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Application of network model in coal mine safety management strategy[1]

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Abstract. In order to study the strategy of coal mine safety management and the application of network model in management, in this paper, through consulting a large number of documents and expert interviews, and combining genetic algorithm and fuzzy neural network model, the deep cause of coal mine safety accident was analyzed, the cause model of coal mine safety production was constructed, and the neural network was optimized. The results showed that the main factors of safety production in coal mine enterprises mainly included 5 aspects: management system, man, machine, environment, and information. And the dynamic monitoring of security management and the better convergence speed of network and the generalization mapping ability of network were guaranteed. A coal mine early-warning model was established, laying a foundation for the application and extension of fuzzy neural network in coal mine safety management.

Key words. Fuzzy neural network, security management, early warning management, genetic algorithm.

1. Introduction

Coal industry is the basic industry of our country and plays an important role in the development of national economy. By 2015, coal resources accounted for 65 % of China's energy consumption. And it is expected to reach 50 % by 2025. Coal is the main energy consumption in our country and makes great contribution to the economic construction of our country for a long time. However, safety production of coal mine has always been a major problem. In 2015, 1863 coal mines in China were closed because they did not have safe production conditions, and the coal mine accidents happened frequently and caused huge economic losses and casualties. In recent years, China has formulated and promulgated a series of safety measures and

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policies to strengthen the safety management of coal mines, and the domestic safety of coal mine has been improved, but the situation has been unoptimistic. Therefore, the coal enterprises should more fully utilize modern technology and combine with computer technology and network communication management to accelerate the upgrading of coal mine safety management, reduce and avoid the occurrence of coal mine accidents, and reduce economic losses and personnel casualties.

2. State of the art

Safety evaluation refers to the method of systematic engineering to evaluate the possible risks and the consequences, and formulate corresponding measures to ensure the safety of the system according to the size of the predicted risk. The most widely used method of safety assessment in China is fuzzy comprehensive evaluation method [1]. In addition, early warning management should be carried out. In foreign countries, foreign scholars have begun to carry out early warning management research at the beginning of the 20th century. Early warning management is originated in the economic field, but the study has found that early warning management is applicable to not only the economic field, but also other areas [2]. The United States first introduced the theory of successful early warning management into the micro field, and then introduced it into the emergency management of enterprises. Since then, countries such as the United States, Japan and Russia have carried out more in-depth research and application of early-warning management theory. In China, the application of early warning management theory is mainly based on the theory of economic early warning, and other industries have relatively little initial application [3]. First of all, the theory of early-warning management is applied to the macro-economic field, and then it is slowly extended to various industries and goes deep into the micro field of the industry. In recent years, early warning management theory has been widely used in various sectors outside the economic sector, and mainly in high-risk industries, such as aviation disasters and early warning of coal mine safety. Scholar Xie Kefan has put forward the theory of "survival risk of enterprises", and enterprise crisis and risk warning have been systematically studied. Hu Huaxia has studied the enterprise forewarning management system from the angle of enterprise's survival crisis. Wang Shuai has put forward the system reengineering of coal mine safety management based on early warning management theory [4]. Li Wen has proposed a control and avoidance process based on the risk of coal mine development, and formulated a concrete method for the assessment and early warning of coal mine development risk [5]. Zhang Haifeng has proposed in his research that there are four main parts of the safety early-warning analysis of coal mine development, namely monitoring, identification, diagnosis and evaluation, and constructed the forecasting system [6].

3. Methodology

With the development of China's economy, China's various industries and enterprises have made great progress and development degree, and the demand for coal and other industries has been increasing with the development of the industry rising speed. China's coal mining has also made some progress, coal mine safety issues have further become one of the important links of China's mining industry [7]. In recent years, China's coal industry has developed to a certain extent. China's major coal mining industry distribution areas are shown in figure 1. The development and progress of China's coal industry have made more coal resources gradually mined and excavated, and have further provided a certain energy support for the development of other industries and provided a certain positive impact for the development of China's industry [8]. However, there are some defects and problems in the coal mine safety management in China; so some security problems appear constantly in the process of coal mine industry development, which has some negative influences on the development of the coal industry; and the emergence of certain insecurity factors makes the process of industry development and the country's sustained stability have a certain constraint [9]. However, the development of computer technology has played a technical support role for coal mine safety management, especially the emergence of network model has made the safety management of coal mine get sustained development, and has had certain positive influence and promotion function to enterprise development [10].

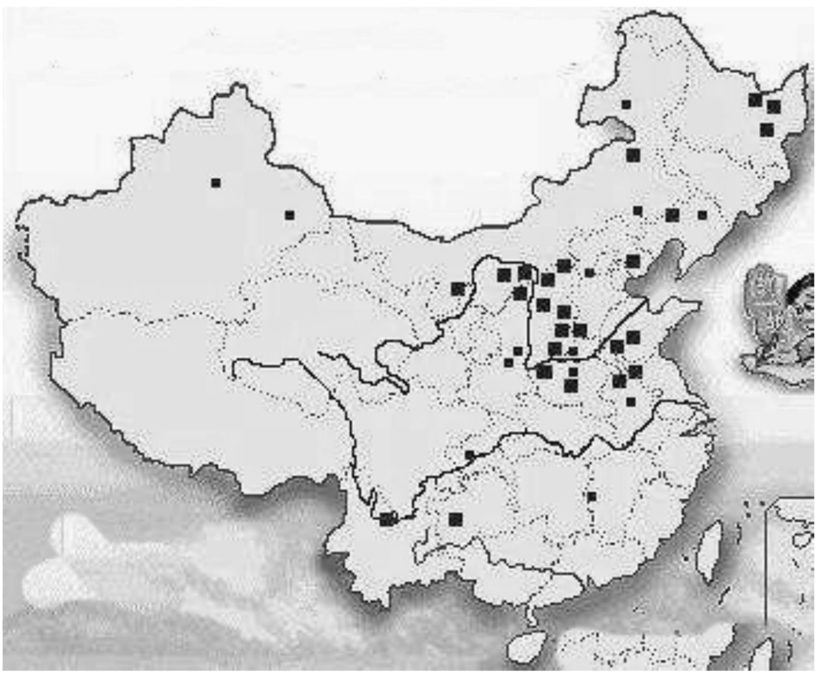

Fig. 1. Distribution of coal mines in China

(1) Information entropy method. The present situation of coal mine safety production management was taken as the starting point, the qualitative and comprehensive analysis of the main influencing factors in the process of safety production was carried out, 24 influencing factors were obtained through comprehensive analysis and qualitative analysis, among which the relevant influencing factors were summarized as shown in Table 1. Then the quantitative analysis method was used to optimize the index, and the scientific evaluation system was constructed.

Table 1. Main evaluation indicators for the impact of coal mine safety production management

Index of the first level	Index of the second level	Index of the first level	Index of the second level
Human factor	The three violation rates of employee	Management factor	Perfect rate of safety system
	Monthly average training time of employees		Perfect rate of safety measures
	Average educational level		Management efficiency
	Average age		Timeliness of management
	Average length of service		Perfect rate of emergency mechanism
	Proportion of migrant workers		Improvement rate of coal mine access management
Device factor	Improvement of the reliability of equipment	Environmental factor	The outstanding times of tons of gas
	Reliable consideration rate of transport equipment		Dip angle of coal seams
	Reliability of power supply equipment		The normal water inflow of mine
	Reliability of mechanical and electrical equipment		Maximum dust concentration on the face
	Reliability of ventilation equipment		Spontaneous combustion period of coal seam
	Reliability of drainage equipment		Reliability of top and bottom plate
	Improvement rate of water proof and fire-fighting facilities		
Information factor	Informatization degree		
	Information identification		
	Ability of processing		

Through the information entropy method, each coal mine safety evaluation index was selected. The relevant model is

$$e(i) = -k \sum_{j=1}^{m} \frac{x_{ij}}{E_i} \ln \frac{x_{ij}}{E_i} \,. \tag{1}$$

Here, E_i is the sum of the main indexes of coal mine safety evaluation in this study, k represents the coefficient of computation (usually 0.2), m is the total number of indicators, and x_{ij} is the evaluation index for all the research.

The overall entropy of the relevant evaluation matrix is

$$E^{'} = \sum_{i=1}^{n} e(i)\,, \tag{2}$$

where $e(i)$ is the evaluation value of all indexes and n represents the total quantity of all assessment indicators.

The measure of all the evaluation indicators used for this study is

$$w_i = \frac{1}{N - E^{'}}[1 - e(i)],\ i = 1, 2, \ldots, N\,, \tag{3}$$

where N represents the number of all assessment indicators.

(2) Questionnaire: in this paper, a questionnaire survey was conducted among 20 employees of 200 coal mines with different specifications in different parts of China, the safety training situation of coal mine workers was investigated and analyzed, and the safety engineering technology and management staffing rate were statistically analyzed.

(3) Statistical analysis: in this study, a large amount of data was obtained through consulting relevant documents about coal mine safety management and conducting questionnaire survey among 20 employees of 200 coal mines with different specifications as well as the consultation with experts concerned. And the SPSS method was used to collect and analyze a large amount of data, the main influencing factors of coal mine safety accidents were determined according to the accurate and scientific analysis results, and application of the fuzzy neural network model provided the scientific theory safeguard in the coal mine safety management.

4. Result analysis and discussion

Coal is the main consumption energy in our country and contributes greatly to the economic construction of our country [11]. Especially since the reform and opening up of China, China's various industries and industries have been greatly improved, and the demand for energy has been also increasing, therefore, China's coal enterprises have been greatly developed, the number of coal has been increasing at the same time, and coal production has also been greatly developed, which has provided certain positive impetus for the development of our country's other industries and even the whole country's comprehensive economic level directly or indirectly. However, coal mine safety production has always been a major problem. In 2015, 1863 coal mines in China were closed because they did not have safe production condition; coal mine accidents happened frequently and caused huge economic losses and casualties. Figure 2 shows the scene of rescue in the accident.

Fig. 2. Rescue after the gas explosion of coal mine in 2016

China has also developed and introduced a series of safety measures and policies to strengthen the safety management of coal mines, the domestic coal mine safety situation has improved, but the situation has been still unoptimistic and coal mine accidents have been frequent [12]. In 2016, there were 197 coal accidents, coal accidents killed more than 20,000 people during 2011 to 2016; an average of more than 3000 people died each year from coal mine accidents, with nearly 10 deaths a day on coal accidents. If the death of one person per death causes economic losses of 50,000 Yuan, China's annual direct losses caused by coal mine accidents reach 150 million Yuan, and the actual economic losses are much higher than this number. Table 2 shows a partial coal mine accident that counts more than 10 deaths from 2011 to 2016.

Coal mine accidents frequently occur, although the mortality rate of millions of tons of coal production in China is declined in recent years, there is still a big gap compared with some advanced coal mining countries. For example, in recent years, the United States has a mortality rate of millions of tons about 0.019, India is 0.45, and Russia is only 0.42. While the mortality rate of millions of tons in China has remained above 2.0 for a long time, and has maintained between 0.5-1.0 in recent years. Table 3 shows the number of coal mine accidents, the number of deaths and the death rate of millions of tons in China during the years from 2007 to 2016.

Based on the current status of coal mine safety, after consulting a large number of documents, research on the coal mine safety management of experts at home and abroad was comprehensively studied and a thorough study of coal mine safety production management was made, and the mechanism of coal mine accidents, the development of early warning management system and fuzzy network model were mainly included to evaluate the safety of the system. Safety evaluation refers to the method of systematic engineering to evaluate the possible risks and the consequences, and formulate corresponding measures to ensure the safety of the system according to the size of the predicted risk.

Table 2. More than 10 deaths caused by recent coal mine accidents in China

Time	Name of the coal mine that occurs accident	Types of accident	Death toll
2011-10-04	Anping coal mine in Libo county, Qiannan city, Guizhou province	Coal and gas outburst	17
2011-10-11	Jindi coal mine in Dong county, Jixi city, Heilongjiang province	Permeable	13
2012-10-16	Hetian coal mine in Yaozhou district, Tongchuan city, Shaanxi province	Gas accident	11
2012-11-06	Fufa coal mine of Dashu town, Fengjie county, Chongqing province	Gas mine	13
2013-10-27	Jiulishan coal mine of Jiaozuo coking coal group in Jiaozuo city, Henan province	Coal and gas outburst	18
2014-11-10	Xialiuchong coal mine of Changjiang town, Hengyang county, Hunan province	Gas explosion	29
2014-11-03	Qianqiu coal mine of Yima coal group in Sanmenxia city, Henan province	Rock burst accident	10
2015-12-07	Liuyi coal mine of Sandu town, Zixing city, Binzhou county, Hunan province	Gas explosion	11
2015-11-18	Shizhuang coal mine of Shizong county, Qujing city, Yunnan province	Gas explosion	43
2016-08-21	Xiaojiawan coal mine of Panzhihua city, Sichuan province	Gas explosion	46
2016-09-02	Gaokeng coal mine of Pingxiang coal industry group in Jiangxi province	Gas explosion	13

Fuzzy theory and neural network technology have received extensive attention and thorough research in recent years [13]. The fuzzy system corresponds to the artificial neural network model (Fig. 3), the model is to simulate the structure of the human brain thinking mode, and it has a strong self-learning ability, high accuracy, but it cannot really handle the fuzzy information like the human brain, so the requirement of the sample is relatively high [14]. The fuzzy neural network requires a lot less samples, and can make better use of the expert's knowledge system, so that the whole reasoning process is easier to understand, and then it also has a long reasoning time and is vulnerable to manual intervention. Therefore, two theories were combined organically to obtain the complementary evaluation effect in this study [15].

Then, all the main impact index values were collected through the questionnaire survey of A, B, C, and D four coal mines of a province. The results are shown in Table 4. Further, the membership degree of each index value of each coal mine was analyzed by formula. The analysis result is shown in Table 5. The results show that the factor of equipment is the main influencing factor for each coal mine, therefore, only the equipment factor is constantly improving, the safe operation can be ensured in the process of using 5BP network model in coal mine safety management in coal industry, and a scientific support can be further provided to the development of other industries.

Table 3. Coal mine accidents and deaths in China from 2007 to 2016

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total number of accidents	3082	4344	4143	3641	3341	2945	2421	1954	1616	1201
Total death toll	5670	6995	6434	6027	5986	4746	3786	3214	2640	1973
Number of major accidents	75	65	58	49	58	38	28	38	24	21
Mortality rate of millions of tons	5.07	4.94	3.71	3.08	2.81	2.041	1.485	1.182	0.749	0.564

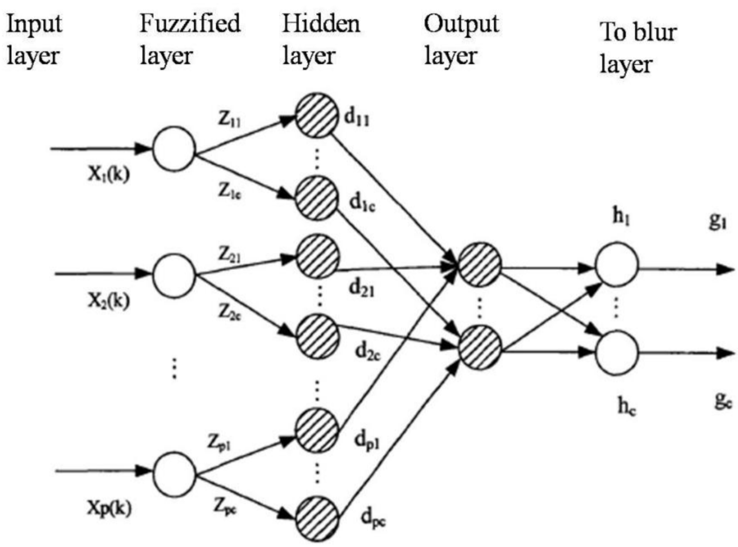

Fig. 3. Analysis of network model development

Table 4. Collection of raw data of A, B, C, D coal mines

Index of the first level	Index of the second level	A	B	C	D	E_i	e_i	w_i
Human factor	Rate of three violations of personnel	2.5 %	5.4 %	3.7 %	9.0 %	21 %	0.992	0.143
	Monthly average training time of employees	7.5	5.6	6.1	4.5	23.70	0.957	0.021
	Average educational level	2.8	1.9	2.1	1.7	8.50	0.931	0.024
	Average age	37.2	38.9	36.4	38.1	150.60	0.921	0.000
	Average length of service	5.4	4.2	6.1	5.0	20.70	0.988	0.011
	Proportion of migrant workers	66 %	72 %	75 %	67 %	280 %	0.987	0.002
Device factor	Improvement of the reliability of equipment	95 %	89 %	93 %	87 %	364 %	0.993	0.003
	Reliable consideration rate of transport equipment	93 %	92 %	93 %	85 %	363 %	0.999	0.002
	Reliability of power supply equipment	96 %	95 %	96 %	94 %	381 %	0.999	0.000
	Reliability of mechanical and electrical equipment	85 %	82 %	89 %	81 %	337 %	0.999	0.002
	Reliability of ventilation equipment	89 %	82 %	89 %	71 %	331 %	0.997	0.005
	Reliability of drainage equipment	77 %	84 %	89 %	80 %	285 %	0.998	0.002
	Improvement rate of water proof and fire-fighting facilities	80 %	70 %	62 %	73 %	330 %	0.997	0.005

Continuation of Table 4 is on the following page

Management factor	Perfect rate of safety system	0.095	0.014	0.011	0.028	0.15	0.732	0.486
	Perfect rate of safety measures	19	24	14	22	79.00	0.986	0.025
	Management efficiency	1830	433	735	1431	4429.0	0.905	0.171
	Timeliness of management	5	7	6	8	26.00	0.902	0.019
	Perfect rate of emergency mechanism	5	4	7	7	23.00	0.989	0.034
	Improvement rate of coal mine access management	77 %	84 %	89 %	80 %	330 %	0.981	0.002
Environmental factor	The outstanding times of millions of tons of gas	82 %	67 %	75 %	59 %	283 %	0.998	0.009
	Dip angle of coal seam	79 %	71 %	74 %	62 %	286 %	0.994	0.005
	The normal water inflow of mine	81 %	74 %	70 %	69 %	294 %	0.997	0.003
	Maximum dust concentration on the face	89 %	81 %	87 %	80 %	337 %	0.998	0.001
	Spontaneous combustion period of coal seam	92 %	90 %	94 %	84 %	360 %	0.999	0.001
	Reliability of top and bottom plate	82 %	83 %	81 %	84 %	330 %	0.999	0.000
Information factor	Informatization degree	62 %	53 %	68 %	49 %	232 %	0.994	0.011
	Information identification	60 %	57 %	70 %	52 %	239 %	0.995	0.008

Finally, the situation of training status of coal mine safety management personnel was investigated. The results of the survey are shown in Fig. 4. The results show that the coal mine enterprises in China begin to strengthen the training for the related staff, and this will also provide certain technical support and guarantee for the safe operation of China's coal mining enterprises, and provide some support of energy for the development of other industries.

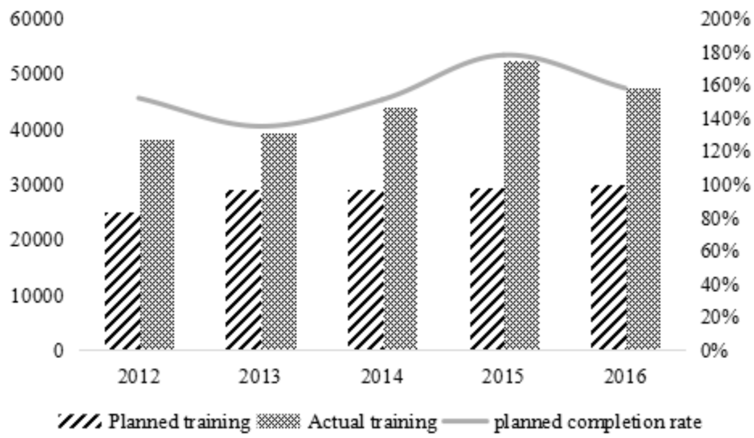

Fig. 4. Analysis of the related personnel training in China's coal mine safety management

Table 5. Membership degree of influence index of each coal mine

Index of the first level	Coal mine A	Coal mine B	Coal mine C	Coal mine D
Human factor	0.9667	0.7000	0.9000	0.6667
Device factor	1.0000	1.0000	1.0000	0.8000
Management factor	0.4000	0.1000	0.6000	0.0000
Environmental factor	0.3333	0.2333	0.6667	0.0667
Information factor	0.6333	0.4667	0.5667	0.6000

5. Conclusion

The coal industry is the basic industry of our country and plays an important role in the development of the national economy. Coal is the main consumption energy in our country and contributes greatly to the economic construction of our country. However, the safety production of coal mine has always been a major problem and has caused huge economic losses and casualties. Therefore, coal mine enterprises should make full use of modern technical means, combine computer technology and network communication management to accelerate the improvement of safety management instructions of coal mine, reduce and avoid coal mine accidents. The deep causes of coal mine safety accidents were first analyzed, and the main factors of coal mine safety production were comprehensively evaluated, including management system factor, human factor, machine factor and environment information factor; and the cause model of coal mine safety production was constructed. On the basis of the study, the dynamic monitoring of coal mine safety management was carried out by using modern scientific theory, and genetic algorithm and fuzzy neural network model were combined to optimize the neural network and guarantee the better convergence speed and the generalization mapping ability of the network; in addition, the early-warning model was established for coal mines, and the key aspects of coal mine safety management were determined, so as to lay the foundation for the application and popularization of fuzzy neural network in coal mine safety management.

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