Research on Safety Early Warning Management of Coal Mining Face Based on Expert System

Fanqiang Meng1,*, Yang Fang2 and Chunxia Li3

1 Donlinks School of Economics and Management, USTB
30 Xueyuan Road, Haidian District, Beijing, 100083, China
2 Business School, Beijing Wuzi University, Beijing, China
3 Taishan Polytechnic, Tai'nan, Shandong, China

*Corresponding author e-mail: meng fq@email.com

Abstract. Coal mining face is the place where coal mine accidents occur frequently. In this paper, the security early warning expert system is built based on the analysis method of system engineering and the investigation of coal mining face in a large number of coal mines. The classification, acquisition mechanism and representation of knowledge are described, and the system structure, reasoning mechanism and the establishment of knowledge base are also introduced.

1. Introduction
As the main production place of coal, the coal mining face is a complex social technology system with narrow space, complex environment, more equipment and concentrated workers[1]. There are many risk factors changing dynamically in the system, which increase the complexity of risk prevention and control in the work. Using the method of system engineering analysis, this paper comprehensively analyzes the risk factors influencing coal mining working face, establishes the expert system of safety early warning of coal mining working face, and carries out early warning of risks and adopts emergency plan.

2. Acquisition of Expert system Knowledge of Coal Mining Face Safety Warning

2.1. Classification of Knowledge
In the knowledge base of coal mining face safety warning expert system, the knowledge can be divided into descriptive knowledge and procedural knowledge. In the knowledge base, most of the knowledge comes from the corresponding rules, standards and regulations, as well as the existing research results in the field. Such knowledge belongs to descriptive knowledge. Procedural knowledge cannot directly describe objective laws, and knowledge can only be acquired by reasoning[2].

According to the types of production systems and risk factors in coal mining, the knowledge of security early warning expert system can be divided into two categories: knowledge of coal mining operation system, knowledge of transportation system, knowledge of ventilation system, knowledge of power supply system, knowledge of drainage system and knowledge of auxiliary operating system. Roof risk knowledge, gas and dust risk knowledge, flood risk knowledge, fire risk knowledge, electromechanical accident risk knowledge, transportation accident risk knowledge and blasting accident risk knowledge[3].
2.2. Acquisition and Collection of Knowledge

The acquisition of knowledge is an important basis for the establishment of expert knowledge base and the most important step for the development of expert system[4]. According to the target requirements of the coal mining face safety warning system and the solution scope of the limited problems in the field, the expert knowledge is collected, generally through several links, such as extracting knowledge, converting knowledge, importing knowledge and testing knowledge[2].

2.2.1. Extraction of knowledge. Knowledge extraction mainly adopts the following methods: referring to the rules, books, materials, literature and various academic reports of coal mining and coal mining; To investigate the working condition and safety management mode of coal mining face in actual operation; Visit experts in the field of coal mining and consult them on relevant issues. The collected knowledge has been sorted out, identified, screened and summarized.

2.2.2. Transfer knowledge. The expert experience, expert knowledge or relevant information knowledge in the field of extracted coal mining safety are expressed in some form of predicate logic, framework, production rules and so on, and transformed into a pattern that can be recognized by computer.

2.2.3. Input knowledge. The process of input knowledge is to transfer the converted security warning knowledge into the knowledge base, and then edit and compile the knowledge base.

2.2.4. Testing knowledge. After several links above, the knowledge base will be established, and any failure of any link will lead to false knowledge, which will lead to false alarm and false alarm. Therefore, knowledge should be detected, possible errors in the knowledge base should be found in time, and corrective measures should be taken timely.

3. Expression of Expert System Knowledge of Coal Mining Face Safety Warning

After knowledge acquisition and knowledge fusion, technical parameters and causality in the field of coal mining safety need some knowledge representation to be stored in the knowledge base of the expert system[6]. Knowledge representation methods can be represented by first-order predicate representation, production representation, frame representation, semantic network representation, etc. The expert knowledge of coal mining face safety warning system is mostly causation.

3.1. Factual Knowledge

The production system makes inference based on rules and facts, which include roof pressure, gas concentration, working face temperature, hydraulic support and state of coal mining machine obtained by the monitoring system on the coal mining face field, as well as the interrelationship between intermediate variables and variables in the process of reasoning by invoking rules.

Facts are often expressed in triples, and variable values are expressed in the format (object, attribute, value). The format used to express the relationship between variables is (relationship, object 1, object 2). For example, the pressure at the front end of E3402 no. 4 bracket of comprehensive mechanized coal mining faces is 9.9mpa, and is represented by triples (before E3402-4 of comprehensive mechanized coal mining faces, Support pressure, 9.9)[5].

3.2. Generate the Representation of Rules

Generally, the production rule consists of two parts: condition and conclusion[7]. If the uncertainty inference to the conclusion is taken into account, the confidence value is generally added after the conclusion. The expression of rules is usually:

If< condition >, Then< conclusion >, CNF< confidence >. CNF is called regular strength, and its value is between [0,1]. In uncertain reasoning, according to the requirement of confidence, a certain degree of similarity can be achieved, and it can be considered that the known facts are matched with the prerequisite conditions. Then, a certain algorithm can be used to pass this possibility to the conclusion, and an early-warning rule knowledge can be obtained[8].
For example, in the coal mine safety regulation, the provisions on the necessity to stop working and withdraw personnel from coal mining face can be expressed by the following production rules:

**RULE Evacuation personnel01**

Air temperature exceeds 30 °C OR IF coal mining face
- The gas concentration of coal face reaches 1.5% OR
- The carbon dioxide concentration in the coal face reached 1.5%

THEN the work area will be closed and the staff will be evacuated CNF 0.98

This RULE means that the rules of the early warning is RULE Evacuation personnel01, if working environment monitoring sensor incoming information to the coalface air temperature exceeds 30 °C, or the gas concentration to 1.5%, or carbon dioxide concentrations by 1.5%, warning system alarm, prompt suspend operation, withdraw from personnel, RULE confidence of 0.98 at this time.

4. Structure and Reasoning Process of Expert System of Coal Mining Face Safety Warning

4.1. System Structure

The expert system of coal mining face safety warning consists of knowledge base, database, reasoning machine, interpreter, knowledge acquisition system and man-machine interface. As the core of the system, knowledge base and reasoning machine are used to store the expert experience knowledge of coal mining safety, known facts and production rules, etc[2]. The system structure is shown in figure 1.

![Figure 1](image)

**Figure 1** Structure diagram of the expert system for safety early warning of coal mining face.

4.1.1. **Knowledge base.** Knowledge base is a system for solving and sharing knowledge management problems according to needs by storing knowledge related to coal mining face safety into a computer in a certain form.

4.1.2. **Man-machine interface.** Man-machine interface is a communication interface between users and the system. It is used to control the process of man-machine interaction, enabling users to exchange and interact with human computer information in an intuitive form.

4.1.3. **Inference machine.** According to the knowledge acquired by the knowledge base and the information obtained from the dialogue with users, the inference machine makes reasoning, decision-making and judgment on the questions raised by users, thus playing an expert role.

4.1.4. **Knowledge acquisition system.** Knowledge acquisition system of the existing experts experience, summarize the facts, such as production rule, extracted, and converted into expert system can accept the internal expression and deposited in the knowledge base, the system also has the knowledge base maintenance, editing function, add, delete, modify, and other functions of the rules.

4.1.5. **Interpreter.** The main function is to explain, illustrate or translate the problems, conclusions and reasoning process involved in the dialogue between the expert system and the user of coal mining safety early warning.
4.1.6. Database. Database is used to store information such as known facts, facts answered by users, inferred intermediate conclusions, etc.

4.2. Reasoning Process
In the expert system of coal face safety warning, because the monitoring system of working face is directly connected with the dynamic database of expert system, it can get basic data or facts quickly, so it is more appropriate to adopt data-driven forward reasoning.

Taking the early warning of coal mining stoppage as an example, the reasoning process of the system is explained, as shown in figure 2.

Figure 2. System inference flow diagram.

5. Using the template knowledge base of expert system of coal mining face safety warning

The knowledge base of coal mining face safety warning expert system is established by relational database, which consists of fact database and rule database. In fact library, it uses fact table to store fact knowledge. In the rule library, rule tables, condition lists, and conclusion lists are used to store heuristic knowledge[9].

5.1. The Library Table

The fact library table stores the user's description of the problem and objective facts, which can be used by the inference machine to match the conditions of the rules in the rule knowledge base to get the solution.

Table 1. The structure of the fact library table.

| The field names | The data type | Instructions |
|-----------------|---------------|--------------|
| FactorID        | The text      | The serial number |
| Factor Name     | The text      | The Name     |
| Blg Sys         | The text      | Facts properties |
| ...             | ...           | ...          |

5.2. Rule Base Table

The rule library table stores the basic information of the rule. After the reason of the warning is found by the reasoning machine, the solution can be matched to the warning.
Table 2. The structure of the rule table.

| The field names        | The data type | Instructions               |
|------------------------|---------------|---------------------------|
| Rule ID                | The text      | Rule number               |
| Rule Name              | The text      | The rules of              |
| Rule pro               | The text      | Before the rules a        |
| Conclusion             | The text      | Conclusion                |
| The final conclusion   | The text      | The final conclusion       |
| CNF                    | Digital       | Rule confidence           |
| Rule rank              | Digital       | Rule level, value between [0, 1], default value 0 |

5.3. Subsystem Table
Because the risk structure of coal mining face is complex and there are many knowledge types of expert system, in order to improve the speed of searching knowledge, a sub-system table can be established to locate the occurrence of early warning in a certain system and improve the speed of safety early warning diagnosis.

Table 3. Subsystem table.

| The field names  | The data type | Instructions          |
|------------------|---------------|-----------------------|
| The System ID    | The text      | System number         |
| The System Name  | The text      | The name of the system|

6. Conclusion
Coal mining face is the place where coal mine accidents occur frequently, accounting for about 40% of coal mine accidents. Roof, flood, fire, gas, dust and other disasters in the face of coal mining in a large proportion. The study on security early warning expert system of coal mining face can effectively monitor the safety production status of coal mining face in real time and play a positive role in preventing accidents.

The knowledge base of the expert system of security early warning is the core of the expert system. Based on the investigation of several coal mines in Shandong, Guizhou and Inner Mongolia, this paper collects and sorts out the safety management knowledge and expert experience knowledge of coal mining working face.

References
[1] Zhang zhijian, Safety management and technical measures for coal mining face production, Inner Mongolia coal economy 10(2014)73-73.
[2] Wang wenjie, Ye shiwei, Principles and applications of artificial intelligence, People's Post and Telecommunications Press, Bei Jing, 2004.
[3] Jiang fuxing, Roof control design and expert system of coal mining face, Coal Industry Press, Bei Jing, 2010.
[4] Duzgun, h. s. b. Analysis of roof fall hazards and risk assessment for headquarters zonguldak coal basin underground mines, International Journal of coal Geology 64(2005)104-115.
[5] Bahn, Susanne, Workplace hazard identification and management: The case of an underground mining operation, Safety Science57(2013)129-137.
[6] Liu xiaosheng, Sun qun. Study on the knowledge base of mine safety early warning expert system, Mining Safety and Environmental Protection 35(2008)34-36.
[7] Hu guohua, Study on the expert system of gas control in coal mining face based on the expandable knowledge base, Diss. Anhui University of Technology, 2007.
[8] Zhou bo, Tang guibin, Sun maocun, An expert system for gas safety early warning based on object orientation, Geographic Information World 4(2013)78-81.

[9] Zhao Dan, Chen shuai, Pan jingtao, Study on early warning and diagnosis system of mine monitoring and control, Chinese Journal of Safety Science 25(2015)63-69.