 | 4 | 2 | 2 | 3 | 4 | 4 | 2 | 3 | 2 | 1 | 3 | 3 | 3 | 4 | 4 | 3 |
| 6 | 3 | 2 | 3 | 2 | 3 | 3 | 4 | 3 | 3 | 1 | 2 | 3 | 2 | 3 | 3 | 3 |
| 7 | 3 | 2 | 2 | 1 | 0 | 3 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 2 |
| 8 | 0 | 2 | 1 | 2 | 2 | 1 | 3 | 1 | 0 | 2 | 1 | 0 | 1 | 1 | 0 | 1 |
| 9 | 1 | 0 | 1 | 3 | 0 | 3 | 0 | 2 | 3 | 3 | 2 | 3 | 1 | 0 | 3 | 3 |
| 10 | 1 | 1 | 3 | 4 | 0 | 3 | 2 | 3 | 2 | 2 | 2 | 0 | 0 | 0 | 3 | 2 |
| 11 | 1 | 3 | 2 | 3 | 0 | 4 | 2 | 4 | 3 | 3 | 3 | 0 | 2 | 3 | 2 | 2 |
| 12 | 3 | 3 | 1 | 2 | 2 | 2 | 0 | 3 | 4 | 4 | 2 | 0 | 1 | 0 | 2 | 3 |
| 13 | 3 | 2 | 3 | 1 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 0 | 1 | 0 | 1 | 2 |
| 14 | 0 | 2 | 0 | 0 | 3 | 0 | 0 | 1 | 2 | 2 | 2 | 0 | 2 | 3 | 4 | 1 |
| 15 | 2 | 0 | 2 | 3 | 2 | 3 | 3 | 1 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 2 |
| 16 | 4 | 1 | 0 | 2 | 0 | 4 | 0 | 0 | 0 | 3 | 3 | 0 | 1 | 0 | 2 | 1 |
| 17 | 3 | 3 | 1 | 2 | 0 | 2 | 2 | 0 | 2 | 0 | 4 | 0 | 0 | 0 | 0 | 1 |
| 18 | 2 | 3 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 1 | 3 | 2 |
| 19 | 2 | 1 | 2 | 2 | 2 | 1 | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 0 | 2 | 3 |
| 20 | 0 | 0 | 4 | 0 | 0 | 0 | 1 | 2 | 3 | 2 | 2 | 0 | 0 | 2 | 1 | 3 |
| 21 | 3 | 2 | 3 | 1 | 3 | 3 | 0 | 4 | 3 | 1 | 4 | 1 | 0 | 2 | 4 | 2 |
| 22 | 1 | 0 | 2 | 4 | 3 | 3 | 2 | 1 | 4 | 0 | 2 | 1 | 2 | 4 | 3 | 2 |
| 23 | 1 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 0 | 3 | 1 | 3 | 2 | 3 | 2 | 2 |
| 24 | 3 | 1 | 3 | 4 | 2 | 3 | 2 | 4 | 2 | 0 | 4 | 3 | 2 | 2 | 3 | 2 |
| 25 | 3 | 3 | 4 | 2 | 1 | 0 | 2 | 3 | 3 | 2 | 3 | 0 | 0 | 2 | 2 | 3 |
| 26 | 0 | 2 | 2 | 2 | 3 | 3 | 0 | 3 | 2 | 2 | 2 | 0 | 2 | 0 | 3 | 3 |
| 27 | 1 | 0 | 0 | 3 | 0 | 3 | 0 | 3 | 3 | 1 | 2 | 0 | 1 | 3 | 3 | 2 |
| 28 | 2 | 0 | 0 | 1 | 0 | 4 | 0 | 2 | 4 | 3 | 3 | 0 | 0 | 2 | 3 | 2 |
| 29 | 3 | 4 | 2 | 1 | 1 | 3 | 4 | 3 | 2 | 3 | 1 | 2 | 2 | 3 | 0 | 1 |
| 30 | 4 | 4 | 3 | 0 | 4 | 3 | 3 | 0 | 0 | 3 | 1 | 2 | 3 | 2 | 3 | 1 |

**TABLE 4 : Attribute reduced results**

| Reduced order | Reduction index | a (%) | Whether can be reduced |
|---|---|---|---|
| 1 | $C_{11}$, $C_8$ | 0 | Yes |
| 2 | $C_{11}$, $C_8$, $C_3$ | 0 | Yes |
| 3 | $C_{11}$, $C_8$, $C_3$, $C_6$, $C_9$ | 0 | Yes |
| 4 | $C_{11}$, $C_8$, $C_3$, $C_6$, $C_9$, $C_4$, $C_1$ | 0 | Yes |
| 5 | $C_{11}$, $C_8$, $C_3$, $C_6$, $C_9$, $C_4$, $C_1$, $C_{10}$, $C_{15}$ | 6.27 | No |

the models were showed as graph 3 and graph 4.

As the TABLE 3 and TABLE 4 showed, WNN outperformed NN in the precision and rate of convergence. After nearly 1000 times iteration, MSE of simply use WNN had decreased from 0.1 to 0.05. Also MSE of GA-WNN had dropped to 0.04 by less than 500 times iteration, of which the rate of convergence was obviously higher than that of simply use WNN.

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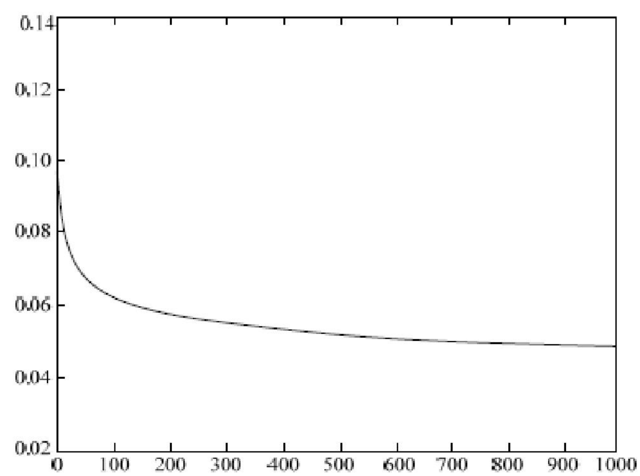
TABLE 5 : Training sample

| NO. | $c_2$ | $c_5$ | $c_7$ | $c_{12}$ | $c_{13}$ | $c_{14}$ | Assessment level | Coal mine safety level |
|---|---|---|---|---|---|---|---|---|
| 1 | 66 | 58 | 69 | 55 | 78 | 68 | 2.687 | normal |
| 2 | 68 | 74 | 85 | 69 | 91 | 76 | 3.742 | better |
| 3 | 94 | 59 | 64 | 85 | 75 | 68 | 2.894 | normal |
| 4 | 78 | 68 | 52 | 72 | 81 | 66 | 2.781 | normal |
| 5 | 75 | 91 | 74 | 84 | 86 | 94 | 4.587 | best |
| 6 | 76 | 86 | 94 | 81 | 79 | 84 | 4.674 | best |
| 7 | 72 | 38 | 48 | 58 | 48 | 49 | 0.783 | worst |
| 8 | 72 | 76 | 86 | 57 | 65 | 67 | 2.642 | normal |
| 9 | 58 | 58 | 47 | 84 | 69 | 58 | 1.587 | worse |
| 10 | 69 | 51 | 72 | 48 | 48 | 57 | 1.919 | worse |
| 11 | 79 | 87 | 59 | 68 | 58 | 77 | 4.146 | better |
| 12 | 58 | 84 | 79 | 65 | 75 | 94 | 3.575 | better |
| 13 | 84 | 76 | 85 | 83 | 76 | 86 | 2.097 | normal |
| 14 | 67 | 76 | 76 | 86 | 76 | 76 | 3.247 | better |
| 15 | 82 | 68 | 76 | 58 | 48 | 72 | 3.502 | better |
| 16 | 78 | 82 | 59 | 56 | 72 | 58 | 1.496 | worse |
| 17 | 46 | 56 | 39 | 59 | 68 | 82 | 4.434 | best |
| 18 | 35 | 58 | 47 | 39 | 58 | 78 | 3.579 | better |
| 19 | 90 | 62 | 94 | 78 | 77 | 86 | 1.386 | worse |
| 20 | 94 | 94 | 89 | 79 | 85 | 78 | 1.117 | worse |

TABLE 6 : Test sample

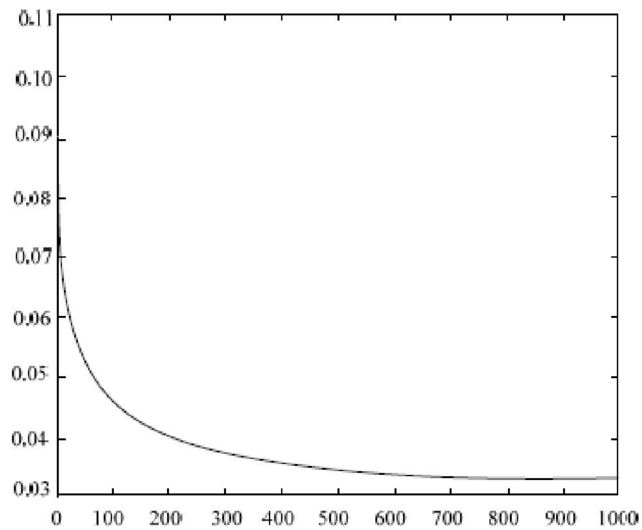
| NO | $c_2$ | $c_5$ | $c_7$ | $c_{12}$ | $c_{13}$ | $c_{14}$ | Assessment level | Coal mine safety level |
|---|---|---|---|---|---|---|---|---|
| 1 | 84 | 55 | 76 | 59 | 78 | 87 | 3.120 | better |
| 2 | 85 | 75 | 49 | 58 | 68 | 58 | 4.242 | better |
| 3 | 76 | 77 | 81 | 59 | 64 | 49 | 2.617 | best |
| 4 | 78 | 83 | 59 | 49 | 75 | 86 | 2.113 | normal |
| 5 | 59 | 74 | 86 | 84 | 79 | 85 | 3.721 | best |
| 6 | 67 | 45 | 35 | 39 | 68 | 39 | 4.667 | better |
| 7 | 89 | 45 | 76 | 58 | 39 | 58 | 0.856 | worse |
| 8 | 87 | 68 | 84 | 71 | 81 | 68 | 3.303 | better |
| 9 | 60 | 54 | 81 | 76 | 71 | 48 | 4.497 | better |
| 10 | 51 | 58 | 67 | 48 | 58 | 73 | 1.625 | worse |



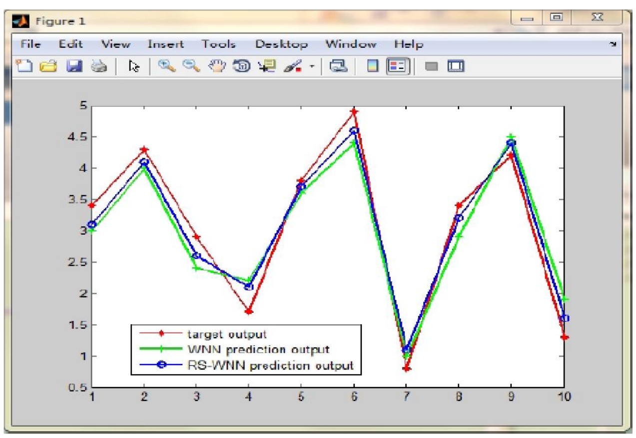

Graph 3 : WNN results

TABLE 7 : Test/output comparison

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| target output | | 3.402 | 4.389 | 2.701 | 1.624 | 3.762 | 4.820 | 0.586 | 3.430 | 4.825 | 1.196 |
| WNN | Prediction output | 3.000 | 4.152 | 2.477 | 2.200 | 3.621 | 4.562 | 0.782 | 2.877 | 4.500 | 1.703 |
| | absolute error | 0.402 | 0.267 | 0.224 | 0.576 | 0.141 | 0.258 | 0.196 | 0.553 | 0.325 | 0.507 |
| | relative error | 7.8% | 6.1% | 8.2% | 5.5% | 3.7% | 5.4% | 9.4% | 6.1% | 6.7% | 4.3% |
| RS-WNN | Prediction output | 3.120 | 4.242 | 2.617 | 2.113 | 3.721 | 4.667 | 0.856 | 3.303 | 4.497 | 1.625 |
| | absolute error | 0.282 | 0.147 | 0.084 | 0.489 | 0.059 | 0.153 | 0.260 | 0.127 | 0.328 | 0.429 |
| | relative error | 6.3% | 3.3% | 3.1% | 3.1% | 1.6% | 3.2% | 4.4% | 3.8% | 6.8% | 5.9% |




**Graph 4 : RS-WNN result**




**Graph 5 : Test/output**

Test 10 data be not used as training samples in TABLE 6 in RS trained, meanwhile, compare target output, WNN prediction output and RS-WNN prediction output, the results are shown as graph 5.

For testing the effectiveness of proposed method, the paper had made analysis and comparison with simply use WNN, and predicted the results by using common measure index, including absolute error and relative error. The results were showed as TABLE 7. Conclusion can be made from TABLE 7 that the average relative error of WNN was 7.32%, and the average relative error of RS-WNN was 4.35%. It can be seen that, the predicting results of using RS-WNN is much closer to the actual safe state output of coal mine production logistics system with less error. Also, the prediction results by simply using WNN had more error compared to original data and more time was taken than which RS-WNN method used. So by using RS to optimize WNN as the paper proposed is quite successful.

## CONCLUSIONS

To increase the prediction accuracy of safe state of coal mine production logistics system, the paper had proposed a predicting method of safe state of coal mine production logistics system based on RS and WNN. The model had fully make use of the advantages of each theory, and introduced the combined method based on RS and WNN into prediction of safe state of coal mine production logistics system. By adapting RS method, elements that affect the safe state can be effectively reduced which could decrease the number of the input neurons of WNN, simplify the network structure and shorten the training. The model test analysis showed that RS-WNN could remedy the predicting defects of simply adapting WNN. The average relative error of prediction was much lower than that of simply adapting WNN. The combined method is quite practicable with high precision in the prediction of safe state of coal mine production logistics system with lots of influencing factors.

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